Assessing the Impact of Transportation Infrastructure on Rural Residents' Income: Using the Quantile Regression Approach

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Abstract: The impact of transportation infrastructure on farmers' income has been the focus of attention by government managers and related scholars in recent years. Based on the panel data from 2000 to 2018, this paper uses the quantile regression model to explore the effect of highway and railway transportation infrastructures on wage income and operating income. The findings show that the highway transportation infrastructure makes a minimal contribution to the wage income in Shanghai, Beijing and Zhejiang provinces, because the highway mileage and highway passenger turnover in these provinces are small. However, the operating income in the upper 90th quantile provinces such as Jilin, Heilongjiang, and Zhejiang, receives the biggest impact from the highway transportation infrastructure, because the construction of rural roads in these provinces is growing faster. The impact of railway transportation infrastructure on the wage income in the 10th-25th, 25th-50th and 50th-75th quantile provinces is small, since their railway passenger turnover is less. The railway transportation infrastructure has not played a role in boosting the operating income in these provinces such as Guizhou, Shaanxi, Gansu, Shanxi, Qinghai, and Ningxia. Therefore, each quantile province should formulate specific policies to promote the construction of transportation infrastructure.

Keywords: Highway transportation infrastructure, Railway transportation infrastructure, Wage income, Operating income, Quantile regression model.

1. INTRODUCTION

The saying "if you want to get rich, you'll have to build roads first" shows the importance of transportation infrastructure to economic development. Over the years, the Chinese government has continued to increase investment in transportation infrastructure, and has made huge achievements that have attracted worldwide attention (Magazzino and Mele, 2020). Statistics display that as of the end of 2020, China's highway mileage reached 5.01 million kilometers, of which expressway mileage reached 0.15 million kilometers. Railway construction has also made great achievements. By the end of 2020, the mileage of high-speed railways was 38,000 kilometers. China has become the country with the longest railway and highway mileage in the world (Guo *et al*., 2020).

Farmers' income mainly includes wage income and operating income.[1] The transportation infrastructure mainly includes highway transportation infrastructure and railway transportation infrastructure. Does transportation infrastructure play an effective role in increasing farmers' income? What is the impact of highway and railway transportation infrastructures on wage income and operating income? These issues are topics worthy of in-depth study. The objective of this paper is to investigate the impact of transportation infrastructure on regional farmers' income. The research results can give the contribution of road traffic and railway traffic to rural residents' income. This helps local governments to formulate transportation policies that meet their own needs, so as to effectively increase the income of rural residents.

A comprehensive analysis of the existing literature shows that these related studies have the following two obvious characteristics. (1) Existing related research only roughly examines the impact of transportation infrastructure on income. Transportation infrastructure mainly includes highway and railway transportation infrastructures. Farmers' income is divided into wage income, operating income, transfer income and property income, and wage income and operating income are most closely related to transportation infrastructure (Tonn *et al*., 2021). The application value of the conclusion obtained from the rough investigation is low. (2) Existing related studies often use the mean models (e.g., difference-in-differences method and cointegration test) to examine the income impact of transportation infrastructure (Umar *et al*., 2020; Liang *et al*., 2021). However, the mean models can only estimate the average impact of transportation infrastructure. As we all know, the farmers' income of

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[1]According to the classification of the National Bureau of Statistics of China, farmers' income includes wage income, operating income, transfer income and property income. Wage income refers to labor remuneration, including the salary of the main occupation, the income of the second occupation, part-time work and sporadic labor. Operating income refers to the income obtained by taxpayers through regular production and business activities.

different administrative regions is heterogeneous. The impact of transportation infrastructure on farmers' income is very different across province.

Compared with the existing research, the novelty of this paper has the following two points: (1) existing studies have only investigated the impact of transportation infrastructure on residents' income. China is a dual economic society, with significant economic differences between urban and rural areas. For a long time, rural residents accounted for half of China's total population. Increasing farmers' income is a long-term strategy for China's social and economic development. This paper focuses on rural areas and subdivides farmers' income into operating income and wage income. The estimated results help local governments to more effectively promote various types of farmers' income. (2) This article uses the quantile regression method to estimate the effects of transportation infrastructure on farmers' income. The quantile regression models can provide the effect of highway transportation and railway transportation on farmers' income at different quantile provinces.

The rest of this article includes the following parts: the second part reviews related low-carbon energy research. The third part gives the model theory and constructs a specific empirical model. The fourth part is the core part and discusses the estimation results in detail. Finally, this article tentatively proposes relevant countermeasures, which can provide a reference for government departments.

2. LITERATURE REVIEW

From the perspective of research scope, this paper divides the existing relevant research into three categories: international regional level, country level and provincial level.

(1) International regional level. Jerome (2011) investigated the poverty in African continent and found that the quantity and quality of transportation infrastructure were far below the international standards. Many poor areas lacked the necessary road transportation, thus restricting economic development and farmers' income. Using a panel data model, Khan *et al*. (2018) investigated 40 countries in the world and found that transportation infrastructure is positively related to residents' income. Pradhan (2019) applied the panel vector error correction model to investigate the contribution of transportation infrastructure in G20 countries. The conclusions showed that there was a long-term causal relationship between transportation infrastructure, economic development, and residents' income. The analysis results of the EU-28 countries supported this conclusion (Cigu *et al*., 2019). On the contrary, the survey results of Europe, North America, and Australia showed that air traffic had a limited impact on the income of residents in remote areas (Ventura *et al*., 2020).

(2) Country level. Using a panel data model, Hong *et al*. (2011) found that different transportation infrastructure had different effects on economic growth and residents' income in China. Land transportation and water transportation infrastructure had the greatest impact on residents' income. This result was confirmed by Li and DaCosta (2013), that is, sound transportation infrastructure would help economic development and residents' income in China. Kuştepeli *et al*. (2012) employed the cointegration test method to explore residents' income in Turkey. The conclusions showed that there was no long-term equilibrium relationship between highway infrastructure investment and residents' income. Additionally, the estimated results of Vector Error Correction Model in India (Pradhan and Bagchi, 2013), Johansen multivariate cointegration approach in Tunisia (Achour and Belloumi, 2016) and Multivariate Probit model in Nigeria (Peter *et al*., 2015) all indicated that transportation infrastructure had a positive role in increasing residents' income. This result is confirmed by the findings of India (Maparu and Mazumder, 2017). Furthermore, the survey of American households found that the impact of transportation infrastructure on high-, middle-, and low-income families was quite different (Barton and Gibbons, 2017).

(3) Provincial level. Based on the panel data of 28 provinces in China, Magazzino and Mele (2020) employed a time-series method to investigate the relationship between transportation infrastructure and economic development. The results showed that perfect transportation facilities were helpful to develop the economy and increase residents' income. Mohmand *et al*. (2017) surveyed transport infrastructure using provincial panel data in Pakistan and found significant provincial differences in the

relationship between transport facilities and economic development. A survey of 337 rural households in China's Guizhou Province found that the continuous improvement of transportation infrastructure had helped to increase the income of rural residents (Lin *et al.*, 2020). An investigation of 29 provinces in China found that the investment in transportation infrastructure could help expand social employment and increase the income of residents (Huang *et al.*, 2022).

Analyzing the existing related research, it is found that there are still two shortcomings. (1) Most existing studies tend to explore the impact of transportation infrastructure on economic growth or residents' income. The farmers' income includes four parts: wage income, operating income, transfer income, and property income. Without distinguishing different types of income, only examining the impact of transportation infrastructure on total income often lacks application value. (2) Most literature assumes that economic variables obey normal distributions and use traditional mean models (e.g. Spatial Durbin model, and panel threshold model) to investigate transportation infrastructure (Arbués et akl., 2015; Lin and Chen, 2020). In fact, most economic variables are skewed, since economic phenomena are prone to volatility.

This article will be improved from the following two aspects: (1) wage income and operating income have the closest relationship with transportation infrastructure. This paper divides transportation infrastructure into highway transportation infrastructure and railway transportation infrastructure, and investigates their impact on wage income and operating income respectively. The research results will provide experience support for the government to optimize the transportation construction plan. (2) This study employs the quantile regression model to investigate transportation infrastructure. Quantile regression can estimate the comprehensive influence of transportation infrastructure on wage income and operating income, not just an average impact. This helps each quantile province to formulate suitable traffic policies, based on the estimated results.

3. METHOD AND MODEL SPECIFICATION

3.1. The Basic Principle of the Quantile Regression Approach

Quantile regression uses the conditional quantile of the dependent variable to regress the independent variable to obtain the comprehensive effect of the explanatory variable on the dependent variable (Koenker and Bassett Jr, 1978). The traditional linear model can only estimate the average influence of the explanatory variable on the dependent variable, which conceals the differential influence of the explanatory variable on the dependent variable under different values. Therefore, the quantile regression model has obvious advantages compared to traditional linear mean models such as panel data and vector autoregressive models. The mathematical formula of the quantile regression method is as follows:

$$y_i = x_i'\beta_\theta + \mu_{\theta i}, 0 < \theta < 1 \tag{1}$$

$$Quant_\theta(y_i \mid x_i) = x_i\beta_\theta \tag{2}$$

Where β is the parameter to be estimated, *x* is the vector of explanatory variables, *y* represents the explained variable, μ represents the random error term, θ represents the quantile point, and Quant represents the quantile regression. The calculation formula for the parameter (β) is as follows:

$$\min \sum_{y_i \geq x_i'\beta} \theta \mid y_i - x_i'\beta \mid + \sum_{y_i < x_i'\beta} (1-\theta) \mid y_i - x_i'\beta \mid \tag{3}$$

Where θ represents the quantile point, and the parameters to be estimated (β) are different cross θ.

The parameter estimation methods of quantile regression model mainly include interior point, and smoothing methods. In recent years, it has become possible to use more advanced parameter estimation methods, with the advancement of computer technology and equipment. The bootstrap method is a method to improve the accuracy of parameter estimation by repeated sampling, under the condition that the computer performance is greatly improved. This article uses the bootstrap method to estimate the parameters of the quantile regression model, and the specific content can refer to Korkmaz *et al*. (2021).

3.2. Model Specification

Based on the Cobb Douglas production function, Solow (1956) constructed a neoclassical growth model. This model has become a new theoretical framework for investigating influencing factors affecting economic growth.

$$Y_t = A_t K_t^\alpha L_t^\beta \tag{3}$$

Where L means labor element, k means the capital element, A indicates the technical element, and Y indicates the output obtained. α and β represent the degree of influence of capital input and labor input on economic output, respectively. In addition to the above factors, relevant documents have also proved that highway transportation infrastructure (Karac *et al*., 2020), railway transportation infrastructure (Yang *et al*., 2020a), urbanization (Ahmed *et al*., 2020), and financial support (O'Donoghue *et al*., 2021) are also closely related to rural economy. Therefore, this article also takes these factors into the analysis framework, and Eq.(3) becomes the following form.

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} HIG_t^{\beta_1} RAIL_t^{\beta_2} FIN_t^{\beta_3} URB_t^{\beta_4} \tag{4}$$

Where HIG stands for highway transportation infrastructure, RAIL means railway transportation infrastructure, URB stands for urbanization, and FIN demotes financial support. In order to eliminate the possible heteroscedasticity, this paper takes the logarithm of all variables in Eq. (4). Meanwhile, this article changes the expression of variables in order to make it easier to understand (Eq.5).

$$LY_{it} = C + \beta_1 LCAP_{it} + \beta_2 LLAB_{it} + \beta_3 LTEC_{it} + \beta_4 LHIG_{it} + \beta_5 LRAIL_{it} + \beta_6 LFIN_{it} + \beta_7 LURB_{it} + \mu_{it} \tag{5}$$

Where CAP means capital investment, LAB means labor input, and TEC means technological progress. β_1, $\beta_2,\ldots,\beta_7$ represent the parameters to be estimated, i represents the number of cross-sectional units, t represents sample period, μ represents a random disturbance term, and L means the logarithm of the variable data.

Eq.(5) determines the influencing factors of the low-carbon energy in China. Meanwhile, according to the theoretical form of the quantile regression model, this paper constructs a specific model for investigating the development of low-carbon energy in China (Eq.6).

$$Q_\tau(LY_{it}) = C_\tau + \beta_{1\tau} LCAP_{it} + \beta_{2\tau} LLAB_{it} + \beta_{3\tau} LTEC_{it} + \beta_{4\tau} LHIG_{it} + \beta_{5\tau} LRAIL_{it} + \beta_{6\tau} LFIN_{it} + \beta_{7\tau} LURB_{it} + \mu_{it} \tag{6}$$

Where *LY* represents the farmers' income, τ means quantile point, and Q means quantile regression.

Wage income and operating income are the main components of farmers' income, and these two incomes are most closely related to transportation infrastructure. Therefore, this article will separately examine the impact of highway transportation infrastructure and railway transportation infrastructure on these two types of income. The specific model form is shown in Eq. (7) and Eq. (8).

$$Q_\tau(LWAG_{it}) = C_\tau + \beta_{1\tau} LCAP_{it} + \beta_{2\tau} LLAB_{it} + \beta_{3\tau} LTEC_{it} + \beta_{4\tau} LHIG_{it} + \beta_{5\tau} LRAIL_{it} + \beta_{6\tau} LFIN_{it} + \beta_{7\tau} LURB_{it} + \mu_{it} \tag{7}$$

Where WAG represents the wage income of farmers. The other parts are the same as Eq.(6).

$$Q_\tau(LOPE_{it}) = C_\tau + \beta_{1\tau} LCAP_{it} + \beta_{2\tau} LLAB_{it} + \beta_{3\tau} LTEC_{it} + \beta_{4\tau} LHIG_{it} + \beta_{5\tau} LRAIL_{it} + \beta_{6\tau} LFIN_{it} + \beta_{7\tau} LURB_{it} + \mu_{it} \tag{8}$$

Where OPE represents the operating income of farmers. The other parts are the same as Eq.(6).

3.3. Data Source

The sample data used in this article is a panel data set, the sample period is 2000-2018, and the cross-sectional unit is 30 administrative regions in China. The Tibet Autonomous Region is not included in the sample unit, because the data on many socio-economic phenomena are complete. The data sources of the variables are explained as follows: (1) wage income. Wage income refers to the labor remuneration obtained by employees through various channels, including the salary of the main occupation, the income of the second occupation and other earning of part-time jobs (Yuan). (2) Operating income. Operating income refers to the income from agricultural production, such as food production, livestock and poultry breeding, and agricultural industrialization (Yuan). (3) Highway transport infrastructure. Highway mileage is measured by the sum of expressway, first-class highway, and second-class highway mileages. Highway transportation infrastructure is measured by the highway mileage per square kilometer of land (Kilometer/Square kilometers). (4) Railway transport infrastructure. Railway transport infrastructure is measured by the railway mileage per square kilometer of land (Kilometer/Square kilometers). (5) Labor input. Labor input is measured by the number of rural residents employed in private enterprises (10,000 person). (6) Capital investment. Infrastructure investment in agriculture, forestry, animal husbandry and fishery industries are an important aspect of agricultural capital investment. This article uses fixed asset investment in the agriculture sector to measure

Table 1: Definition of all the Variables

Variable	Definition	Units
Wag	Wage income	Yuan
OPE	Operating income	Yuan
CAP	Capital investment	100 million yuan
LAB	Labor input	10,000 person
TEC	Technological progress	Pieces/10^4 person
HIG	Highway infrastructure	Kilometer/Square kilometers
RAIL	Railway infrastructure	Kilometer/Square kilometers
FIN	Financial support	Percent
URB	Urbanization	Percent

capital investment (100 million yuan). (7) Technological progress. The approved patented technology is most directly related to technological progress. This article uses the number of patents per 10,000 people to measure technological progress (pieces/10,000 person). (8) Urbanization. This article employs the proportion of urban population in total population to measure the level of urbanization (%). (9) Financial support. This article uses the proportion of fiscal expenditure on agriculture, forestry and water affairs in total fiscal expenditure to measure fiscal support (%). The original data of all variables come from the China Statistical Yearbook. The definitions of all variables and their calculation units are listed in Table **1**, and the results of descriptive statistical analysis are listed in Table **2**.

4. RESULTS

4.1. Unit Root Test

In recent years, panel data has been widely used in economics, finance, management and other fields. Therefore, people will inevitably pay attention to the stability of panel data. In econometrics, the most common method for testing data stationarity is the unit root test. Extensive applications promote the rapid development of unit root test for panel data. The unit root test method of panel data is similar to that of time series, but the two are not exactly the same. Panel data considers the AR(1) process:

$$y_{it} = \alpha_i y_{it} + \beta_i X_{it} + \mu_{it} \quad (9)$$

Where i=1, 2,…, N; t=1, 2,…,T. N represents the number of cross-section individuals, and T represents the number of periods. *X* represents the exogenous variable vector, including individual fixed effects and time trends. The random error term (μ) satisfies the assumption of mutual independence, and independent and identically distributed. α_i is the autoregressive coefficient. If $|\alpha_i|<1$, the sequence (y_i) is a stationary sequence. If $|\alpha_i|=1$, it means that the sequence (y_i) is a non-stationary sequence. According to the different constraints of the parameter (α_i), the unit root test of panel data can be divided into two categories. One

Table 2: The Statistical Description of all the Variables

Variable	Units	Mean	Std.dev.	Min	Max
Wag	Yuan	3061.8	3253.1	104.6	20289.2
OPE	Yuan	2885.2	1563.8	589.7	7878.1
CAP	100 million yuan	176.69	208.95	1.50	966.70
LAB	10,000 person	114.79	149.66	1.5	1195.8
TEC	Pieces/10^4 people	4.52	9.27	0.07	77.31
HIG	Kilometer/Square kilometers	0.021	0.024	0.003	0.133
RAIL	Kilometer/Square kilometers	0.022	0.018	0.001	0.102
FIN	Percent	9.46	3.42	1.18	18.97
URB	Percent	50.08	15.34	23.2	89.6

Table 3: Results of Unit Root Tests for Panel Data

Series	LLC	Breit	PP	IPS	Fisher ADF
LWAG	-2.811***	1.998	19.362	4.612	19.916
LOPE	1.206	0.042	22.556	7.667	20.068
LHIG	-8.120***	4.625	179.76***	-5.856***	152.95***
LRAIL	-0.653	0.247	38.011	4.244	38.396
LFIN	-5.169***	-2.339***	139.68***	-4.729***	127.35***
LURB	6.082	2.141	111.87***	0.342	76.46*
LLAB	0.130	-0.471	64.949	0.171	59.421
LCAP	0.580	0.401	29.750	1.165	45.067
LTEC	4.591	1.378	2.915	11.730	6.143

Notes: The significance levels of 1%, 5%, and 10% are represented by ***, ** and * respectively. Levin, Lin & Chu test is represented by LLC, Breitung test is represented by Breit, and Im, Pesaran and Shin test is represented by IPS.

type of method is the test with the same unit root process, that is, the parameter $\alpha_i=\alpha(i=1,2,\ldots,N)$. This method includes LLC test and Breitung test. Another type of method is testing under different unit root process, that is, allowing α_i to vary across the cross-section. This method includes IPS test, ADF test, ADF-Fisher test and PP-Fisher test. This article applies these five methods to test the stationarity of the economic variable sequence used, which can strengthen the reliability of the results. The results in Table **3** that only financial support (FIN) passes all five tests. This means that the sequence of these three economic variables is stationary, and the other variable sequences are non-stationary.

4.2. Cointegration Tests

The test results in section 4.1 show that most economic variable sequences used in this article are non-stationary. According to the theory of econometrics, non-stationary variable series cannot be used for regression estimation. In order to solve this problem, some scholars propose to differentiate variable data, such as first-order difference and second-order difference. In general, the differentiated variable sequences are stationary. However, the differentiated sequences of economic variables often lose their economic significance (Xu and Lin, 2018). In view of the shortcomings of the existing methods, Engle and Granger (1987) proposed a new theory, namely the cointegration theory. As long as there is an overall long-term equilibrium relationship between the explanatory variables and the explained variables in the model, these economic variables can be used for regression estimation. According to the type of data analyzed, cointegration methods are divided into two categories. The first type of method is the time series cointegration test, and the second type of method is the panel data cointegration test. The newly developed panel data cointegration methods mainly include Westerlund test and Kao test. This paper uses these two methods to test the cointegration relationship of economic variable series. The results in Table **4** that the results of all statistics passed the significance test. This means that there is a long-term equilibrium relationship between these economic variables. Therefore, these variables can be used for regression estimation.

Table 4: Panel Cointegration Test

Method	Statistics	Dependent variable: wage income	Dependent variable: operating income
		Statistical value (P-value)	
Kao test	ADF	1.487*	-1.351*
Westerlund test	Variance ratio	1.500*	1.310*
Pedroni test	Modified PP	7.671***	9.081***
	PP	-4.699***	-5.626***
	ADF	-5.518***	-6.335***

Notes: Phillips-perron is represented by PP, Augmented Dickey-Fuller is represented by ADF.

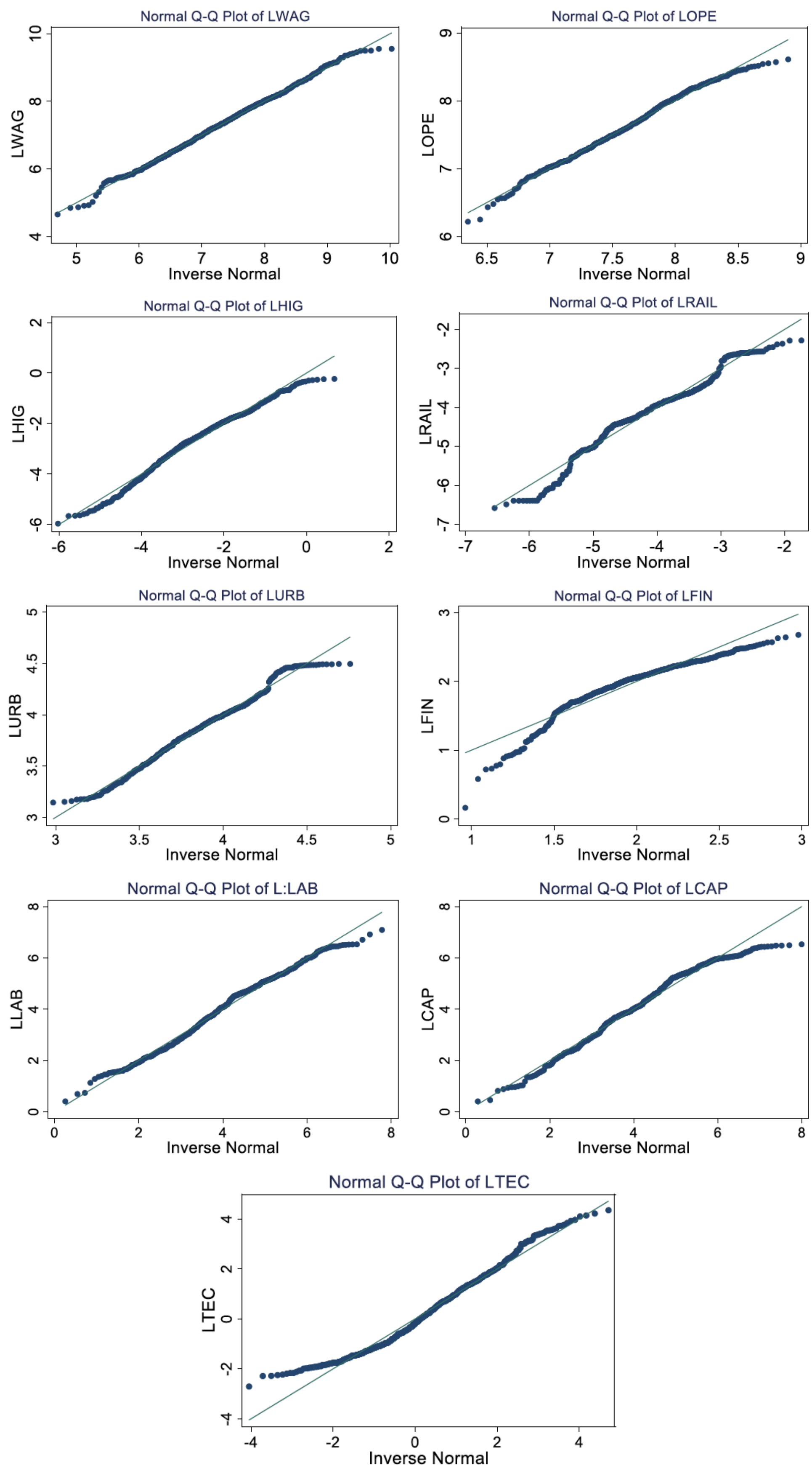

Figure 1: The normal Q-Q plot of economic variables in this paper.

4.3. Tests of Normal Distribution

Normal distribution means that if there are no major errors in observations or experiments, the socio-economic phenomena should follow the normal distribution (Lin and Xu, 2018). This conclusion is supported by a large number of empirical facts as well as theoretical basis, such as the central limit theorem. But in the case of a small sample, the assumption that the population follows a normal distribution is invalid. There are many methods to judge whether the distribution of an economic sequence is a normal distribution. The first method is the graphic method. It mainly includes the histogram of frequency distribution, Q-Q diagram (i.e., quartile-quartile) and P-P diagram (i.e., percentile-percentile). The second method is the statistical index method. It mainly includes Shapiro-Wilk, Kolmogrov-Smirnov, skewness, and kurtosis tests.

The theory of the Q-Q graph points out that if the Q-Q graph of a variable sequence coincides with the X=Y line, and this economic sequence is normally distributed. On the contrary, this economic sequence is a skewed distribution, including left-skewed distribution or right-skewed distribution (Xu and Lin, 2023). The Q-Q graph has the advantages of intuitive results and easy judgment. Therefore, this article uses the Q-Q graph to test whether the variable sequence belongs to the normal distribution. The results in Figure **1** show that the Q-Q graphs of these variable sequence used in this article are not consistent with the X=Y line. Therefore, it can be concluded that these variable sequences are not normally distributed.

4.4. Quantile Regression Results

4.4.1. Estimated Result of Wage Income

According to the basic principle of the quantile regression method, the explained variable between 0 and 1 can be divided into 100 equal parts. Drawing on the experience of existing related research, this article mainly gives the parameter estimation results of five representative quantile points (i.e., 10th, 25th, 50th, 75th, and 90th). These five representative quantile points divide the 30 cross-sectional provinces into 6 groups, and the grouping results are shown in Table **5**. The results of quantile regression are shown in Table **6**, and Table **6** gives the estimated results of five representative quantiles. The estimated results of all quantile points are given in Figure **2**. In addition, this paper also uses traditional panel data regression models for estimation, in order to highlight the advantages of quantile regression. The estimation results of the traditional panel data regression model are shown in the rightmost column in Table **6**.

The results in Table **6** show that the regression coefficients of highway transportation infrastructure are all positive, and all have passed the significance test. This means that the construction of highway transportation infrastructure has significantly promoted wage income. The regression coefficient of railway transportation infrastructure is significantly smaller than that of highway transportation infrastructure. It means that the contribution of highway transportation infrastructure is greater than that of railway transportation infrastructure. Moreover, the regression coefficients of the 10th-25th and 25th-50th quantile groups are negative, and have not passed the significance test. This indicates that railway transportation infrastructure has not played a significant role in promoting the wage income in these two quantile groups. The main reason is that most of the provinces in these two quantile groups are located in the western region, such as Sichuan, Shaanxi, Ningxia, Guangxi, Guizhou, Qinghai, and Gansu provinces. These provinces are economically backward and have

Table 5: The Grouping Results of 30 Provinces in China, Based on the Disparity in Wage Income and Operating Income

Quantile group	wage income	operating income
	Province	
upper 90th group	Shanghai, Beijing, Zhejiang	Jilin, Heilongjiang, Zhejiang
75th-90th group	Tianjin, Jiangsu, Guangdong, Fujian	Inner Mongolia, Fujian, Shandong, Tianjin
50th-75th group	Hebei, Shandong, Liaoning, Hunan, Jiangxi, Shanxi, Anhui, Chongqing	Liaoning, Xinjiang, Hainan, Hubei, Jiangsu, Henan, Jiangxi, Yunnan
25th-50th group	Hubei, Henan, Sichuan, Shaanxi, Ningxia, Hainan, Guangxi, Guizhou	Guangxi, Anhui, Hebei, Sichuan, Hunan, Guangdong, Ningxia, Chongqing
10th-25th group	Qinghai, Heilongjiang, Jilin, Gansu	Qinghai, Shanxi, Gansu, Shaanxi
lower 10th group	Inner Mongolia, Yunnan, Xinjiang	Guizhou, Beijing, Shanghai

Table 6: Estimated Results of Quantile Regression for Wage Income

Variables	Quantile regressions					OLS
	10th quant	25th quant	50th quant	75th quant	90th quant	
Constant	8.830***	8.016***	7.367***	6.993***	6.375***	7.621***
LHIG	0.228***	0.294***	0.214***	0.242***	0.166***	0.263***
LRAIL	0.072**	-0.055	-0.006	0.009***	0.060**	0.001
LFIN	0.135	0.098	-0.013	-0.003	-0.101	0.093**
LURB	-0.423***	-0.155	0.064	0.242***	0.461***	-0.032**
LLAB	0.130***	0.069***	0.102***	0.060***	0.054**	0.116***
LCAP	-0.068***	-0.074***	-0.041***	-0.001	0.034*	-0.048***
LTEC	0.474***	0.442***	0.366***	0.311***	0.285***	0.370***
Pseudo R^2	0.678	0.672	0.684	0.703	0.727	0.859

Notes: OLS represents the results of the panel data fixed-effects model, using ordinary least squares. The significance levels of 1%, 5%, and 10% are represented by ***, ** and * respectively.

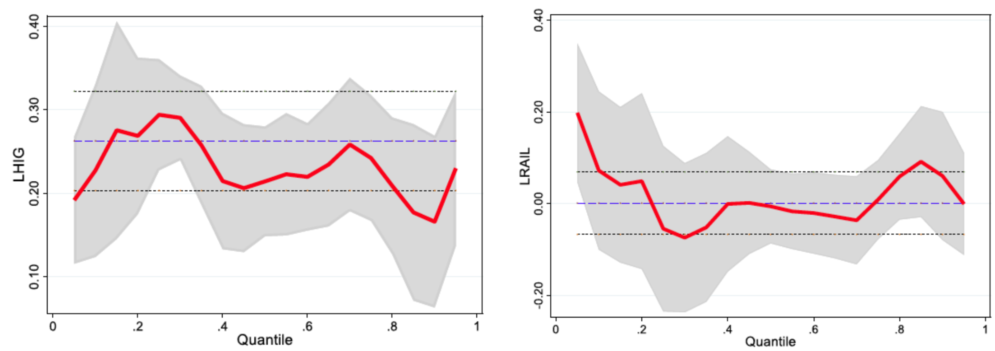

Figure 2: Quantile regression plot: the influence of highway transportation infrastructure and railway transportation infrastructure on wage income.

Notes: The effect of highway transportation infrastructure and railway transportation infrastructure on wage income at different quantiles is represented by the red curve. The result of least squares estimation is represented by the blue horizontal dashed line, and its 95% confidence interval is represented by two black dashed lines. The 95% confidence interval of quantile regression is represented by the grey area.

complex terrain. Railway construction lags behind and cannot significantly promote local farmers' income.

4.4.2. Estimated Result of Operating Income

The effect of highway transportation infrastructure and railway transportation infrastructure on operating income is shown in Table **7** and Figure **3**. For comparison purposes, this article also uses the traditional fixed effects model for estimation and the results are placed in the rightmost column of Table **7**. (1) The regression coefficients of highway transportation infrastructure in all quantile provinces are all positive. This means that the construction of highway transportation infrastructure contributes to the increase in operating income. Moreover, the upper 90th quantile group has the largest regression coefficient (0.242), indicating that highway transportation has the greatest impact on operating income in this quantile group. (2) The regression coefficients of railway transportation infrastructure in the lower 10th, 10th-25th, and 25th-50th quantile groups are negative (i.e., -0.122, -0.072 and -0.006). This means that railway transportation has not played a role in promoting operating income. The regression coefficients of the 50th-75th and 75th-90th quantile groups are positive, which are 0.034 and 0.056, respectively. It denotes that the income effect of railway transportation construction is obvious in these two quantile groups.

5. DISCUSSION

The empirical regression results are worthy of in-depth analysis and discussion. It is a prerequisite for the management department to formulate a reasonable energy policy.

Table 7: Estimated Results of Quantile Regression for Operating Income

Variables	Quantile regressions					OLS
	10th quant	25th quant	50th quant	75th quant	90th quant	
Constant	4.761***	4.826***	5.521***	5.622***	6.341***	6.333***
LHIG	0.158***	0.130***	0.072**	0.068*	0.242**	0.112***
LRAIL	-0.122**	-0.072**	-0.006	0.034**	0.056**	-0.056**
LFIN	0.198***	0.207***	0.197***	0.254***	0.264***	0.180***
LURB	0.395***	0.430***	0.369***	0.494***	0.351**	0.167***
LLAB	-0.098***	-0.098***	-0.098***	-0.101***	-0.104***	-0.151***
LCAP	0.233***	0.242***	0.200***	0.112***	0.090***	0.226***
LTEC	-0.053	-0.031	0.059**	0.115***	0.181***	0.087***
Pseudo R^2	0.444	0.445	0.441	0.447	0.422	0.892

Notes: quant is the quantile point. The 10% significance level is represented by *, 5% significance level is represented by **, and 1% significance level is represented by ***.

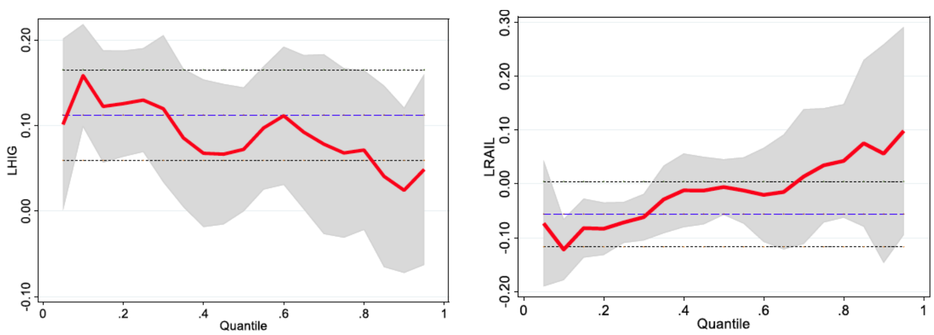

Figure 3: Quantile regression plot: the influence of highway transportation infrastructure and railway transportation infrastructure on operating income.

5.1. Highway Transportation Infrastructure Contributes the Least to Farmer's Wage Income in the Upper 90th Quantile Groups

The differences in highway transportation mileage and highway passenger turnover can explain this result. (1) Highway transportation mileage. Wage income refers to the labor remuneration obtained by employees through various channels. Rural residents need to work in various enterprises in urban areas or township enterprises to obtain wage income. Because the distribution of highway traffic is much denser than that of railway traffic, rural residents mainly rely on highway traffic to go out for work (Yu and Zhao, 2021). Statistics show that from 2000 to 2018, highway passenger traffic accounted for 48.0% of total passenger traffic. The better the highway network, the more convenient rural resident travel. Statistics show that from 2000 to 2018, the average highway mileage in the upper 90th quantile group was 7764.5 kilometers, less than that of the 75th-90th group (19,038.5 kilometers), 50th-75th group (17,854.9 kilometers), 25th-50th group (12,798.7 kilometers), 10th-25th group (9,490.4 kilometers), and lower 10th group (13,246.1 kilometers). Imperfect highway transportation is not conducive to the flow of rural residents. The upper 90th quantile group has the shortest average highway traffic mileage. Therefore, the highway infrastructure has the smallest contribution to farmers' wage income in this quantile provinces. (2) Highway passenger turnover. In recent years, urbanization has greatly promoted the changes in rural areas. More and more rural laborers are entering urban areas to find employment opportunities, which has contributed to a significant increase in their wage income (Outay *et al.*, 2020). Statistics show that from 2000 to 2018, the average growth rate of highway passenger turnover in the upper 90th quantile group was small, only 0.7%. During the same period, the growth rates of highway passenger turnover in the 75th-90th, 50th-75th, 25th-50th, 10th-25th, and lower 10th quantile groups was 1.5%, 1.4%, 2.9%, 2.5%, and 1.5% respectively. The growth rate of highway passenger turnover in the upper 90th quantile provinces is the lowest. The slow growth of highway passenger turnover means less population flow. As a result, highway transportation infrastructure has a smaller contribution on wage income in this quantile group.

5.2. Railway Transportation Infrastructure has a Small Contribution to the Wage Income in the 10th-25th, 25th-50th and 50th-75th Quantile Provinces

This result can be explained by railway passenger turnover and railway construction mileage. (1) Railway passenger turnover. The economic practice of economically developed countries such as the United States, Germany and Japan, has confirmed that perfect road traffic is a prerequisite for promoting social and economic development and expanding residents' income. In recent years, the Chinese government has vigorously promoted the construction of high-speed railways, and China has become the country with the longest high-speed railway in the world. Statistics show that by the end of 2019, China's high-speed railway mileage reached 35,000 kilometers, ranking first in the world. High speed railways have the advantages of comfortable riding environment and fast speed. The fast pace of work and life promotes more residents willing to travel by rail (Rode *et al*., 2020). Statistics show that from 2000 to 2018, the average growth rate of railway passenger turnover in the 50th-75th, 25th-50th, and 10th-25th quantile provinces was 6.0%, 6.6% and 4.7% respectively, lower than that in the upper 90th quantile (7.7%). 75th-90th quantile (8.4%), lower 10th quantile (6.9%). (2) Railway construction mileage. The improvement of the railway network will help more rural residents to find employment opportunities in cities and thus obtain corresponding wage income. On the other hand, the newly built high-speed railway will connect more counties to the railway network (Liang *et al*., 2020). This attracts funds and enterprises from big cities to invest in small towns, promotes local industrial development, and increases employment for rural residents. Statistics show that from 2005 to 2018, the average growth rate of railway construction mileage in the 10th-25th quantile, 25th-50th quantile, and 50th-75th quantile was 3.2%, 4.0%, and 4.3% respectively, lower than that in the upper 90th quantile (4.5%), 75th-90th quantile (5.5%), and lower 10th quantile (5.4%). The railway construction mileage of the 10th-25th, 25th-50th, and 50th-75th quantile provinces has increased slowly. It has led to a smaller contribution of railway transportation infrastructure to farmers' wage income in these quantile provinces.

5.3. The Operating Income in the Upper 90th Quantile Group Received the Greatest Contribution from Highway Transportation Infrastructure

This result can be explained by the difference in rural road mileage. Rural road can transport agricultural products, such as food products, and agricultural by-products, to urban areas, thereby helping to increase farmers' operating income (Temudo *et al*., 2020). This upper 90th quantile group includes the three provinces of Heilongjiang, Jilin and Zhejiang. Heilongjiang and Jilin provinces are the main grain producing areas in China, producing large amounts of agricultural products such as soybeans, corn, and rice every year. Statistics show that from 2014 to 2018, the total exports of soybeans, paddy and rice in Jilin and Heilongjiang provinces were among the top in the country, with an average export volume of 111.8 kilotons and 335.7 kilotons, respectively. These agricultural products are transported by road to cities for sale, increasing farmers' income. Zhejiang province is one of the provinces with the most developed private economy in China, with a large number of township and village enterprises (Han *et al*., 2021). Enterprise products and raw materials need to be transported by road. Statistics show that from 2000 to 2018, the average growth rate of rural road mileage in the upper 90th quantile group was 9.1%, which was significantly higher than that of the 75th-90th group (3.8%), 50th-75th group (7.4%), 25th-50th group (0.9%), 10th-25th group (4.0%) and lower 10th group (4.7%). Rural road construction in the upper 90th quantile group is growing faster. This will promote the sale of local agricultural products and help farmers purchase much-needed agricultural materials such as pesticides, fertilizers, seeds and agricultural machinery. Therefore, highway transportation infrastructure contributes the most to the operating income in the upper 90th quantile provinces.

5.4. The Railway Transportation Infrastructure has not Played a Role in Boosting the Operating Income in the Lower 10th, 10th-25th and 25th-50th Quantile Provinces

The main reason is explained as follows: for a long time, the transportation and sales of grain products and agricultural by-products have been completed by highway. Railway transportation mainly carries industrial and mineral products, such as coal and rare earth mines (Yang *et al*., 2020b). (1) The lower 10th quantile group includes Beijing, Shanghai and Guizhou provinces. Beijing and Shanghai are municipalities, occupying a small area, and most local agricultural products are transported by automobiles. Statistics show that the volume of cargo transportation in this quantile group in 2018 was 0.9 times that of 2000, which means that cargo transportation has decreased. Therefore, the railway transportation infrastructure has not played a role in boosting operating income. (2) The 10th-25th quantile group includes Qinghai, Shanxi, Gansu and Shaanxi provinces. Shaanxi and Shanxi provinces are rich in coal resources. The local production companies mainly transport coal and mineral resources to economically developed areas by railway, and railway transportation has little impact on rural industrialization. Qinghai and Gansu provinces have few railway lines, which are difficult to drive the rural economy and increase farmers' income. (3) The 25th-50th quantile group mainly includes the provinces of Guangxi, Sichuan, Chongqing and Ningxia. In recent years, the highway network has been continuously improved. Local farmers rely on road transportation to transport agricultural products to large cities and economically developed areas for sale (Branco *et al.*, 2020). The volume of railway freight has declined. For example, the volume of cargo transportation was a continuous negative growth during the period 2014-2016, and the volume of railway cargo transportation decreased by 8.5%, 11.9% and 4.2% respectively. Therefore, railway transportation has not played a role in promoting farmers' operating income.

6. CONCLUSIONS AND POLICY IMPLICATIONS

The test results show that the economic variable sequence is skewed, so this article uses a quantile regression model to study how transportation infrastructure affects farmers' income. The empirical findings indicate that the contribution of highway transportation infrastructure to the wage income in the upper 90th quantile groups is minimal. However, highway transportation infrastructure makes one of the greatest contributions to the operating income in the upper 90th quantile group. The impact of railway transportation infrastructure on wage income in the 10th-25th, 25th-50th and 50th-75th quantile provinces is the smaller. Furthermore, the railway transportation infrastructure has not played a role in boosting the operating income in the lower 10th, 10th-25th and 25th-50th quantile groups. Based on the above empirical results, this study makes relevant recommendations to reasonably plans the construction of transportation infrastructure.

6.1. The Upper 90th Quantile Provinces should further Improve the Rural Road Network

(1) The upper 90th quantile group includes Beijing, Shanghai, and Zhejiang province, which have a developed economy and strong financial ability. The local government should increase financial investment, speed up the construction of rural highway and connect more remote villages to the highway network and urban agglomerations. This will help remote rural residents enter urban areas for employment, and increase wage income. (2) The local government can rationally plan the road network, promote the construction of rural industrial parks and attract investment. Rural industrial parks can attract investment from urban enterprises, and promote the employment of rural residents. In addition, the local government can make reasonable plans to connect more abandoned villages to the highway network. This can attract investment and transform abandoned villages into tourist homestays, ultimately increasing the wage income of rural residents.

6.2. The 10th-25th, 25th-50th and 50th-75th Quantile Provinces should Strengthen the Development of Railway Station Areas along the Railway

(1) These quantile provinces should actively play the supporting role of rail transit in township areas, and promote the integrated development of railway transportation and land. The government takes the train station as the center and develops supporting real estate, hotel, finance, catering, entertainment, and sightseeing services. The train station area becomes a prosperous commercial center, promote employment of surrounding rural residents, and increase farmers' wage income. (2) These quantile provinces can actively attract social capital to invest in the construction of the local railway network. These quantile groups include many provinces in the central and western regions, such as Gansu, Qinghai, Guizhou, Guangxi, Shaanxi, Sichuan, and Chongqing provinces. Railway construction in these provinces lags far behind the Yangtze River Delta, Pearl River Delta and Beijing-Tianjin-Hebei region. This not only restricts the flow of rural residents in remote mountainous areas, but also is not conducive to attracting investment. The local government can promote the implementation of a shareholding system in railway operations. This can attract social capital to invest in railway construction, and accelerate the improvement of railway network.

6.3. The Lower 10th, 10th-25th, 25th-50th, 50th-75th and 75th-90th Quantile Provinces could Strengthen Transportation Construction in Poor Areas and Promote Agricultural Industrialization

Currently, road construction in many remote mountainous areas is still insufficient. Local agricultural products cannot be sold smoothly to urban areas, restricting local farmers' income. (1) The government's finances should increase investment in highway transportation construction in remote rural areas. In some areas with limited financial funds, government departments can make reasonable plans to attract investment for the construction of rural highway and the development of land around the roads. The government can sign agreements with social capital to clarify their rights and obligations to ensure that social capital obtains due benefits. This can speed up the construction of rural roads and connect more rural areas to the road network as soon as possible. (2) The government could make "Village Cadres" a long-term mechanism. The cadres in the villages can lead the rural residents to actively develop characteristic agriculture and increase farmers' operating income.

6.4. The Lower 10th, 10th-25th and 25th-50th Quantile Provinces could Expand the Construction of Railway Networks in Small and Medium County-Level Cities

(1) The government can consider allowing some county-level cities with conditions to become the starting stations of high-speed rail. This can promote the flow of talents, materials and capital between small cities and large cities, and improve the operating environment. (2) The railway management department can speed up the construction of the Internet of Things, which can provide an information exchange platform for the supply and demand of agricultural products transportation. Agricultural production enterprises release railway transportation demand information through this platform. According to the needs of agricultural production enterprises, railway companies deploy railway operating capabilities to deliver agricultural products to the urban areas more quickly.

7. THE LIMITATIONS OF THIS STUDY AND FURTHER RESEARCH

This paper investigates the impact of transportation infrastructure on farmers' income using a quantile regression model. But this paper does not take into account the possible spatial effects, namely spatial heterogeneity and spatial correlation. In recent years, the research results of spatial econometrics have shown that spatial effects are ubiquitous and have an important impact on social and economic development. Therefore, in future research, this paper will construct a spatial quantile regression model and use it to investigate the impact of transportation infrastructure on residents' income. The research results will provide empirical support for local governments to fully consider the spatial heterogeneity and formulate targeted policies.

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