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Analysis of the Impact and Mechanism of Carbon Trading Pilot Policies on the Urban-Rural Income Gap

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Abstract

China, as the world's largest developing country and carbon emitter, faces numerous challenges in achieving the "dual carbon" goals, and the environmental governance process will inevitably have systemic impacts on the economy and society. This paper treats the carbon trading pilot as a quasi-natural experiment, based on panel data from 172 prefecture-level cities across the country from 2010 to 2022, and uses a progressive difference-in-differences model to examine the impact and mechanism of the carbon trading pilot policy on the urban-rural income gap. The study shows that the carbon trading policy can narrow the urban-rural income gap by increasing the level of non-agricultural employment among rural residents. This conclusion remains valid after a series of placebo tests and robustness checks, and the policy's effect is more pronounced in the eastern regions and areas with a high degree of marketization. In light of this, this paper proposes three policy implications: strengthen the coordinated governance of carbon emissions and urban-rural income gaps, accelerate the construction of a unified national carbon market; formulate policy measures according to local conditions based on different regional endowment characteristics; and the government should improve non-agricultural employment through multiple channels to help narrow the urban-rural income gap.

JEL classification numbers: Q58, D31, O18, H23.
Keywords: Carbon trading pilot, Urban-rural income gap, Non-agricultural employment, Generalized difference-in-differences.

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1. Introduction

The report of the 20th National Congress of the Communist Party of China pointed out that since the reform and opening up, through continuous efforts, China successfully won the largest-scale poverty alleviation battle in human history by the end of 2020, historically resolving the issue of absolute poverty. However, it must be clearly recognized that the development gap between urban and rural areas and the income distribution disparity in China remain significant, and the problems of unbalanced and insufficient development are still prominent. Continuously narrowing the urban-rural income gap is a pressing practical issue in the process of achieving Chinese-style modernization. Current research mainly focuses on the impact of economic development, digital inclusive finance, industrial structure, and public services on the urban-rural income gap (Cui, 2023; Zhan, 2022; Zhou and Li, 2021; Xiong and Li, 2025), with less attention paid to the role of environmental regulation in narrowing the urban-rural income gap.

In recent years, the proposal of the "dual carbon" goals has brought high attention to environmental regulations related to carbon reduction across various sectors. Among these, the carbon trading pilot policy, as a crucial environmental regulation at the regional level, has been widely discussed. He and Song (2022) believe that the carbon trading policy significantly reduces carbon emissions, and the impact effect increases year by year. Wang and Huang (2024) argue that the carbon trading policy can significantly improve the employment in pilot areas. The question then arises: does the carbon trading pilot policy, while reducing carbon, affect farmers' income and thereby influence the urban-rural income gap? Are there differences in its impact on the urban-rural income gap across different regions? And through what mechanism does it affect the income gap? These questions have rarely been explored in existing literature.

In view of this, this paper, based on panel data from 172 prefecture-level cities across the country from 2010 to 2022, treats the "Notice on the Pilot Work of Carbon Emission Trading" issued by the National Development and Reform Commission as a quasi-experiment, using a progressive difference-in-differences model to examine the impact and mechanisms of the carbon trading pilot policy on the urban-rural income gap. This research holds significant theoretical and practical importance for exploring the social effects of environmental regulations. In order to ensure that while reducing emissions and carbon, it also promotes balanced social development and fairness in income distribution.

Compared to existing research, the marginal contributions of this paper may include the following three points: First, in terms of research content, this paper is one of the first empirical studies to explore the impact and mechanisms of the carbon trading pilot policy on the urban-rural income gap. It addresses the lack of research in past literature on the social effects of this policy, particularly on the urban-rural income gap, and provides theoretical and practical foundations for further establishing a unified national carbon market. Second, in terms of research perspective, past literature has not considered the carbon trading market in detail by dividing it into the quota market and the offset market. This paper separately explores the mechanisms through which the carbon trading pilot policy affects the urban-rural income gap from the perspectives of these two markets. Third, in terms of policy value, this paper comprehensively considers both carbon reduction and the urban-rural income gap to propose policy insights, offering practical application solutions for achieving the dual goals of "carbon peaking and carbon neutrality" and common prosperity through carbon trading policies.

The subsequent structure of this paper is arranged as follows. The first part is the policy background and literature review, the second part is the research hypothesis, the third part is the research design, the fourth part is the empirical results analysis, the fifth part is the mechanism analysis, and the sixth part is the conclusion and policy implications.

2. Policy background and literature review

2.1 Policy background

"Carbon trading" is a market-based environmental regulation, originating from the "United Nations Framework Convention on Climate Change" and the "Kyoto Protocol." This policy treats carbon dioxide emission rights as a commodity, establishing a corresponding trading system to achieve the goal of controlling greenhouse gas emissions at the lowest total social cost. The main international carbon trading markets include: the European Union Emissions Trading System, the Chicago Climate Exchange, the Quebec Carbon Market in Canada, the UK Emissions Trading System, the New Zealand Carbon Market, the Tokyo Cap-and-Trade System, the South Korean Carbon Market, Singapore's Carbon Trading System, and the New South Wales Greenhouse Gas Reduction Scheme in Australia. The "Notice on Launching the Pilot Work of Carbon Emission Trading" issued by the National Development and Reform Commission in October 2011 became the beginning of the development of China's carbon trading market. The document clearly stated, "Our commission agrees that Beijing, Tianjin, Shanghai, Chongqing, Hubei Province, Guangdong Province, and Shenzhen will carry out pilot carbon emission trading." Since June 2013, the first batch of seven pilot provinces and cities have successively opened their carbon trading markets. In 2016, Fujian Province became the eighth carbon trading pilot region in China. In July 2021, the national unified carbon market targeting the power industry officially started trading. Subsequently, key industries such as steel, petrochemicals, chemicals, and aviation will be gradually included. China's carbon market will become the largest carbon market in the world.

The main participants in the carbon trading markets of China's eight pilot provinces and cities are key emission units with annual greenhouse gas emissions reaching 260,000 tons of carbon dioxide equivalent, as well as institutions and individuals that comply with the relevant national trading rules. The quota market is the main body of the carbon market, with the trading product being carbon emission quotas; the offset market is a supplement to the carbon market, with the trading product being China Certified Emission Reductions (CCER). In addition to purchasing carbon emission quotas in the carbon market, enterprises can also fulfill their emission reduction tasks by purchasing emission reductions verified by third-party institutions, but the proportion of using CCER as quota offsets in each pilot province and city must not exceed 5-10% of the enterprise's initial quota. As of 2023, China's CCER project registration list includes a total of 861 projects, with over 90% located in rural areas, involving renewable energy projects, forestry carbon sink projects, biomass energy projects, etc. Carrying out CCER projects helps to invigorate the carbon market, promote the reflection of market supply and demand in quota prices, and drive the development of financial derivatives.

2.2 Literature review

2.2.1 Research Progress on the Impact of Environmental Regulation on the Urban-Rural Income Gap

In recent years, in order to promote global environmental protection and ecological balance, various environmental regulation measures have been adopted around the world. More and more scholars are exploring the environmental, economic, and social effects of environmental regulations. Some of the literature focuses on the impact of environmental regulation on farmers' income and the urban-rural income gap, but no unified conclusion has been reached.

Chen and Liu (2023) used data from rural households in China to explore the relationship between environmental regulations and farmers' income. The results showed that environmental regulations can significantly increase farmers' agricultural production income, while the impact on self-employment and non-agricultural employment is not significant. Moreover, the improvement in agricultural total factor productivity is the channel through which environmental regulations promote farmers' income growth. Liu et al. (2023), based on data from 591 farmers in Xinjiang, empirically tested that pro-environmental behavior can increase farmers' income by promoting the expansion of cultivated land area and enhancing farmers' willingness for future land transfer.

Ma et al. (2022) used data from 30 provincial-level regions in China and concluded that there is an "inverted U" characteristic between environmental regulation and the urban-rural income gap. Meng et al. (2022) based on panel data from 265 prefecture-level cities in China from 2006 to 2018, used the Spatial Durbin Model and the mediation effect model to examine the impact of urban green transformation on the urban-rural income gap. The results indicate that urban green transformation can narrow the urban-rural income gap through technological innovation effects and digital effects. Chen and Zhang (2023) used panel data at the prefecture level to explore the impact of low-carbon city pilot policies on the urban-rural income gap. The results show that this policy exacerbated the urban-rural income gap in the pilot areas. Wei and Zhao (2024) utilized the difference-in-differences method to discover that the central environmental protection inspection led by the central government of our country would widen the urban-rural income gap.

2.2.2 Research Progress on Carbon Trading Pilot Policies

Since the proposal in 2011 to establish the first batch of carbon trading pilots in China, scholars have conducted research, mainly focusing on exploring the environmental and economic effects of the carbon trading pilot policies, with less attention paid to the social effects of the carbon trading pilot policies.

Many studies focus on the environmental effects of carbon trading pilot policies. For example, Yang et al. (2023) used data from Chinese prefecture-level cities for evaluation and found that the carbon trading policy can promote the decline of carbon emissions in pilot areas by facilitating the transformation of green consumption, improving ecological efficiency, and promoting industrial structure upgrading. Liao et al. (2024) studied the pollution reduction and carbon reduction effects of carbon trading policies through Synthetic Control Method and Spatial Difference-in-Differences models. The results show that carbon trading reduces the overall pollution and carbon levels by 34.1%. In addition, it has the best synergistic reduction effect on CO2 and SO2, but the reduction effect on PM2.5 is poor. Zhang et al. (2025) based on data from A-share listed enterprises from 2010 to 2019, used propensity score matching and the difference-in-differences method to examine the pollution reduction effect of carbon trading policies at the enterprise level. The study found that carbon trading can reduce pollutant emission intensity by improving total factor productivity and input-output efficiency of enterprises. However, its impact on the total amount of pollutant emissions is not significant.

Other literature explores the economic effects of carbon trading pilot policies. Liu et al. (2022) used provincial-level data and the difference-in-differences method to study the impact of carbon emissions trading policies on green technology innovation. They found that the policies significantly promoted green technology innovation, and the policy effects were more pronounced in regions with stronger human capital, intellectual property protection, and marketization levels. Zhao et al. (2022) utilized data from Chinese prefecture-level cities from 2006 to 2019 and a multi-period DID model, finding that carbon trading promotes industrial structure upgrading through green innovation. Moreover, the effect is more significant in large cities and non-resource-based cities. Nie et al. (2022) based on panel data from 30 provincial levels in China, using the Data Envelopment Analysis-Malmquist index model and the Propensity Score Matching-Difference in Difference method to explore the impact of carbon trading policies on green economic growth. The results show that the implementation of carbon trading policies has promoted green economic growth and improved the green total factor productivity in pilot regions.

A few studies focus on the social effects of the carbon trading pilot policy, including aspects such as income and employment. Li et al. (2023) utilized provincial-level data from 2005-2019 to conclude that carbon trading policies reduce the level of per capita disposable income. This is mainly due to insufficient liquidity in the pilot carbon markets, residents' consumption patterns, and the industry-oriented economic structure. Yu and Li (2021) utilized panel data of Chinese A-share listed companies in Shanghai and Shenzhen to construct a triple difference model for research. They found that the implementation of carbon trading policies increased employment in pilot regions by 11.5%, with the effect growing year by year, and had a positive spillover effect of around 10% on surrounding regions.

Through the above literature review, it is found that the literature on the impact of environmental regulation on the urban-rural income gap is relatively abundant, but the literature specifically focusing on the carbon trading pilot policy is very scarce. Only Yu et al. (2021) based on panel data from 273 cities in China from 2010 to 2018, using a multi-period difference-in-differences model, concluded that carbon trading can reduce the urban-rural income gap in pilot areas. Moreover, the effect is more significant in the first batch of pilot cities, cities with higher carbon dioxide emissions, and cities with higher per capita GDP. Although this literature evaluates the impact of carbon trading policies on the urban-rural income gap, the mechanisms are not clearly revealed, and the reasons for the increase in farmers' income are not analyzed, leaving room for improvement. Therefore, this paper uses data at the prefecture-level city level in China to focus on the impact of carbon trading on the urban-rural income gap and its mechanisms.

3. Research hypothesis

Carbon trading pilot policy, as an environmental regulation tool, has the most important goal of reducing society's carbon emissions. However, due to the complex relationships among economy, society, and environment, it is difficult to balance and coordinate. So, can it simultaneously promote the reduction of the urban-rural income gap while achieving environmental effects? And through what pathways does it affect the urban-rural income gap? This section will use logical deduction to explore the impact of carbon trading pilot policy on the urban-rural income gap.

On one hand, from the perspective of rural residents' costs and benefits, the implementation of carbon trading in the quota market enables energy industrial enterprises to provide more affordable and high-quality clean energy such as electricity, natural gas, and liquefied petroleum gas to rural areas. Simultaneously, in the offset market, the CCER projects of the carbon trading market generate renewable and clean energy in rural areas, directly supplied to farmers for use. Both pathways reduce the production and living costs of farmers and increase the economic income of rural residents. Additionally, after the emission reductions generated by CCER projects are registered and filed in the national voluntary emission reduction trading registry, developers sell them to emission control enterprises, allowing rural residents to obtain corresponding economic benefits, thereby narrowing the urban-rural income gap.

On the other hand, analyzing from the perspective of rural residents' employment. After the implementation of the carbon trading policy, in the quota market, enterprises will pay more attention to the issue of carbon emission management in the production process. To meet emission requirements, they will accelerate the high-quality transformation of the industrial structure and increase the proportion of service-oriented industries, thereby increasing the number of personnel employed.

This provides more opportunities for farmers to work in urban areas, increasing their income. In the offset market, enterprises will increase investment in environmental governance projects, establishing various CCER projects in rural areas. During the construction, maintenance, and operation of these projects, employment opportunities can be created in rural areas, increasing the proportion of non-agricultural employment in rural areas and raising farmers' income. Based on the analysis of the above two markets, it can be inferred that there is a mechanism of "carbon trading pilot policy → non-agricultural employment → farmers' income → urban-rural income gap."

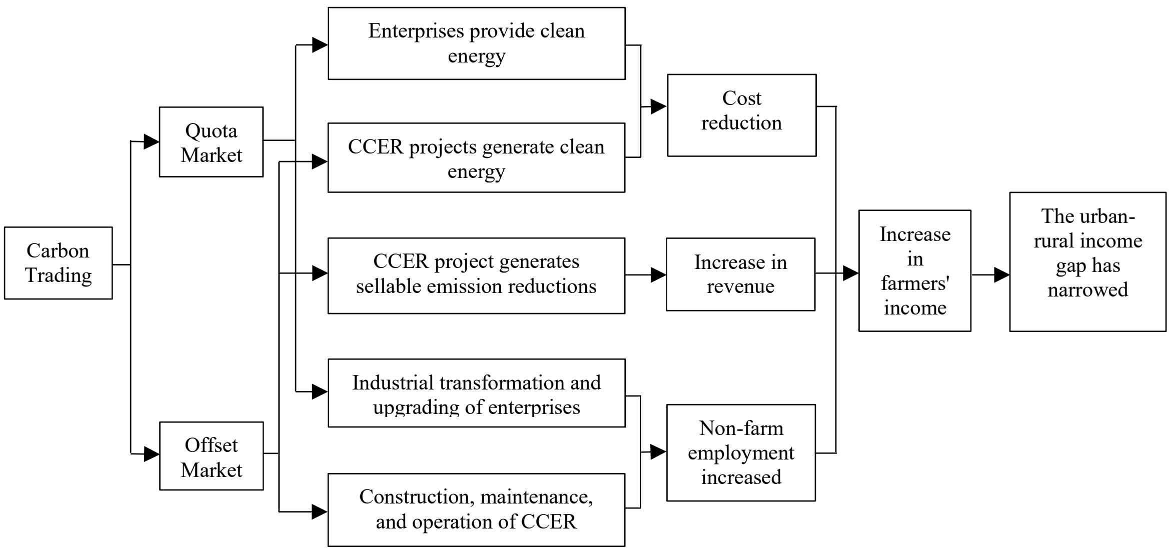

Figure 1: The Impact Mechanism of Carbon Trading Pilot Policies on the Urban-Rural Income Gap

Accordingly, this paper proposes the following 2 hypotheses.

Hypothesis 1: The carbon trading pilot policy helps to narrow the urban-rural income gap.

Hypothesis 2: The carbon trading pilot policy will narrow the urban-rural income gap by increasing non-agricultural employment.

4. Research Design

4.1 Variable measure

4.1.1 Explained variable: Urban-rural income gap (Gap_{ct})

Currently, the commonly used indicators to measure the urban-rural income gap include the Gini coefficient, the ratio of per capita disposable income between urban and rural areas, and the Theil index. This paper adopts the logarithmic Theil index to measure the urban-rural income gap. A larger value indicates greater regional disparity, that is, a larger urban-rural income gap. The calculation method is as follows:

$$Gap_{ct}=ln(\sum_{i=1}^{2}\frac{I_{it}}{I_t}\times ln\frac{\frac{I_{it}}{P_{it}}}{\frac{I_t}{P_t}}) \tag{1}$$

Among them, Gap_{ct} represents the urban-rural income gap in region c during period t. i=1 represents urban, i=2 represents rural. I_{it} represents the per capita disposable income of urban or rural areas in period t, I_t represents the per capita disposable income in period t. P_{it} represents the resident population of urban or rural areas in period t, P_t represents the total resident population in period t.

4.1.2 Core explanatory variable: Carbon Trading Pilot Policy ($Treat_c \times Time_t$)

$Treat_c \times Time_t$ is the interaction term between the time of implementing the carbon trading pilot policy and the policy dummy variable. Specifically, $Treat_c$ is the group dummy variable, which is assigned a value of 1 if city c belongs to the pilot region, otherwise 0. $Time_t$ is the time dummy variable. If a city c is approved as a carbon trading pilot city in year t, it is assigned a value of 1 in the year of policy implementation and subsequent years, otherwise it is 0.

4.1.3 Control variable

The permanent population density (*PPD*) is expressed by the number of permanent residents per unit area. The urbanization level (*UL*) is expressed by the proportion of urban permanent residents to the total permanent population. The education level (*EL*) is expressed by the proportion of education expenditure to local general public budget expenditure. The technology level (*TL*) is expressed by the proportion of science and technology expenditure to local general public budget expenditure. The financial development level (*FD*) is expressed by the proportion of RMB loan balance of financial institutions to GDP. The industrial structure (*Priind*) is expressed by the proportion of the added value of the primary industry to GDP. The economic development level (*lnPGDP*) is expressed by the logarithm of GDP per capita.

4.1.4 Mediating variable: Non-Farm Employment (NFP)

The proportion of employment in the secondary and tertiary industries to the total employment is used to represent it.

4.2 Sample Selection, Data Sources, and Descriptive Statistics

Considering the availability and validity of the data, this paper selects the period from 2010 to 2022 as the research interval and chooses 172 prefecture-level cities in China as the research sample. Among them, 38 cities are pilot cities, and 134 cities are non-pilot cities.

The data is sourced from the "China City Statistical Yearbook" and the statistical yearbooks and bulletins of various provinces and cities in China. Missing data were supplemented using the linear interpolation method, resulting in a final sample of 2236 data points. The descriptive statistical results of each variable are shown in Table 1.

Table 1: Descriptive Statistics of Variables

Variable	Average value	Standard deviation	Minimum value	Maximum value
Gap	-2.870	0.598	-5.525	-1.495
PPD	570.469	562.105	8.370	4282.590
UL	58.639	14.129	17.612	95.948
EL	17.661	3.705	4.363	35.621
TL	2.141	1.861	0.052	17.797
FD	1.074	0.622	0.223	4.502
Priind	9.982	6.150	0.161	29.304
lnPGDP	10.840	0.534	9.256	12.456
NFP	70.871	13.753	29.368	99.417

4.3 Model Construction

Since the carbon trading pilot was implemented in batches, this paper uses the Generalized Difference-in-Differences model for evaluation. In June 2013, the Shenzhen carbon trading market was the first to launch trading, followed by the first batch of pilot provinces and cities including Beijing, Tianjin, Shanghai, Chongqing, Guangdong, and Hubei. The second batch of pilot provinces, Fujian, initiated its carbon trading market in December 2016. Following common practice, this paper selects 2014 as the policy time demarcation point for the first batch of pilot cities and 2017 as the policy time demarcation point for the second batch of pilot cities. Since Shenzhen is the only city in the country without rural areas, it is excluded. The cities under the jurisdiction of the remaining seven provinces and cities are used as the treatment group, while the cities in other provinces serve as the control group. Constructing an evaluation model for the impact of city-level carbon trading pilot policies on the urban-rural income gap:

$$Gap_{ct}=\alpha_1+\beta_1 Treat_c \times Time_t+\theta_1 X_{ct}+\mu_c+\gamma_t+\varepsilon_{ct}^2 \quad (2)$$

Among them, Gap_{ct} is the explained variable, representing the urban-rural income gap in city c in period t. $Treat_c \times Time_t$ is the core explanatory variable, where $Treat_c$ indicates whether it is a pilot city (1=yes, 0=no), and $Time_t$ indicates whether the policy has been implemented (1=yes, 0=no). X_{ct} is a series of other control variables affecting the urban-rural income gap, including permanent population density (*PPD*), urbanization level (*UL*), education level (*EL*), technological level (*PPS*), financial development level (*FD*), industrial structure (*Priind*), and economic development level (*lnPGDP*). μ_c is the city fixed effect, γ_t is the time fixed effect; and ε_{ct}^2 is the random disturbance term.

5. Analysis of Empirical Results

5.1 Parallel Trend Test

The key premise of using the progressive difference-in-differences model is to satisfy the parallel trend assumption, that is, there are no systematic differences between the experimental group and the control group before the event occurs. This paper uses the event study method proposed by Jacobson et al. (1993) to conduct a parallel trend test, verifying that all sample regions have similar trends in the urban-rural income gap before the implementation of the carbon trading pilot policy, to ensure the validity of the regression results. The model is as follows:

$$Gap_{ct}=\alpha_1+\sum_{\tau=-4}^{+6}\rho_\tau Treat_c \times Time_{t_0+\tau}+\theta_1 X_{ct}+\mu_c+\gamma_t+\varepsilon_{ct}^2 \quad (3)$$

Among them, $Treat_c \times Time_{t_0+\tau}$ is a set of dummy variables. If city c implemented the carbon trading pilot policy in the year $t_0+\tau$, it takes the value of 1, otherwise it is 0. The meanings of the symbols for the remaining variables are the same as in equation (2).

Considering the limited data for the 5 years before and the 6 years after the policy implementation, this paper aggregates the data from the 5 years before the policy implementation into the -5th period, and the data from the 6 years after the policy implementation into the 6th period, selecting the 5th period before the policy implementation as the base period. The test results, as shown in Fig.2, indicate that the estimated coefficients before policy implementation are not significant, while the estimated coefficients after the policy implementation are significant. This suggests that there were no systematic differences between the pilot and non-pilot cities before the implementation of the carbon trading pilot policy, and the research sample passed the parallel trend test. From the perspective of dynamic effects, the coefficient estimates after the policy implementation are significantly negative, indicating that the carbon trading pilot policy can effectively reduce the urban-rural income gap.

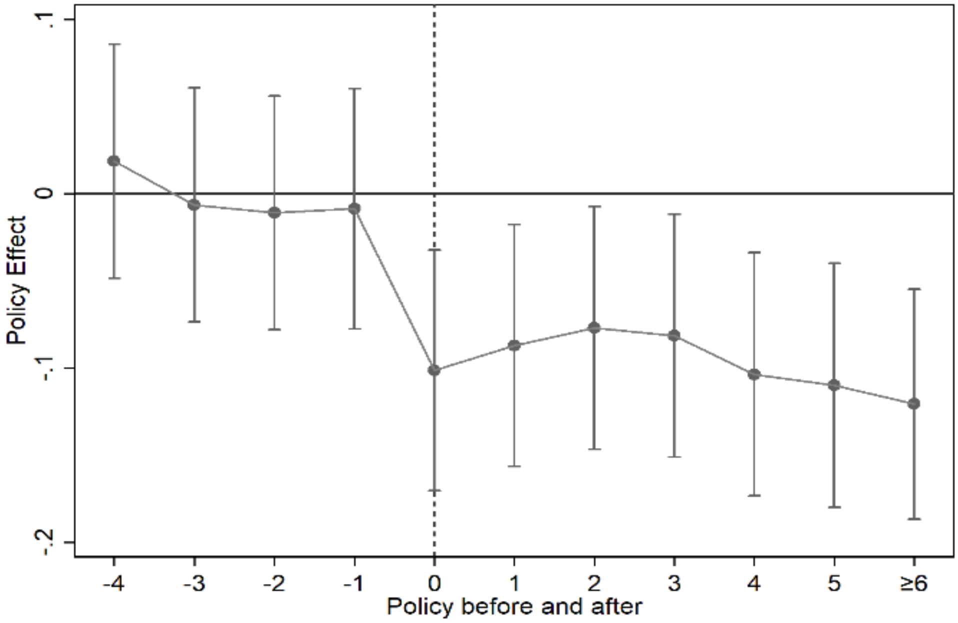

Figure 2: Parallel Trend Test

Solid dots represent the estimated coefficient ρ_τ of equation (3), and short vertical lines indicate the 95% confidence intervals corresponding to the robust standard errors.

5.2 Benchmark regression results

A Hausman test was conducted before the regression, and the results showed a χ^2 value of 70.17 with a P-value of 0.0000, indicating that a fixed effects model should be established.

Table 2 reports the regression results of the progressive difference-in-differences model in this paper. Column (1) shows the results with control variables and individual fixed effects added, Column (2) shows the results with control variables and time fixed effects added, and Column (3) shows the results with control variables, individual fixed effects, and time fixed effects added. The coefficients of $Treat_c \times Time_t$ in Columns (1)-(3) are all significantly negative and pass the significance test at the 1% level, indicating that the carbon trading pilot policy significantly reduces the urban-rural income gap.

Table 2: Benchmark Regression Results

	(1)	(2)	(3)
Variable	***Gap***	***Gap***	***Gap***
$Treat_c \times Time_t$	-0.144*** (0.014)	-0.232*** (0.027)	-0.096*** (0.013)
Constant	2.998*** (0.205)	0.947*** (0.310)	-2.997*** (0.362)
N	2236	2236	2236
R^2	0.792	0.728	0.833
Control variable	Yes	Yes	Yes
Time Fixed Effects	No	Yes	Yes
Individual Fixed Effects	Yes	No	Yes

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses. The same applies to the following tables.

5.3 Placebo Test

The cities in the sample of this paper have differences. In order to further confirm that the trend changes in the urban-rural income gap between the control group and the experimental group are due to the impact of the carbon trading pilot policy, rather than being caused by other unobservable random factors. This paper refers to the approach of Cai et al. (2016), randomly selecting 38 cities from the sample as a fictional list of carbon trading pilot cities, with the remaining cities serving as the control group. By conducting a baseline regression, the coefficient estimates of the impact of the carbon trading pilot policy on the urban-rural income gap can be obtained. Repeat the above process 500 times, using the regression coefficients from column (3) of Table 2 as a reference. Plot the estimated coefficients of $Treat_c \times Time_t$, their corresponding P-values, and kernel densities in the same figure, as shown in Figure 3. It can be observed that the regression coefficients follow a normal distribution and are all located to the right of the true coefficient -0.096, distributed around 0. The corresponding P-values are mostly greater than 0, indicating insignificance. This result aligns with the expectations of the placebo test, suggesting that the baseline regression results of this paper are not due to interference from unobservable random factors.

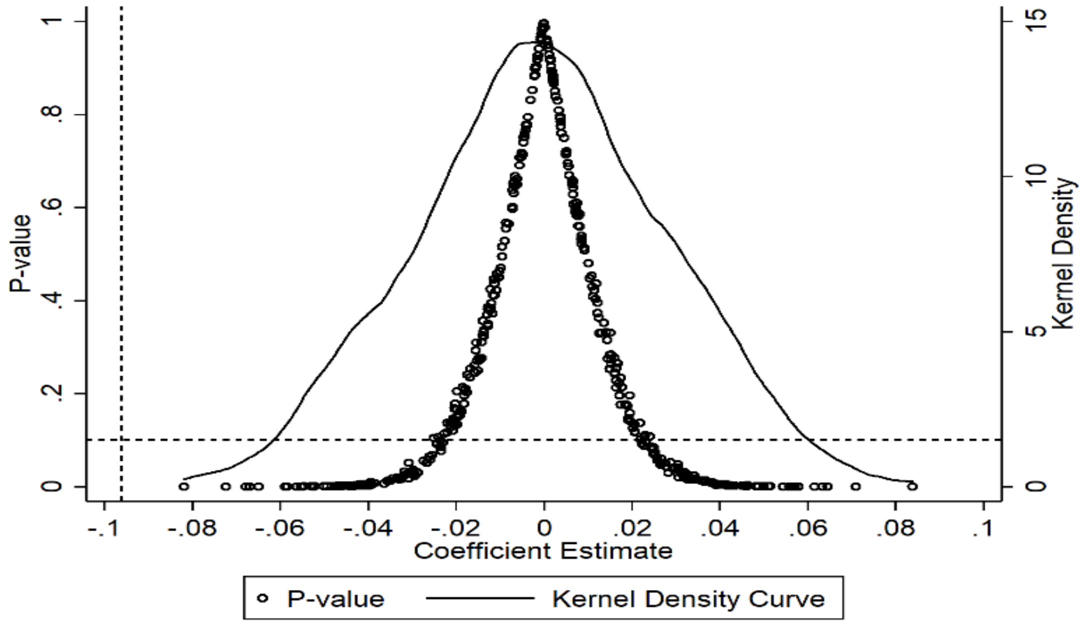

Figure 3: Placebo Test

5.4 Robustness Test

The benchmark regression results above demonstrate that the carbon trading pilot policy effectively narrows the urban-rural income gap. To ensure the reliability of the results, the following robustness tests were conducted.

5.4.1 Adding the interaction term between the baseline variable and the time trend

Considering that the explained variable may change over time and have an exogenous growth or decline. To avoid bias in estimating the changes in the urban-rural income gap across cities due to time trends, this paper incorporates the interaction terms of city characteristic factors and time trends into the regression, resulting in a new regression equation (4). Among them, Z_c represents a set of dummy variables for urban characteristic factors. It includes whether it is a "Two Control Zone," whether it is a provincial capital, whether it is a special economic zone, and whether it is located on the eastern side of the Hu Line, assigning a value of 1 if yes, otherwise 0. $Trend_t$ is the time trend term.

$$Gap_{ct}=\alpha_1+\beta_1 Treat_c\times Time_t+\theta_1 X_{ct}+\sigma Z_c\times Trend_t+\mu_c+\gamma_t+\varepsilon_{ct}^2 \quad (4)$$

Table 3 shows the regression results. Columns (1)-(4) sequentially include the interaction terms of "Two Control Zones," provincial capitals, special economic zones, and the east side of the Hu Line with the time trend into the regression equation. Column (5) simultaneously includes the interaction terms of the above four urban characteristic factors with the time trend in the equation. The results consistently show that the estimated coefficient of the core explanatory variable $Treat_c \times Time_t$ are significantly negative at the 1% level, indicating that the benchmark regression results are robust. The carbon trading pilot policy can significantly narrow the urban-rural income gap.

Table 3: Robustness Test Results

	(1)	(2)	(3)	(4)	(5)
Variable	***Gap***	***Gap***	***Gap***	***Gap***	***Gap***
$Treat_c \times Time_t$	-0.096***	-0.103***	-0.095***	-0.098***	-0.102***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Constant	-3.001*** (0.363)	-3.065*** (0.362)	-2.998*** (0.362)	-2.953*** (0.365)	-3.037*** (0.365)
N	2236	2236	2236	2236	2236
R^2	0.833	0.834	0.834	0.833	0.835
Control variable	Yes	Yes	Yes	Yes	Yes
Two Control Zones	Yes	No	No	No	Yes
Provincial Capital	No	Yes	No	No	Yes
Special Economic Zone	No	No	Yes	No	Yes
Hu Line	No	No	No	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Individual Fixed Effects	Yes	Yes	Yes	Yes	Yes

5.4.2 Using Propensity Score Matching Difference-in-Differences Model

When selecting pilot cities for carbon trading, the state is influenced by factors such as local economic development, industrial structure, technological strength, educational level, and financial level. That is, the selection of carbon trading pilot regions is not entirely random, leading to endogeneity. Therefore, this paper uses the Propensity Score Matching Difference-in-Differences method to address the impact of the aforementioned selection issues on the regression results. First, the control variables in (1) are taken as covariates, and a 1:2 caliper nearest neighbor matching method is adopted for matching, ensuring that there are no significant differences in covariates between the experimental and control groups. Then, the model is re-regressed, and the results are shown in column (1) of Table 4. The estimated coefficient of the core explanatory variable $Treat_c \times Time_t$ passes the significance test at the 1% level and is negative, further verifying the robustness of the benchmark regression results.

5.4.3 Lagging the control variables by one period

Considering that there may be a reverse causal relationship between the explained variable of urban-rural income gap and the control variables, leading to endogeneity in the model and biased estimation results. Therefore, by introducing the lagged period of all control variables into the model for re-regression, the results are shown in column (2) of Table 4. The estimated coefficient of the core explanatory variable $Treat_c \times Time_t$ remains negative at the 1% significance level, similar to the benchmark regression results, proving the reliability of the results.

5.4.4 Truncation processing

To avoid the impact of extreme values on the regression results, the explained variables were truncated by 1% and 5% respectively, and the regression was re-conducted. The results are shown in columns (3) and (4) of Table 4, indicating that after removing the extreme values, the estimated coefficient of the core explanatory variable $Treat_c \times Time_t$ still passed the significance test at the 1% level, and the estimates were negative. Similar to the baseline regression results, this further demonstrates that the carbon trading pilot policy can narrow the urban-rural income gap.

Table 4: Robustness Test Results

Variable	(1) PSM-DID	(2) Lagging one period	(3) Truncate 1%	(4) Truncate 5%
	Gap	*Gap*	*Gap*	*Gap*
$Treat_c \times Time_t$	-0.104***	-0.093***	-0.097***	-0.103***
	(0.014)	(0.014)	(0.013)	(0.013)
Constant	-3.095*** (0.367)	-3.242*** (0.399)	-3.173*** (0.375)	-3.440*** (0.386)
N	2116	2064	2192	2013
R^2	0.835	0.820	0.831	0.838
Control variable	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
Individual Fixed Effects	Yes	Yes	Yes	Yes

5.5 Heterogeneity Analysis

5.5.1 Regional Heterogeneity

The economic development levels in the eastern, central, and western regions of China are extremely unbalanced. It is necessary to examine the differences in the impact of the carbon trading pilot policy on the urban-rural income gap in cities across the eastern, central, and western regions. This paper divides the cities in the sample into three groups: eastern, central, and western, and conducts grouped regression. The results are shown in columns (1)-(3) of Table 5. In the group of the eastern region, the estimated coefficient of the core explanatory variable $Treat_c \times Time_t$ is -0.113, with the coefficient value in the same direction as the benchmark regression results and passing the significance test at the 1% level. In the groups of the central and western regions, the estimated coefficients of $Treat_c \times Time_t$ are -0.005 and 0.028 respectively and are not significant. The above results indicate that the carbon trading pilot policy has the strongest effect in narrowing the urban-rural income gap in the eastern region.

First, the reason may be that the eastern region is the most economically developed, with more high-pollution and high-energy-consuming industries. Implementing the carbon trading pilot policy is conducive to promoting the industrial upgrading of these industries, creating more high-quality employment opportunities, thereby absorbing more rural labor and narrowing the urban-rural income gap. Second, the eastern region has a high level of technology, and implementing carbon trading pilot policies makes it easier for the eastern region to achieve research and promotion of renewable energy. This reduces the energy costs in rural areas and allows for the sale of renewable energy to generate income, further narrowing the urban-rural income gap. Third, the administrative efficiency of the government in the eastern region is relatively high. Efficient policy execution helps to promptly convert the benefits of the carbon trading pilot policy into actual gains in rural areas, thereby narrowing the urban-rural income gap.

5.5.2 Heterogeneity of Marketization Degree

As a market-based environmental regulation, the effectiveness of carbon trading pilot policies may be constrained by the degree of local marketization. To verify whether the impact of the carbon trading pilot policy on the urban-rural income gap varies with the level of marketization, this paper divides the cities in the sample into three groups—high marketization, medium marketization, and low marketization based on the "China Provincial Marketization Index Report (2021)" and conducts grouped regressions. However, since the carbon trading pilot cities do not include low marketization areas, Table 4 only reports the regression results for high marketization and medium marketization regions. The results are shown in columns (4) and (5) of Table 5. In the sample with a high level of marketization, the estimated coefficient of the core explanatory variable $Treat_c \times Time_t$ is -0.098 and passes the 1% significance test. The estimated coefficient is consistent with the direction of the benchmark regression results. In the sample with a medium level of marketization, the estimated coefficient of $Treat_c \times Time_t$ is -0.020 and does not pass the significance test. The above results indicate that the carbon trading pilot policy has a stronger effect on narrowing the urban-rural income gap in regions with a high level of marketization.

First, the reason may be that regions with a higher degree of marketization have more efficient resource allocation. In such an environment, the carbon trading pilot policy can operate more effectively, and rural residents can access more high-quality resources and opportunities, thereby increasing their income and narrowing the urban-rural income gap. Second, with the implementation of carbon trading pilot policies, related industries such as clean energy and energy conservation will generate a large number of job opportunities. Regions with a high degree of marketization are more likely to convert these job opportunities into actual positions, thereby absorbing more rural labor and increasing the income of rural residents. Third, in regions with a high degree of marketization, capital and technology can flow more freely. This can attract more green investment for the carbon trading pilot policy, promoting the implementation of environmental technologies and clean energy projects in rural areas. It provides more sufficient prerequisites for achieving energy self-sufficiency and reducing energy costs, which is conducive to narrowing the urban-rural income gap.

Table 5: Heterogeneity Test Results

Variable	**Regional Heterogeneity**			**Heterogeneity of Marketization Degree**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Eastern region	**Central region**	**Western region**	**High marketization**	**Medium marketization**
$Treat_c \times Time_t$	-0.113^{***}	-0.005	0.028	-0.098^{***}	-0.020
	(0.019)	(0.028)	(0.056)	(0.016)	(0.043)
Constant	-4.104^{***} (0.940)	-3.594^{***} (0.534)	-2.034^{***} (0.593)	-4.352^{***} (0.788)	-4.704^{***} (0.578)
N	819	962	455	910	403
R^2	0.839	0.833	0.881	0.839	0.874
Control variable	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Individual Fixed Effects	Yes	Yes	Yes	Yes	Yes

6. Mechanism Analysis

6.1 Mediation Effect Model

This section focuses on exploring the channel mechanism of the impact between the carbon trading pilot policy and the urban-rural income gap. Non-agricultural employment is selected as the mediating variable for verification, and the Sobel and Bootstrap (1000 bootstrap samples) methods are used to test the results. The specific mediating effect model equations are as follows:

$$Gap_{ct}=\vartheta_0+\vartheta_1 Treat_c\times Time_t+\vartheta_2 X_{ct}+\mu_c+\gamma_t+\varepsilon_{ct}^2 \quad (5)$$

$$NFP_{ct}=\delta_0+\delta_1 Treat_c\times Time_t+\delta_2 X_{ct}+\mu_c+\gamma_t+\varepsilon_{ct}^2 \quad (6)$$

$$Gap_{ct}=\omega_0+\omega_1 Treat_c\times Time_t+\omega_2 NFP_{ct}+\omega_3 X_{ct}+\mu_c+\gamma_t+\varepsilon_{ct}^2 \quad (7)$$

Among them, NFP_{ct} represents the non-agricultural employment in city c during period t, and the settings of the remaining variables are consistent with those described earlier.

Table 6 reports the regression results of the mediation effect model. Column (1) shows that the carbon trading pilot policy can significantly reduce the urban-rural income gap, and the total effect of the policy on the urban-rural income gap is -0.096. Column (2) indicates that the carbon trading pilot policy can increase the level of non-agricultural employment in the pilot regions. In Column (3), the coefficients of both the carbon trading pilot policy and non-agricultural employment are significantly negative, and the direct effect of the policy on the urban-rural income gap is -0.090. Further Sobel and Bootstrap tests were conducted on the mediation effect. The results proved the existence of partial mediation, with a mediation effect of -0.007, accounting for 6.955%. It was verified that the carbon trading pilot policy can narrow the urban-rural income gap by increasing non-agricultural employment.

Table 6: Mechanism Analysis Test Results

	(1)	**(2)**	**(3)**
Variable	***Gap***	***NFP***	***Gap***
$Treat_c\times Time_t$	-0.096***	2.389***	-0.090***
	(0.013)	(0.396)	(0.013)
NFP			-0.003*** (0.001)
Constant	-2.997*** (0.362)	-35.139*** (11.012)	-3.095*** (0.362)
Sobel test	-0.007***(z=-3.252)		
Goodman-1	-0.007***(z=-3.221)		
Goodman-2	-0.007***(z=-3.284)		
Mediating Effect	-0.007***(z=-3.252)		
Proportion of Mediating Effect	6.955%		
Ind_eff test(P-val)	0.008 The mediation effect is established.		
N	2236	2236	2236
R^2	0.833	0.581	0.834
Control variable	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes
Individual Fixed Effects	Yes	Yes	Yes

6.2 Heterogeneity Test

To further verify the existence of the above-mentioned mechanism, the following section conducts grouped regressions based on the level of non-agricultural employment and the degree of industrial structure advancement.

6.2.1 Non-farm Employment Heterogeneity

This paper sorts the data according to the size of non-agricultural employment and divides 2236 samples into three groups of low non-farm employment, medium non-farm employment, and high non-farm employment at a ratio of 30%, 40%, and 30% for regression analysis. Since it is more difficult to create non-agricultural employment opportunities for rural residents by implementing the carbon trading pilot policy in areas with higher non-agricultural employment. Therefore, if the aforementioned mechanism exists, the effect of narrowing the urban-rural income gap should be smaller in areas with higher non-agricultural employment.

The empirical results are shown in columns (1)-(3) of Table 7. In the low and medium groups, the estimated coefficients of the core explanatory variables $Treat_c \times Time_t$ are significantly negative, and the absolute value of the coefficient for low non-agricultural employment is greater than that for middle non-agricultural employment. Moreover, the coefficient estimate for the high non-agricultural employment group is positive and not significant. It indicates that the carbon trading pilot policy has a stronger effect on narrowing the urban-rural income gap in regions with low non-agricultural employment. As the proportion of non-agricultural employment continues to increase, the effect of narrowing the urban-rural income gap gradually weakens. This is consistent with the above reasoning results, verifying the existence of the mechanism "carbon trading pilot policy → non-agricultural employment → farmer income → urban-rural income gap."

6.2.2 Heterogeneity of Advanced Industrial Structure

This paper adopts the industrial structure upgrading index to measure the advanced level of industrial structure, and the calculation formula is as follows:

$$IS=\sum_{i=1}^{3} q_i \times i = q_1 \times 1 + q_2 \times 2 + q_3 \times 3 \quad (8)$$

Among them, IS represents the advancement of industrial structure, q_i represents the proportion of the added value of the i-th industry to the regional GDP. The larger the industrial structure upgrading index, the higher the level of industrial structure advancement.

Secondly, rank the cities based on the calculated level of industrial structure advancement. Divide the cities in the sample into three groups with low, medium, and high levels of industrial structure advancement at the proportions of 30%, 40%, and 30%. Then perform regressions separately. Due to the implementation of carbon trading policies, enterprises are encouraged to innovate and transition from high-energy-consuming, high-emission heavy industries to clean production high-tech industries and modern service industries to meet carbon emission requirements. During this transformation process, non-agricultural employment can be increased. In regions with a lower degree of industrial structure advancement, the proportion of non-agricultural employment is usually smaller, and the potential to increase non-agricultural employment through the implementation of carbon trading is greater. Therefore, if the aforementioned mechanism exists, the effect of narrowing the urban-rural income gap should be more significant in regions with a lower degree of industrial structure advancement.

The empirical results are shown in columns (4)-(6) of Table 7. In the groups with low and medium levels of industrial structure advancement, the estimated coefficients of the core explanatory variable $Treat_c \times Time_t$ are significantly negative, and the absolute values are smaller in the medium-advanced group. In the group with a high level of industrial structure advancement, the estimated coefficient of $Treat_c \times Time_t$ is significantly positive. The above results indicate that the carbon trading pilot policy has a stronger effect on narrowing the urban-rural income gap in regions with a lower level of industrial structure advancement. As the level of industrial structure advancement continues to increase, the effect of narrowing the urban-rural income gap gradually weakens, and eventually, it may even widen the urban-rural income gap. Since this aligns with the reasoning results mentioned above, it once again proves that the mechanism of action holds.

Table 7: Heterogeneity Test Results

Variable	**Non-farm employment heterogeneity**			**Heterogeneity of Advanced Industrial Structure**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Low	**Middle**	**High**	**Low**	**Middle**	**High**
$Treat_c \times Time_t$	-0.170***	-0.147***	0.036	-0.139***	-0.060***	0.059**
	(0.031)	(0.018)	(0.023)	(0.026)	(0.020)	(0.029)
Constant	-2.190*** (0.717)	-4.107*** (0.558)	-1.289 (0.905)	-2.062*** (0.751)	-4.898*** (0.609)	0.844 (0.886)
N	671	894	671	671	894	671
R^2	0.800	0.846	0.845	0.778	0.829	0.844
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

7. Conclusion and Policy Implications

This paper takes the carbon trading pilot policy as a "quasi-natural experiment", based on panel data from 172 prefecture-level cities in China from 2010 to 2022, and uses the Generalized Difference-in-Differences model to estimate the impact and mechanism of the carbon trading pilot policy on the urban-rural income gap. The results show that the carbon trading pilot policy has significantly improved the regional urban-rural income gap. Moreover, this conclusion still holds after conducting placebo tests and a series of robustness checks, such as adding the interaction term between the benchmark variable and the time trend, using the propensity score matching difference-in-differences model, lagging the control variables by one period, and truncation processing. In addition, the negative impact of the carbon trading pilot policy on the urban-rural income gap is more significant in the eastern regions and areas with a high degree of marketization. This paper further analyzes the transmission mechanism of the policy's impact on the urban-rural income gap. The results show that the carbon trading pilot policy can indirectly narrow the regional urban-rural income gap by promoting non-agricultural employment. Based on the above conclusions, this paper proposes the following policy implications:

First, strengthen the coordinated governance of carbon emissions and the urban-rural income gap, and accelerate the construction of a unified national carbon market. In the process of formulating carbon trading policies, fully consider the impact on the urban-rural income gap. Establish a real-time evaluation and adjustment system for the coordination of carbon trading policies and policies promoting the reduction of the urban-rural income gap. Ensure the steady realization of the "dual carbon" goals and common prosperity, and avoid systemic risks caused by excessive carbon reduction. In addition, starting with pilot projects in specific cities and industries to gain experience, gradually accelerate the construction of a nationwide unified carbon market, incorporating industries with high carbon emissions such as building materials, steel, fossil fuels, non-ferrous metals, papermaking, and aviation. In this process, attention should be paid to formulating a comprehensive legal and regulatory system, establishing an accurate and efficient carbon accounting system, standardizing carbon pricing rules, strengthening the regulatory mechanism of the carbon market, and enhancing the cultivation of talent in related fields.

Second, formulate policy measures according to the different endowment characteristics of the region and tailored to local conditions. Regarding the analysis of regional differences, for the eastern region, due to its characteristics of economic development and strong innovation capabilities, the formulation of carbon trading policies should focus on optimizing industrial structure and developing green and low-carbon technologies. According to the heterogeneity analysis results in this paper, the negative impact of carbon trading on the urban-rural income gap is most significant in the eastern region. The eastern region should play a leading and exemplary role, first exploring a mature carbon trading market model, and then gradually expanding to the central and western regions after gaining experience. For the western regions, due to their characteristics of abundant resources, the development of carbon trading policies should encourage the orderly transfer of high-emission and high-energy-consuming industries to the western regions. Make full use of local renewable energy sources such as wind, water, and solar power to promote the low-carbon transformation of industries. Regarding the analysis of differences in marketization levels, for regions with lower marketization levels, the focus should be on establishing a complete carbon trading market system, strengthening regional coordination and cooperation, and avoiding market fragmentation. For regions with a higher degree of marketization, it is necessary to leverage their own advantages and play a major role in driving carbon reduction and narrowing the urban-rural income gap through carbon trading pilot policies. Continue to encourage more enterprises to participate in carbon trading to stimulate market vitality. Develop more types of carbon financial products to increase market liquidity. Regarding the analysis of the differences in the degree of industrial structure advancement, for regions with a high degree of industrial structure advancement, due to the limited space and high difficulty of low-carbon industrial transformation, alternative methods of carbon reduction should be sought, such as increasing the development of clean energy and improving the utilization rate of clean energy. In addition, the transformation experience should be promoted to regions with a low level of industrial structure advancement to achieve broader regional collaborative emission reduction. For regions with a low level of industrial structure advancement, the results of heterogeneity analysis show that these regions have significant potential in achieving the dual effects of carbon reduction and income increase. The government should provide technological and financial support to help achieve the advancement and rationalization of the industrial structure as soon as possible.

Third, the government should enhance non-agricultural employment through multiple channels to help narrow the urban-rural income gap. According to the findings of this study, there exists a mechanism of "carbon trading pilot policy → non-agricultural employment → farmers' income → urban-rural income gap." Additionally, the Certified Emission Reduction (CCER) projects in the offset market play a significant role in increasing non-agricultural employment. However, due to the general regulation that the offset ratio of CCER projects cannot exceed 5% of the total carbon emission allowances to be cleared (with a maximum of 10%), and the approval of new CCER projects was suspended in 2017. Therefore, the current carbon trading pilot policy has limited effectiveness in achieving both carbon reduction and income increase. Call for the prompt resumption of the approval process for CCER projects and the expansion of its proportion, so that they can effectively become a powerful policy tool. In addition, the government should conduct publicity and education on the relationship between carbon trading and rural residents' income, increasing recognition of carbon trading among all parties. Subsidies should be provided to enterprises engaged in renewable energy projects to reduce their carbon reduction costs and attract more companies to join CCER projects. Financial investment should be increased to improve related facilities and service systems in rural areas, providing a foundation for the construction of CCER projects. Support should be given to the development of green finance to ensure assistance to the agricultural sector, promoting sustainable economic development through market means.

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