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Can Carbon Emissions Trading Pilot Policies Increase New Quality Productive Forces in Cities

-- Empirical Evidence from Panel Data of Chinese Cities

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Abstract

New quality productive forces is an important driving force for high-quality development, and it is worthwhile to pay attention to whether the pilot carbon emissions trading policy, as a key environmental regulatory tool for realizing the goal of "dual-carbon", can be an effective promoter for cultivating new quality productive forces. Based on the panel data of 256 Chinese cities from 2009 to 2021, this study treats the carbon emissions trading pilot as a quasi-natural experimental design, and applies double-difference models to assess the impact of the policy on the new quality productive forces of cities, and systematically analyzes its transmission path, heterogeneous characteristics and spatial effects. The empirical results show that the pilot carbon emissions trading program significantly improves the level of new quality productive forces in cities; the mechanism test shows that the policy promotes the development of green finance, industrial structure upgrading, and green technological innovation through three paths; the heterogeneity analysis shows that the effect of the policy is particularly significant in the cities of the western part of the country, which are of higher administrative level, non-resource-dependent, and with a solid foundation of innovation, and with a higher degree of maturity of the development of NPRO; the spatial double-difference test reveals the significant effect of the policy on the development of the city. The spatial double difference test reveals that the policy has a positive spillover effect on neighboring cities. This study reveals the mechanism of carbon emissions trading policy on NPRO from the theoretical level, and provides a decision-making basis for optimizing the effectiveness of policy implementation and innovating the development path of productivity.

Keywords

Carbon Emissions Trading Pilot Policy; New Quality Productive Forces; Green Finance; Industrial Structure Supererogation; Green Technology Innovation.

1. Introduction

In September 2023, General Secretary Xi Jinping pointed out that "NPRO are the concrete embodiment of contemporary upgrading productivity, are innovation-led, in line with the new development concept of the form of productivity." This strategic positioning not only ushers China's economic development into a new phase of qualitative leap, but also a key choice to cope with global industrial change and reshape the competitive advantage, and their levels of development have become a core indicator to measure the quality of regional economic as well as societal growth. In the process of promoting the twin goals of carbon peak and carbon neutrality in China, the carbon emissions trading mechanism has been established as a key policy tool for realizing the twin goals. In accordance with the strategic directives outlined in

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the 12th Five-Year Plan, beginning in 2011, China introduced market-based carbon pricing systems in selected pilot areas, such as Beijing and Shanghai. Empirical evidence indicates that this regional policy experiment has demonstrated measurable progress in operationalizing emissions reduction frameworks. 2024 statistics show that the on-market turnover of the carbon trading market has reached RMB 27.9 billion. The carbon emissions trading mechanism directly promotes the development of NPRO through the transmission of market pressure and the innovation of policy tools: accelerating breakthroughs in new energy sources, carbon capture and other key areas at the technological level; reconfiguring the green manufacturing, digitalized carbon management and other emerging industrial chains at the industrial level; and reshaping the logic of allocating capital and talents to low-carbon technology at the factor level. Eventually, a sustainable growth paradigm centered on innovation drive will be developed, giving factor system support enabling China to grab the high point of new high-quality productivity in the global energy revolution.

Therefore, a crucial theoretical and practical problem that has to be resolved is how to best encourage the establishment of a carbon trading system in order to further raise the level of development of new, high-quality productive forces and strengthen the socialist economic system. In conclusion, in order to investigate whether the introduction of the carbon emissions trading pilot program is a significant element in the creation of NPRO in cities at the prefecture level following the proposal of new high-quality productive forces, This study uses the exogenous influence of the carbon trading pilot policy on NPRO within the framework of high-dimensional fixed-effects regression, based on the economic and social data of 256 prefectural-level cities across the country from 2009 to 2021. A difference-in-differences model(DID) is constructed for causal identification. In addition, this paper will also introduce a spatial DID model to test the spatial spillover effect in the process of carbon trading pilot policies affecting NPRO. This study will aid in improving comprehension of the mechanism via which pilot carbon trading policies affect NPRO at different spatial scales. Additionally, it will offer a strong theoretical basis and insightful proposals for the establishment of more targeted and effective regional policies that support the twin goals of carbon peak and carbon neutrality as well as the cooperative development of NPRO across different areas. In the context of integrated regional development and the low-carbon transition, such an approach has significant research and practical effects.

2. Literature Review

This study is closely associated with at least three categories of literature. The first pertains to the evaluation of policy impacts generated by carbon trading pilots.The second is research on new quality productive forces.And the third is on the impact of carbon trading pilots on new quality productive forces.

The existing research on the impacts of carbon emissions trading pilot policies is predominantly conducted from three dimensions: its environmental effect, economic effect and social effect. From the perspective of environmental effects, many scholars pay attention to its carbon emission reduction performance, and theoretical and empirical analyses show that this policy can have a positive impact on carbon emission reduction through the paths of industrial structure improvement[1], market mechanism and administrative regulation[2] and so on. In addition, the carbon emission right pilot policy also has a significant role in improving regional environmental pollution[3],promoting the transformation of energy consumption structure[4] and other environmental aspects. In terms of economic effects, at the macro level, it is found that the plot policy can promote high-quality economic development[5], promote outward foreign direct investment[6]and so on, and at the micro level, it is shown that this policy has a significant effect on facilitating enterprises to engage in ESG practices[7] and improving the efficiency of enterprise investment[8] among others, with significant effects. There are relatively few studies on the social effects of this policy, focusing mainly on its impact on employment[9], and studies show carbon trading pilots expand employment and raise rural residents' income.

Studies on new quality productive forces have been carried out mainly from two aspects: qualitative and quantitative. In qualitative research, many scholars have elaborated on the connotation of new quality productive forces. NPRO are a new concept proposed by General Secretary Xi Jinping in September 2023, and emphasized at the Central Economic Work Conference in December of the same year that the core of the “new” lies in scientific and technological innovation to promote industrial innovation. In-depth interpretation, in the change from the industrial era to the digital information era, NPRO is the embodiment of the productivity leap[10], and it is a multidimensional concept where "newness" manifests as new factors, technologies and industries, and "quality" embodies high-level, multi-faceted and dual-efficiency standards,and “force” is manifested in the five major productive forces of digital, collaboration, green, blue, and openness[11]. In terms of quantitative analysis, scholars mostly construct the evaluation index system by selecting different indicators from the three dimensions of productivity, i.e., workers, labor materials, and labor object[12]. Some scholars have also assessed the level of new-quality productive forces according to its three basic characteristics: high-tech, high-efficiency, and high-quality[13]. With the connotation and index measurement of NPRO having been thoroughly explored, many scholars have combined theoretical and empirical analyses to explore the practical application and impact of new quality productive forces in agriculture and rural areas[14]and the construction of the modern industrial system[15], which have broadened the scope of studies on NPRO.

Research on how carbon emissions trading pilot policies affect NPRO remains relatively scarce.Regarding the enterprise aspect, this policy can improve the level of NPRO of enterprises through green technological innovation and strengthening corporate ESG practices[16]. From the provincial level, carbon emissions trading promotes green and high-quality development by enhancing technological innovation, industrial structure supererogation and improving the living standards of residents, which helps accelerate the formation of new quality productive forces and injects new kinetic energy into green and high-quality development, and there is regional heterogeneity in this effect[17].Clearly, the influence of the carbon emissions trading pilot policy has extended to the realm of new quality productive forces,but the research perspectives in existence mainly concentrate on the provincial and enterprise echelons, failing to conduct a comprehensive study at the city level. For this reason, this paper utilizes the panel data of Chinese cities from 2009 to 2021 to study the effect of the carbon emissions trading pilot on NPRO of cities through the employment of a difference - in - differences model.

The possible marginal contributions of this paper are as follows: first, in terms of research perspective, the existing literature mainly focuses on the single-dimension effect of the pilot policy, and pays less attention to its effect on the comprehensive variable of NPRO, especially at the city level, and this paper explores its effect on NPRO of the city, which expands the research perspective and makes up for the shortcomings of the existing literature. Second, in terms of research content, this research is expanded to analyze the spatial spillover effect of the policy, employing the spatial double - difference model (SDID), to delves into how the carbon emissions trading pilot policy exerts a spatial spillover effect on NPRO, which breaks through the limitations of the existing research in this area is limited to a single region, and provides the theoretical basis for the coordinated development of the region and the synergy of policies. Third, in terms of policy value, this paper puts forward a set of targeted and differentiated policy recommendations based on the empirical analysis, heterogeneity analysis and spatial spillover effect analysis, which provides useful references for the better implementation of the carbon emissions trading pilot policy and the development of new quality productive forces.

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3. Research Hypothesis

This pilot policy functions as a market - based form of environmental regulation, and when the enterprise's carbon dioxide emissions exceed the amount specified by the government, the enterprise needs to buy the corresponding quota, which will increase the enterprise's environmental pollution costs and pressure, forcing all kinds of enterprises in pursuit of cost minimization of technological innovation, which is conducive to the cultivation of new quality productive forces. Secondly, technological innovation can not be separated from the talent support and scientific and technological investment, to carry out technological innovation enterprises need to recruit a large number of scientific and technological talent, will produce talent concentration phenomenon, is also conducive to the improvement of the level of human capital. The rollout of the carbon emissions trading pilot policy is conducive to improving the quality of human capital, and the improvement of human capital means the improvement of labor quality, which can further release the potential of new quality productive forces. At the same time, the implementation of this policy can also increase the operating costs of enterprises in the pilot area, and then promote the upgrading of industrial structure by incentivizing enterprises to innovate in green technology and develop green finance[18], and the upgrading of industrial structure will improve the efficiency of production and the quality of development, and the high productivity and high-quality development as a new quality productive forces, which can provide impetus for the improvement of the level of NPRO. The upgrading of industrial structure will improve production efficiency and development quality, while high production efficiency and high-quality development, as the meaning of new quality productive forces, can provide power for the level of NPRO.Therefore, this paper r proposes the following hypothesis:

H1: The implementation of the carbon emissions trading pilot policy can enhance the level of NPRO of cities.

After the initiation of the carbon emissions trading pilot policy, enterprises have turned to investing in green technologies in order to reduce costs, thus requiring the support of green finance. Research shows that the launch of this trading pilot policy will give rise to multi-level and diversified demand for green financing services, prompting green finance to connect with the demand for green transformation, and the carbon trading policy has become a reliable policy guarantee for the innovation and development of green finance[19]. In addition, carbon emissions trading has given rise to a series of financial product innovations, such as carbon futures, carbon options, carbon-related funds and bonds,which enhances the development of the green financial market. "Green and innovative" embodies the essence of new - quality productive forces,and the advancement of green finance can drive the growth of green productivity and foster innovation in green technologies,which is beneficial to the cultivation of NPRO of cities. Research findings suggest that green finance contributes to the growth of new - quality productive forces.This is achieved through promoting technological innovation in terms of both quantity and quality, as well as elevating the environmental consciousness of the government and the general public[20]. Therefore, this paper proposes the following hypothesis:

H2: Carbon emissions trading pilots increase the level of NPRO of cities by promoting the development of green finance.

The pilot carbon emissions trading program has made carbon emission rights a scarce resource, and if carbon emissions exceed the standard, enterprises will need to spend a large amount of money to buy carbon quotas, which will reduce the market competitiveness of these enterprises and force them to consider transformation and upgrading. Backward production capacity enterprises with low technology level, high energy consumption and heavy pollution will be gradually eliminated to make room for the development of new industries and low-carbon industries, which is conducive to the realization of the pilot area to achieve the industrial structure supererogation. Research has pointed out that carbon emissions trading facilitates industrial structure supererogation by enhancing the level of regional technological innovation and promoting the evolution of regional industries[21]. Industrial structure supererogation can optimize the efficiency of resource allocation, promote the realization of efficient and free flow of factors, which is conducive to the formation of more efficient, higher quality and higher level of productivity, and improve the level of new quality productive forces in the pilot region. Studies have shown that industrial structure supererogation has a promoting effect on both new quality productive forces and its subsystems - green productivity and digital productivity[22]. As a result, this paper proposes the following hypothesis:

H3: Carbon emissions trading pilots increase the level of NPRO of cities by facilitating industrial structure supererogation.

This trading pilot policy can positively promote green technology innovation by impacting foreign direct investment[23]. The execution of the pilot policy can, in the first place, stimulate enterprises to conduct green technology innovation.To be specific, on the one hand, carbon emissions trading can overcome enterprises' difficulties in green technology innovation through the "cost of buying carbon", "benefit of selling carbon" and "return on investment". On the one hand, carbon emissions trading overcomes the disadvantages of enterprises in green technology innovation through "buying carbon has cost", "selling carbon has benefit" and "investment return", and on the other hand, it boosts enterprises' inclination towards green technology innovation by escalating the costs of non - compliance and providing tax incentives, subsidies, and special funds [24]. Secondly, the pilot carbon emissions trading can promote the development of green finance, the improvement of green information network, and the construction of a series of policy tools and legal and regulatory systems, all of which provide favorable conditions for the development of green technology innovation. Green technology innovation is not merely the crucial impetus for economic green transformation and high - quality development, but also plays an important role in upgrading NPRO. NPRO itself is green productive force, and green technology innovation can accelerate the development of NPRO[25]. As a result, this paper proposes the following hypothesis:

H4: Carbon emissions trading pilots increase the level of NPRO of cities by promoting green technology innovation.

4. Model Setting, Variable Selection and Data Description

4.1. Modeling

The double difference model (DID) is a widely used empirical analysis method in the field of policy effect assessment. This method realizes the accurate measurement of the net effect of policies by comparing the changes in observed data before and after the implementation of policies and analyzing them in combination with the data of the control group that has not implemented policies, in order to successfully eliminate the influence of additional outside variables.In this paper, the year 2013 is identified as the starting year of policy implementation, which serves as the time demarcation point, and the study period is assigned a value of 1 if it is in the year 2013 or later, otherwise it is 0. In terms of the sample grouping, following the prevailing approach documented in scholarly discourse, the pilot cities of the policy are defined as the treatment group, and the non-pilot cities as the control group. The baseline DID model was constructed as follows:

$$Npro_{it} = \alpha + \beta_1 DID_{it} + \beta_2 controls + \delta_i + \sigma_t + \varepsilon_{it} \tag{1}$$

Where i and t denote city and year, $Npro_{it}$ denote the level of NPRO, DID_{it} is the core explanatory variable, controls represent control variables, δ_i and σ_i denote city fixed effects and time fixed effects. Since the perturbation terms for the same individual at different times may be correlated, i.e., there may be within-group autocorrelation, it is also necessary to use cluster-robust standard errors with each individual as a cluster, i.e., clustering standard errors at the city level.

4.2. Variable Selection

4.2.1. Explained Variables

Urban NPRO ($Npro_{it}$). Based on the research of Han Wenlong et al. (2024), this paper selects city data closely related to NPRO as samples for measuring NPRO. Among them, the $Npro_{it}$ index system comprehensively measures the level of city's NPRO in the development of new industries, quality of labor force, infrastructure construction, ecological environmental protection, technological innovations and intelligence, greening transformation, and utilization of data elements through multi-dimensional components. In assessing the new-quality labor force, the scale of employees in emerging industries is taken into account, and attention is also paid to the personal competence and high quality level of the employees; in examining infrastructure, key indicators such as the number of Internet broadband access subscribers and the total amount of telecommunication services are covered. In addition, the role of green development and data elements is also particularly emphasized. By setting indicators such as investment in environmental pollution control, development of carbon trading market, rate of harmless treatment of domestic garbage, and level of utilization of data elements,While pursuing economic growth, the city is encouraged to pay more attention to environmental protection and the development and utilization of data resources, and finally the entropy method is used to measure NPRO.

4.2.2. Explanatory Variables

Construct dummy variable DID, $DID = time \times group$, group indicate the grouping dummy variables of the city. When the value is 1, it means that these cities belong to the pilot region of the policy; other regions take the value of 0. time is the time grouping virtual variable, when the time is greater than or equal to 2013, it takes the value of 1. The condition of taking the value of 1 is that the region is a pilot region and the time is in 2013 and after 2013.

4.2.3. Control Variables

Referring to Xu Aiting et al.'s (2024) study on NPRO, the following control variables are chosen :ecological environment quality ($\ln CO2$) is measured as the logarithm of total carbon emissions (10,000 tons); regional consumption level ($Consume$) is expressed as the ratio of total retail sales of consumer goods (10,000 yuan) to GDP; urbanization level ($Urban$) is expressed as the proportion of the urban population in the household population; fiscal decentralization ($Finance$) is expressed as the proportion of the budgeted revenue to the budgeted expenditure; and fiscal decentralization is expressed as the proportion of the budgeted expenditure to the budgeted revenue. budget revenue to fiscal budget expenditure ratio; financial deposit level ($Banking$), using the ratio of deposit balances in financial institutions to regional GDP.

4.2.4. Mechanism Variables

Green financial development index, industrial structure supererogation and green technology innovation. In this paper, we refer to Mao Xiaomeng et al. (2024) to construct the index system of green financial development level, and finally use the entropy weight method to measure to get the green financial development index (GF). In addition, considering that the policy may be conducive to promote the optimization and upgrading of the city's industrial structure and provide endogenous potential energy for the generation of NPRO. the industrial structure supererogation(TS) is selected as a mechanism variable, and since the servitization of the economic structure driven by information technology is an important feature of the supererogation of industrial structure, the quantification of industrial structure supererogation refers to the study of Chunhui Gan (2011), and this paper adopts the tertiary industry In this paper, measuring the sophistication of industrial structure by the ratio of tertiary industry output to secondary industry output. Finally, this paper draws on the research method of Wang Xiangyan and Li Jinye (2024) on green technological innovation(Gti). Based on the classification standard of green technological innovation of the International Patent Classification (IPC), this paper extracts the number of green invention patent applications at the city level from the patent retrieval system of the State Intellectual Property Office (SIPO), and uses the ratio of the indicator to the total number of patent applications in the city as the quantitative indicator of green technological innovation.

4.3. Data Description

Based on the research objectives and data availability, this study selects city-level panel data from 2009-2021, and samples of cities with too high a rate of missing variables and those that did not participate in the policy pilot are excluded. The data were mainly obtained from the National Bureau of Statistics (NBS). The result in Table 2 show that the minimum value of NPRO indicator is 0.002, the maximum value reaches 0.618, the mean is 0.052, and the standard deviation is 0.0755, indicating that there is a significant difference in the level of NPRO among the sample cities, which is characterized by polarization. The significant difference in the extreme values of the control variables indicates that each control variable has sufficient variability in the sample, which can effectively control the potential interfering factors and provide a guarantee for the accuracy and robustness of the research conclusions.

Table 1. Descriptive statistics of main variables

Variable	Observed	Minimum value	Maximum value	Mean value	Standard deviation
NPRO	3261	0.002	0.618	0.052	0.075
LnCO2	3261	14.145	19.545	16.996	0.890
Finance	3261	0.055	1.541	0.473	0.221
Banking	3261	0.588	21.302	2.458	1.213
Consume	3261	0.000	1.013	0.381	0.110
Urban	3261	0.151	1.000	0.558	0.150
TS	3261	0.187	0.196	1.246	0.649
GF	3261	0.064	0.650	0.332	0.096
Gti	3261	0.000	0.538	0.026	0.021

5. Evaluation and Analysis of Research Results and Path Exploration Effect

5.1. Analysis of Benchmark Regression Results

The main regression coefficients of NPRO all show a significant positive effect, according to the benchmark regression results of the carbon emissions trading pilot policy on the development of urban NPRO, which are displayed in Table 3. The conclusion is strong whether or not control variables are included in the model. Specifically, The results indicate that the carbon-trading pilot policy has a significant role in fostering the development of urban new quality productive forces. In particular, the coefficients are significantly positive when no control variables are

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included in column (1), and when control variables are inserted one at a time in the following columns, the results show that the treatment group has an average increase of approximately 1.5% in new quality productive forces after the treatment, and the DID coefficients are still positive at the 5% significance level.

The regression estimates of the control variables in Model (6) reveal several statistically significant patterns. Both log-transformed carbon dioxide emissions and social consumption levels exhibit a statistically significant negative association at the 1% level, suggesting that intensified consumption patterns characterized by high resource utilization - as reflected in elevated carbon emissions - may constrain the cultivation of new quality productive forces. Furthermore, the urbanization rate demonstrates a negative coefficient significant at the 5% level. Regarding fiscal and financial factors, while local fiscal decentralization and financial deposit levels show statistically insignificant effects, their coefficient directions merit attention: financial deposit levels display a positive tendency whereas local fiscal decentralization manifests a negative orientation.

Table 2. Carbon emissions trading pilot policy regression results on new quality productive forces benchmarks

Variables	(1)	(2)	(3)	(4)	(5)	(6)
DID	0.0166** (2.47)	0.0178*** (2.63)	0.0168** (2.54)	0.0166** (2.53)	0.0147** (2.38)	0.0146** (2.340)
LnCO2		-0.0170*** (-3.08)	-0.0176*** (-3.15)	-0.017*** (-3.13)	-0.0174***(-3.08)	-0.0174*** (-3.12)
Consume			-0.0220*** (-2.94)	-0.0233*** (-2.93)	-0.0287*** (-3.22)	-0.0285*** (-3.06)
Finance				-0.0131 (-1.26)	-0.0118 (-1.12)	-0.0120 (-1.07)
Urban					-0.0461** (-2.18)	-0.0460** (-2.17)
Banking						-0.0002 (-0.12)
Constant	0.0508*** (77.38)	0.3401*** (3.64)	0 .3589*** (3.73)	0.3620*** (3.74)	0.3894*** (3.68)	0.3902*** (3.78)
City fixed effects	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES
N	3261	3261	3261	3261	3261	3261
Adjusted R-Square	0.9515	0.9515	0.9522	0.9524	0.9531	0.9531

Note: **P<0.05, ***P<0.01; t values are shown by values in parenthesis.

5.2. Reliability and Validity Analysis of The Regression Results

5.2.1. Parallel Trend Test

To verify the core assumptions of the difference-in-difference model and to test the robustness of the regression results, this study needs to carry out a parallel trend test. According to the results obtained from the dynamic effect plot of the policy in Figure 1, the coefficients in the

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first three periods are insignificant and the confidence intervals contain zero values, indicating that there is no discernible difference between the experimental and control groups. The results after the implementation of the policy show that even though the first two years are subject to the policy lag effect, the coefficients are not included and are significantly positive from the third year onwards, indicating that the carbon emissions trading pilot policy has a sustained and progressively stronger impact on urban new quality productive forces. In summary, It is evident that the parallel trend premise assumption is satisfied by the DID model.

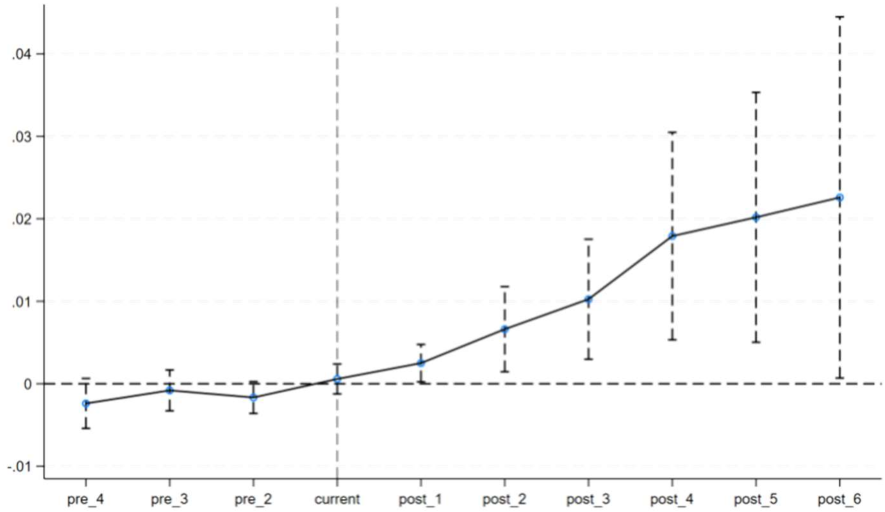

Figure 1. Parallel Trend Test

5.2.2. Placebo Test

This study conducts an additional robustness test by creating the pseudo-treatment group in order to confirm the robustness of the benchmark regression results. Steps include: ①Randomly assigning the identity of the treatment group in the whole urban sample; ②Utilizing the reorganized sample to carry out the parameter estimation of the benchmark model. Figure 2 shows that after 500 repeated samples, the parameter estimates of the core explanatory variables show obvious characteristics of null-centered distribution, in which 89.7% of the estimates are smaller than the true coefficient of the baseline regression (0.0146) in absolute value, and the overall distribution does not reject the null hypothesis. This logic chain effectively excludes the interference of model-setting bias on the conclusions, so the results of the benchmark regression are reliable.

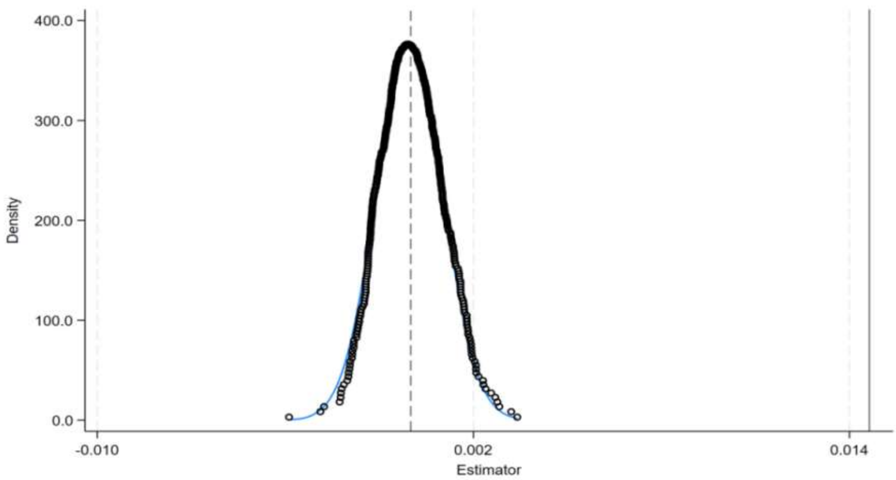

Figure 2. Placebo test

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5.2.3. Confirmatory Factor Analysis

1) Excluding Other Policy Interference

Considering that other policies on urban development during the sample period may interfere with the causal identification of the article, drawing on He Xionglang (2025) and Li Yuxin (2023), a binary dummy variable containing the pilot new energy city policy or the pilot low carbon city policy is constructed (with a value of 1 assigned to the region where the policy is implemented, and 0 to the region where the policy is not implemented), and table 4's columns (1) and (2) display the regression findings. The DID regression coefficient results are 0.015 and 0.0134, respectively, as can be observed, both passing the 5% significance level test, which indicates that the evaluation of the effect of the carbon emissions trading pilot policy is not interfered by the competing policies, so the empirical results are robust.

2) Deletion of Special Cities

This study notes that key administrative regions (provincial capitals/municipalities/special economic zones) have significant heterogeneity in the dimensions of resource endowment, location, and institutional resource allocation, and the government tends to superimpose preferential policies on municipalities and provincial capitals, as well as to play the role of their risk markers, and the existence of such differences will make the regression results produce some bias, and this study eliminates these unique city samples to further assess the robustness of the findings and evaluate the estimation's validity. The robustness of the results is further demonstrated by the fact that, even after altering the sample scope, the carbon emissions trading pilot policy still has a 10% significant positive impact on the creation of new high-quality productive forces, as shown in result (3) in Table 4.

3) PSM-DID Regression

In order to address the potential for self-selection bias in the DID model used to assess policy effects, this study employs the 1:3 nearest-neighbor matching method (PSM) to control for sample selection bias and computes the propensity score value by building a propensity score matching model to achieve covariate Distributional Equilibrium. This is done in reference to the non-parametric propensity matching method proposed by Dachan Shi et al. (2018) and Linlin Sun et al. (2020). The distribution of propensity scores of the treatment group and the control group before matching is significantly different, whereas the distribution curves of the two groups after matching are highly overlapped. This significantly reduces the distribution difference between the two groups and confirms that the matching method is effective in controlling selection bias. This is demonstrated by comparing the kernel density estimation plots of propensity scores before and after matching. PSM-DID model regression results are shown in Table 3. The double robust estimation test is passed in the near neighbor matching subsample with k=3 because the regression coefficient of the interaction term in model (4) is significant at the 10% level.

4) Replacement of Explanatory Variables

In order to avoid regression bias caused by different measures, we refer to the indicator measure of new quality productive forces constructed by Jiang Yongmu et al. (2024), and replace the explanatory variables with the level of this new quality productive forces, and the results of the benchmark regression in Column (5) indicate that It further confirms the robustness of the initial benchmark regression by passing the significance test at the 1% level.

Table 3. Robustness test results

Variables	Exclusion of other policy disturbances	Exclusion of special samples		PSM-DID	Replacement of explanatory variables
	New energy cities	Low carbon cities	Excluding provincial capitals		new quality productive forces
	(1)	(2)	(3)	(4)	(5)
DID	0.0150** (2.45)	0.0134** (2.11)	0.0117* (1.91)	0.0331* (28.42)	0.0086*** (2.83)
New Energy Pilot DID	0.0074* (1.84)				
Low Carbon City Pilot DID		0.0113*** (3.23)			
Constant	0.3841*** (3.65)	0.3825*** (3.71)	0.1985** (2.60)	0.3690*** (3.66)	0.1847** (2.55)
Control Variables	YES	YES	YES	YES	YES
City fixed effects	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES
N	3261	3261	2889	2917	2496
Adjusted R2	0.954	0.9540	0.935	0.952	0.963

Note: *P<0.1,**P<0.05, ***P<0.01; values in parentheses are t-values.

5.3. Heterogeneity Analysis

5.3.1. Heterogeneity of Urban Location

There are large differences between regions in China, and the impact of the implementation of the carbon emissions trading pilot on NQP will also differ across regions. Considering that there may be such differences between the central and western regions, the article defines the western region as 1 and the central and eastern region as 0. The dummy variable for region is regressed on the interaction term of the carbon emissions trading pilot policy, and the regression coefficient is 0.033 and is significant at the 1% level from the regression results in column (1) of Table 5, which indicates that compared to the central and eastern regions, the effect of the carbon emissions trading pilot policy on the The boosting effect of the pilot carbon emissions trading policy on NPRO in the western region is more obvious. It may be because the western region has a weaker economic base compared to the central and eastern regions, the innovation compensation effect is stronger, and the marginal boosting effect of the carbon emissions trading pilot on the development of new quality productive forces in the west is stronger.

5.3.2. Heterogeneity of Cities' Development Stages

Differences in the development stages of NPRO between cities also make a difference in the impact of the implementation of the carbon emissions trading pilot policy on NPRO. According to the ratio of each city's level of new mass productivity to the national average, the 256 cities are divided into those with a high degree of development (ratio > 1) and those with a low degree of development (ratio < 1) (Xu Aiting, 2024). The article incorporates the interaction term (SOD_did) of whether it is a high degree of development dummy variable (yes for 1, no for 0) with carbon emissions trading into the regression model. From the regression results in column (3) of Table 5, it can be seen that the coefficient of the interaction term is significantly positive, and the implementation of the carbon emissions trading pilot policy is more favorable to the development of NPRO in cities with high levels of development compared to cities with low levels of development. This may be due to the fact that cities with a high degree of development usually have more complete innovation ecosystems and more prominent factor endowment advantages, and the synergistic effect of system-technology-industry is more significant.

5.3.3. Heterogeneity of City Class

The industrial base and allocable resources will be different for different city classes. In this study, the capital cities, municipalities directly under the central government and sub-provincial cities are assigned a value of 1, and the rest of the cities are assigned a value of 0 to construct a binary variable and analyze it with the interaction term (CT_did) of the carbon emissions trading pilot policy. The empirical results show (column 3 of Table 5) that the regression coefficient is 0.064 and is significant at the 1% level, indicating that provincial capital cities, municipalities directly under the central government, and sub-provincial cities for the rest of the cities carbon emissions trading pilot policy will significantly enhance NPRO. These cities have significant location advantages in terms of the degree of green finance development, economies of scale and agglomeration effects, outstanding output efficiency of economic and social benefits, higher levels of human capital accumulation, as well as significant policy support and regulatory effects, and more prominent policy synergies, which make the impact of the carbon emissions trading pilot program on NPRO more significant.

5.3.4. Heterogeneity of Urban Resource Endowment

The implementation of the carbon emissions trading pilot policy will affect cities with different resource endowments to different degrees. The sample cities are categorized into 101 resource-endowed cities and 155 non-resource-endowed cities according to the official categorization criteria of the State Council. The article includes the interaction term (NRBC_did) between the dummy variable for whether it is a non-resource city (yes is 1, no is 0) and carbon emissions trading in the regression model, which shows from column (4) of Table 5 that the pilot carbon emissions trading policy in non-resource cities can significantly increase NPRO at the 5% level relative to resource cities. This may be due to the fact that non-resource cities have high resource allocation efficiency, strong innovation-driven and scientific research capabilities, and low environmental regulatory pressures; whereas resource cities generally suffer from the phenomenon of path-dependence and the problem of homogenization of industrial structure. At the same time, these cities have relatively insufficient technological accumulation and a weak innovation base, which constrains industrial transformation and upgrading and the enhancement of sustainable development capacity.

5.3.5. Heterogeneity of Innovation Foundation

Innovation is the core driving force to promote NPRO, and there are significant differences in the innovation foundation of different cities. This paper utilizes the innovation index distributed by Prof. Kou Zonglai's team at Fudan University and divides the sample into two groups based on the city's innovation index, with cities with a better innovation base defined as 1 and 0 otherwise.This dummy variable is regressed on the interaction term (FOI_did) of the carbon emissions trading pilot policy, and the results are shown in Column (5) of Table 4, with the regression coefficient of 0.075 and significant at the 1% level, which suggests that the high innovation index cities have a more significant effect of carbon emissions trading pilot policy on NPRO compared to low innovation index cities. Cities with high innovation index have stronger R&D investment and technology diffusion ability, and the pilot emissions trading policy can more effectively stimulate innovation ability, promote innovation-driven, green and low-carbon, efficient and intensive, inclusive and sharing, and enhance NPRO.

Table 4. Heterogeneity regression results

Variable	Urban location	Development stage	Urban class	Resource endowment	Innovation base
	(1)	(2)	(3)	(4)	(5)
WEST_did	0.033*** (28.42)				
SOD_did		0.048*** (4.45)			
CT_did			0.064*** (3.09)		
NRBC_did				0.038** (2.22)	
FOI_did					0.075*** (3.35)
Constant term	0.369*** (3.66)	0.325*** (3.94)	0.325*** (3.96)	0.619*** (4.12)	0.302*** (4.05)
Control variables	YES	YES	YES	YES	YES
City fixed effects	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES
N	3261	3261	3261	3261	3261
Adjusted R^2	0.948	0.953	0.953	0.950	0.954

Note: *P<0.1,**P<0.05, ***P<0.01; values in parentheses are t values.

6. Analysis of the Mechanism of Action

According to the theoretical analysis in the previous section, the carbon emissions trading pilot policy may promote the improvement of urban NPRO level by promoting the development of green finance, improving the upgrading industrial structure and improving green technological innovation, and then we test the mechanism of carbon trading pilot to promote the improvement of NPRO level from these three perspectives with reference to the method of Jiangting (2022).according to the model (1), the following mechanism testing model is established:

$$M_{it} = \gamma_0 + \gamma_1 DID_{it} + \gamma_2 controls_{it} + \delta_i + \sigma_i + \varepsilon_{it} \tag{2}$$

Where M_{it} is the mediating variable, expressed as GF, TS, Gti, respectively, the green financial development index, industrial structure supererogation and green technological innovation, the other items are the same as the definition of equation (1).

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6.1. Green Financial Development Test Results

Column (1) of Table 6 shows the mechanism test results of green financial development. The coefficient of DID is 0.011, which is significantly positive at the 1 percent level, showing that the carbon emissions trading pilot policy can significantly improve the level of green financial development in the pilot cities, thus promoting the development of NPRO. The performance of enterprises in the pilot cities in the carbon emissions trading market, such as the surplus or shortage of carbon emissions rights, becomes an important reference indicator for financial institutions to assess their green development potential and credit risk. Financial institutions are more willing to provide financial support, including green credit, green bond issuance, green fund investment and other financial services, to green industries and enterprises that have excellent performance in carbon emission reduction and good development prospects. The precise allocation of financial resources not only promotes the expansion and deepening of green financial business, but also promotes the innovation of green financial products and services. In addition, the carbon emissions trading pilot policy has also led to the synergistic development of the relevant industrial chain, giving rise to a series of emerging industries around carbon emissions trading, such as carbon verification, carbon auditing, carbon asset management and other service industries. The rise and development of these industries further expands the scope of demand for green finance, attracts more financial resources to flow into the green field, and then effectively promotes the development of NPRO, and the results verify the hypothesis H2.

6.2. Mechanism Test Results of The Upgrading Industrial Structure

Column (2) of Table 6 shows the results of the mechanism test of the upgrading industrial structure. The coefficient of the core explanatory variable DID is 0.217 and it's significantly positive at the 1% level, which shows that the implementation of the pilot policy of carbon emissions trading right city, industrial structure adjustment provides a clear direction. The traditional mode of industrial development is often accompanied by high carbon emissions, and the policy, by setting trading rules and restrictions on carbon emissions, prompts enterprises to have to re-examine their production methods and energy utilization efficiency. For those enterprises with high pollution and energy consumption, they face greater pressure on the cost of carbon emissions, which forces them to seek ways of technological innovation and industrial upgrading to reduce carbon emissions and adapt to the policy requirements. This shift not only optimizes the allocation of resources within the industry and improves production efficiency, but also frees up space for the development of NPRO, so that emerging industries can get more resources to support their rise. The results prove the hypothesis H3.

6.3. The Results of The Mechanism Test of Green Technology Innovation

Column (3) of Table 5 shows the results of the mechanism test of green technological innovation. The coefficient of the core explanatory variable DID is 0.004, which is significantly positive at the 5% level, indicating that the carbon emissions trading pilot policy has a significant effect on the green technology innovation level of the pilot cities. Specifically, the pilot cities' innovation activities in the field of green technology are significantly enhanced, probably because the policy provides cities with a clear price signal for carbon emissions, which prompts urban enterprises and research institutions to increase their investment and R&D in green technology, and then promotes the innovation and application of green technology. Therefore, the carbon trading pilot policy is one of the effective means to promote green technology innovation in cities. The results verify hypothesis H4.

Table 5. Role mechanism test

	Green financial development	industrial structure supererogation	Green technology innovation
	(1) GF	(2) TS	(3) Gti
DID	0.011*** (3.89)	0.217*** (5.38)	0.004** (1.99)
Constant term	0.272*** (3.05)	2.623 (1.49)	-0.063 (-0.86)
Control Variables	YES	YES	YES
Year fixed effects	YES	YES	YES
Individual fixed effects	YES	YES	YES
N	3261	3261	3261
Adjust R2	0.944	0.950	0.424

Note: *P<0.1,**P<0.05, ***P<0.01; values in parentheses are t-values

7. Extensibility Analysis: Spatial Spillover Effect Test

According to the theoretical analysis in the previous section, the implementation of the carbon emissions trading pilot policy will promote the development of urban NPRO. However, the implementation of the carbon emissions trading pilot policy may also have an impact on the neighboring areas of the pilot cities through demonstration effects, technological spillovers, etc.In view of this, this paper establishes a SDID model to further analyze the effects of China's carbon emissions trading pilot policy, with reference to the research of Song et al., (2024), to construct the following general spatial Durbin model:

$$NPRO_{it} = \varphi_0 + \rho\sum_{j=1}^{N} W_{ij} NPRO_{it} + \varphi DID_{it} + \theta\sum_{j=1}^{N} W_{ij} DID_{it} + \beta X_{it}\gamma\sum_{j=1}^{N} W_{ij} controls_{it} + \delta_i + \sigma_t + \varepsilon_{it} \tag{3}$$

Where: w is the spatial weight matrix, and and are the spatial correlation coefficients. When and are 0 the model is a spatial lag model (SLM). When and and are 0, the model is a spatial error model (SEM).

7.1. Global Spatial Correlation Test

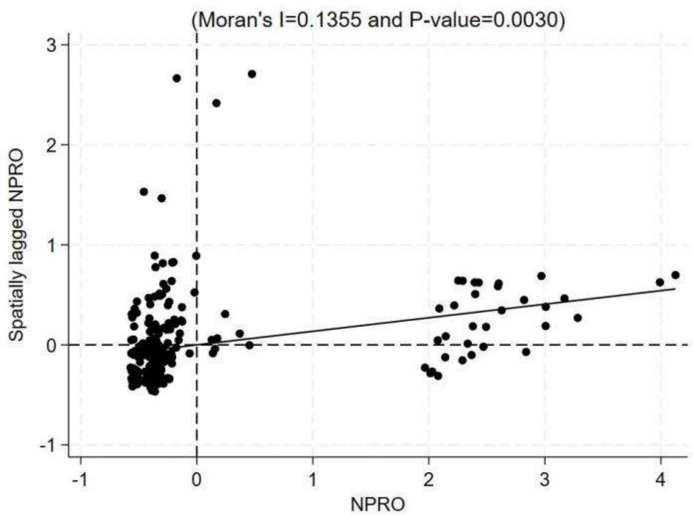
Before parameter estimation, this study uses the economic-geographical nested matrix to conduct a global spatial autocorrelation test to test whether there are significant spatial spillovers in urban NQP. The results of global Moran's index and its significance test reported in Table 6 show that the global Moran's index of NPRO in Chinese cities from 2009 to 2021 are all significantly positive at the 1 percent level, indicating that there is a significant positive spatial autocorrelation characteristic of NPRO in Chinese cities. The global Moran's index shows a significant increasing trend, reaching 0.201 in 2021, which is significantly higher than the 0.153 in 2009, indicating that the spatial correlation of NPRO of Chinese cities continues to increase.

Table 6. Global Moran's I test results

Year	Moran's I	E(I)	Sd(I)	Z	P-value
2009	0.136	-0.004	0.031	4.431	0.000
2010	0.141	-0.004	0.031	4.595	0.000
2011	0.145	-0.004	0.031	4.724	0.000
2012	0.160	-0.004	0.031	5.206	0.000
2013	0.167	-0.004	0.031	5.433	0.000
2014	0.173	-0.004	0.031	5.621	0.000
2015	0.182	-0.004	0.031	5.905	0.000
2016	0.195	-0.004	0.031	6.337	0.000
2017	0.215	-0.004	0.031	6.990	0.000
2018	0.215	-0.004	0.031	6.988	0.000
2019	0.208	-0.004	0.031	6.757	0.000
2020	0.204	-0.004	0.031	6.641	0.000
2021	0.201	-0.004	0.031	6.558	0.000

7.2. Local Spatial Correlation Test

In order to deeply explore the spatial and temporal evolution characteristics of NPRO of Chinese cities, this paper plots the local Moran's I scatterplot of the economic-geographical nested matrix of NPRO of Chinese cities in 2009 and 2021 (Figure 3). The analysis results show that the scatter plots of both years exhibit significant low-low (L-L) spatial correlation characteristics, which is manifested by the fact that most cities are concentrated in the third quadrant. The value of the slope of the line fitted to the scatter plot increases in 2021 compared to 2009, the finding corroborated with the global Moran's I index measurements. The degree of spatial agglomeration of urban new quality productive forces shows a strengthening trend, and urban new quality productive forces are gradually shifting to a spatially intensive development pattern.



(a)Moran Chart of NPRO in Chinese Cities 2009

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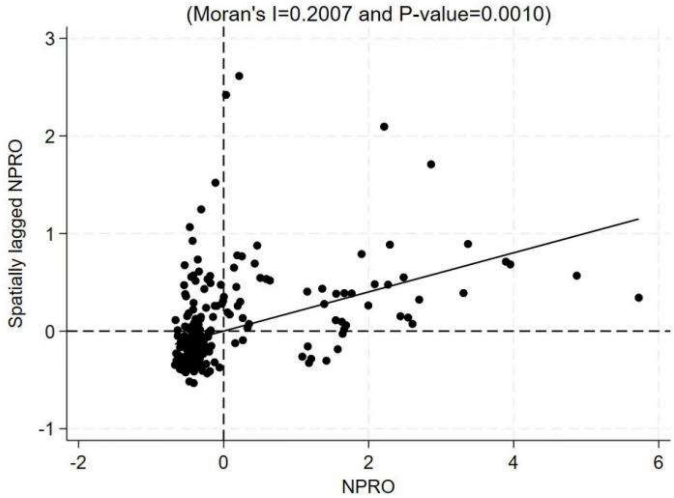

(b)Moran Chart of NPRO in Chinese Cities 2009

Figure 3. Localized Moran's I scatter plot of economic-geographic nested matrices

7.3. Regression Analysis of Spatial Spillover Effects

Table 7. Results of spatial spillover effects

	W1			W2		
	SEM	SAR	SDM	SEM	SAR	SDM
DID	0.014*** (8.601)	0.015*** (9.248)	0.016*** (9.545)	0.015*** (7.230)	0.013*** (7.584)	0.007** (2.197)
W1*DID			0.017*** (3.394)			
W2*DID						0.009** (2.208)
direct effect		0.016*** (9.023)	0.018*** (9.520)		0.014*** (7.436)	0.008*** (2.554)
Indirect effect		0.017*** (6.338)	0.047*** (4.488)		0.005*** (6.254)	0.014*** (3.340)
total effect		0.033*** (7.916)	0.064*** (5.644)		0.019*** (7.372)	0.022*** (7.082)
Constant term	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES
individual fixed effect	YES	YES	YES	YES	YES	YES
N	3261	3261	3261	3261	3261	3261
Adjust R2	0.128	0.205	0.205	0.168	0.071	0.071

Note: *P<0.1,**P<0.05, ***P<0.01; values in parentheses are t values.

The article is based on the economic-geographical nested matrix (W1) and spatial double difference regression using spatial error model, spatial lag model and spatial Durbin model. As shown in Table 7, the results of the SDM model of the economic-geographical nested matrix show that: the coefficient of the model's spatial core explanatory variable (W1*DID) is 0.017, and the indirect effect is significant at the 1% level and the coefficient is 0.047, which indicates that the policy has a positive radiating effect on the neighboring regions through economic linkages and technological spillovers, and that there is a significant spatial heterogeneity of the effect of the pilot carbon emissions trading policy on the new-quality productivity The impact of the pilot carbon emissions trading policy on NPRO has significant spatial heterogeneity.

To strengthen the robustness of the conclusions, the study further introduces the spatial neighbor matrix (W2) for systematic verification.The results of the SDM model show that the coefficient of the spatial interaction term (W2*DID) is 0.009, and the coefficient of its indirect effect is 0.014, which is significant at the level of 1%, confirming that the radiative effect of the policy through economic linkages and technological spillovers is characterized by multidimensional conduction. The total effects under both spatial weight matrices show significant positive effects at the 1% level, with coefficients of 0.064 and 0.022, respectively, and the core conclusions are highly consistent, which further verifies that the carbon emissions trading pilot policy has a significant positive spatial spillover effect on NPRO of the neighboring regions.

8. Conclusion and Recommendations

8.1. Conclusion of The Study

As an economic and social systematic change, the in-depth promotion of carbon emissions trading pilot will inevitably have a significant impact on the development of new quality productive forces. Based on the panel data of 256 prefecture-level and above cities in China from 2009 to 2021, the article empirically examines the impact of carbon emissions trading pilot policy on NPRO by using the double difference model. The results of the study show that: (1) the pilot carbon emissions trading policy significantly enhances the development of new quality productive forces, which is supported by a series of robust tests; (2) The pilot carbon emissions trading policy promotes the transformation of the economy in the direction of green and low carbon by facilitating green technology innovation,green finance development and the industrial structure supererogation, and ultimately promotes the development of NPRO characterized by high efficiency, cleanliness and sustainability.(3) The carbon emissions trading pilot policy has a significant effect on NPRO enhancement of cities with high administrative rank, non-resource-based and strong innovation base; at the same time, its promotion effect is particularly obvious for cities in the western region and those at a higher stage of NPRO development. (4)Pilot carbon emissions trading policies have positive spatial spillover effects on NPRO in neighboring regions

8.2. Policy Implications

Based on the above research conclusions, the following three policy recommendations are proposed to further promote the carbon emissions trading pilot policy and enhance NPRO:

Precise policy making based on local conditions. Differentiated policies need to be formulated according to the heterogeneity of city locations, resource endowments and innovation foundations. As the economic development of western cities is relatively lagging behind, policies should focus on technology transfer and financial support. For example, by means of financial transfer payments and special funds, western cities should increase their investment in technological innovation and industrial upgrading, etc. For resource cities, they should actively promote the transition from a single resource-dependent economy to a diversified economy.

Amplify the effect of the mechanism and strengthen the role of the carbon emissions trading pilot policy in stimulating the development of NPRO. Policies in the areas of talent, technology

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and capital will further promote green technological innovation, upgrading industrial structure and green financial development. Set up a special fund for green technology research and development, optimize the dynamic adjustment mechanism of carbon quotas, and take measures to guide enterprises to convert carbon emission costs into innovation inputs. Promote the deep integration of industrial structure and green technology, and facilitate the transformation and upgrading of industries to high-end, intelligent and green technologies. At the same time, we will innovate the combination of carbon financial tools, build a multi-level green financial service system, improve the green financial support network, smooth carbon emissions trading and green investment and financing channels, effectively guide social capital to gather in the field of green innovation, and accelerate the cultivation of NPRO.

Strengthening regional synergistic development and utilizing positive spatial spillover effects. The government should deepen the cross-regional collaboration mechanism, focus on promoting policy docking and resource sharing with neighboring cities, promoting the integrated construction of the carbon emissions trading system, and building a unified national carbon trading platform. For example, it should establish a platform for collaborative development of cities, promote technology transfer and knowledge overflow between cities, promote the optimization and upgrading of industrial structure, and enhance the synergistic effect of system-technology-industry in low-development cities. Meanwhile, the demonstration effect of high-level cities should be strengthened, and high-level cities should take the lead in exploring the optimal operation mechanism of the carbon emissions trading market, and strengthening the regional synergistic development with neighboring cities. Summarize the experience of carbon emissions trading pilot cities, expand the scope of pilot cities, drive the upgrading of NPRO in other cities, and form a radiation effect leading to the whole area, so as to promote the balanced development of new quality productive forces on a nationwide scale.

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