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A Study on the Impact of Policy Synergy on Corporate Green Innovation-Evidence from Listed Companies

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Keywords: Carbon emissions trading; innovative city; pilot policy; green innovation; DID modeling

Abstract: Green innovation is the driving force of corporate green development, and there is insufficient research on how the carbon emissions trading pilot and innovative city pilot policies jointly affect corporate green innovation. This paper examines the effects of the dual pilot policy on enterprise green innovation, and the results show that: the dual pilot of carbon emissions trading and innovative cities can effectively promote enterprise green innovation and have a "crowding out" effect on other innovative activities; from the viewpoint of the intermediary mechanism, the dual pilot policy promotes enterprise green innovation by enhancing the research and development intensity of regional enterprises and optimizing the cash flow ratio of enterprises; and the dual pilot policy promotes enterprise green innovation by enhancing the R&D intensity of regional enterprises and optimizing the cash flow ratio of enterprises. In terms of intermediary mechanism, the dual-pilot policy promotes green innovation by increasing the R&D intensity of regional enterprises and optimizing the cash flow ratio of enterprises; compared with the single-pilot policy, the dual-pilot policy is more effective in enhancing the level of green innovation of enterprises, and there is a synergistic effect between the two pilot policies; and conducting the pilot of innovative cities first and then conducting the pilot of carbon trading has a stronger effect on the promotion of green innovation.

1. Introduction

Against the international and domestic backdrop of global climate change and the growing contradiction of resource constraints, green development has become the fundamental concept of China's overall development, and green innovation plays an important role in the improvement of environmental quality. How to promote green innovation is of great significance to the economic transformation and development under the "dual-carbon target". The carbon emissions trading pilot policy was proposed by the Chinese government in 2011, which controls carbon emissions in a market-oriented way, while the innovative city pilot policy aims to promote the transformation of urban economic development from traditional factor-driven to innovation-driven. As the carbon emissions trading pilot policy focuses on "green" and the innovative city pilot policy focuses on "innovation", is there a causal relationship between these two policies and green innovation of enterprises? If the two pilot policies can influence enterprises' green innovation, what is the mechanism behind? If the government can use these two policies to regulate green innovation

activities of enterprises, how to maximize the effectiveness of the policies? At present, the academic research on the above issues is still insufficient, for this reason, this paper discusses the combination of theoretical analysis and empirical evidence, in order to provide a basis and reference for the government to formulate green low-carbon policies.

2. Literature review

Regarding enterprise green innovation, academics mainly believe that external constraints and incentives are the key factors affecting green technological innovation [1-4], and most scholars believe that the carbon emissions trading pilot policy supports the "weak Porter's hypothesis", i.e., the policy has a positive incentive effect on technological innovation [5]. As for the innovative city pilot policy, those who hold the "facilitation" view believe that the innovative city pilot policy significantly improves the level of enterprise innovation [6-8]. Those who hold the "inhibition" view believe that the incentive-based policies include tools such as government innovation subsidies, which have a crowding-out effect on firms' green product innovation [9].

In summary, the impact of innovative city pilot policies and carbon emissions trading pilot policies on corporate green innovation has not formed a unified conclusion. Innovative city pilot policy and carbon emissions trading pilot policy have certain complementarity, innovative city pilot more reflected in the incentive level, carbon emissions trading pilot more reflected in the regulatory level. Although there is a wealth of research on the impact of pilot policies on technological innovation, there is a lack of research on the synergistic effects of the policies.

3. Theoretical analysis and research hypothesis

3.1 Theoretical analysis

When the carbon emissions trading pilot and the innovative city pilot dual policies are implemented in conjunction, the effect on enterprises can be split into two parts, one is the "constraint effect" brought about by environmental regulations, and the other is the "incentive effect" brought about by compensation for innovation resources, which will form a positive mechanism of "incentives within constraints" when combined. The combination of the two creates a positive mechanism of "incentives within constraints". The principle is that the constraint effect is specifically manifested in the fact that enterprises are caught in the predicament of innovation or carbon purchase, and must choose one of the two paths[10]. If enterprises choose both paths equally in general, the opportunity cost of green innovation becomes relatively smaller after being supported by innovation incentives, thus attracting more enterprises to carry out green innovation. At the same time, the expected benefits of green innovation are relatively larger, because the benefits from innovation are mostly in the form of induced benefits. Relatively speaking, the sum of the two effects is a "crowding-in" effect on green innovation, which forms a "crowding-out" effect on other innovative activities. Therefore, the following research hypothesis is proposed:

H1: The dual-pilot policy is conducive to promoting enterprises' green technological innovation, and green innovation has a crowding-out effect on other innovations.

3.2 Mechanism Analysis

When the carbon emissions trading pilot and the innovative city pilot policy are implemented at the same time, enterprises facing carbon constraints can only choose to buy carbon emission rights or carry out green technological innovation, if enterprises continue to "buy carbon" in the carbon market, and if they choose green innovation, they can research and develop green technologies by

themselves or buy them from the technology market. Both forms of expenditure will be included in the R&D investment expenditures of enterprises, and will be reflected in the increase in the intensity of R&D investment by enterprises[11].Therefore, the following hypotheses are proposed:

H2: The dual-pilot policy can promote enterprises' green technological innovation by increasing their R&D intensity

The dual-pilot policy can also promote enterprise green innovation through the mechanism of easing enterprise financing constraints. Financing constraints have an inhibitory effect on enterprise innovation activities [12], the relaxation of financing constraints will have a significant positive impact on enterprise innovation, the stronger the enterprise is subjected to financing constraints, the higher the difficulty and cost of obtaining external financing, and the higher the sensitivity to investment-cash flow, therefore, the following hypotheses are proposed:

H3: The dual-pilot policy can promote enterprises' green technological innovation by alleviating financing constraints.

4. Research Design

4.1 Sample selection and data sources

This paper uses the relevant data of listed companies in China's Shanghai and Shenzhen cities from 2007 to 2018 as the initial sample. The patent data of listed companies come from CNRDS database and so on, based on the principle of territoriality to determine the scope of the pilot policy attributed to different enterprises, and finally get a total effective sample of 18324 items.

4.2 Variable Selection

(1) Explained variables: the number of green patent applications of listed companies in the sample in the current year. +1 followed by logarithm, expressed as GreInvia; the ratio of the number of green patent applications of listed companies in the year to the total number of patent applications, expressed as GreInviaratio.

(2) Explanatory variables: carbon emissions trading pilot policy differential variable (Trad), innovative city pilot policy differential variable (Crea), carbon emissions trading pilot policy and innovative city pilot policy differential variable interaction term (Trad*Crea).

(3) Control variables: ① Asset and liability flow rate (Flow): measured by the enterprise current assets/current liabilities. ② firm size (Cap): take the natural logarithm of the total annual value of assets of the enterprise. ③Debt ratio (Deb): measured by the total liabilities of the enterprise at the end of the year divided by the total assets at the end of the year. ④Profit: Measured by net profit/average balance of total assets. ⑤ Corporate Social Wealth Creation (Wealth): measured by Tobin's Q, Q=(Market value of outstanding shares + number of non-outstanding shares x net assets per share + book value of liabilities)/total assets.⑥Corporate maturity (Age): measured by the corporate age of listed companies.

4.3. Model Construction

This paper adopts the multi-period double-difference method to estimate the effect of the simultaneous implementation of two pilot policies, namely the carbon emissions trading pilot and the innovative city, on the green innovation of enterprises. The model formula is as follows:

$$\mathrm{panel}_{it}(\mathrm{Grenlnvia}, \mathrm{Grelnviaratio}) = \beta_0 + \beta_1 \mathrm{policy}_{it} + \sum \beta_2 \mathrm{control}_{it} + \eta_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where is the explanatory variable, including the number of green patent applications in the year and the proportion of green patent applications in the year; i and t denote the enterprise and the year, respectively; is the dummy double-difference explanatory variable, including the dummy variables of the pilot carbon emissions trading program and the pilot innovative city, which represents whether the enterprise i is located in the scope of influence of the policy in the period of t; is the control variable; is the intercept term, and is the regression coefficient of the control variable, and is the regression coefficient of the control variable, and the regression coefficient is the regression coefficient of the control variable. η_i denotes individual firm fixed effects, γ_t denotes time fixed effects; is the standard error. Among them, the core explanatory variable is the difference variable, which takes the value of 1 in the current and subsequent years of policy implementation if the enterprise meets the conditions of being located in the province or city where the policy is implemented, and 0 if it does not meet the above conditions at the same time. β_1 is the core coefficient of interest in this paper, which can respond to the level of the net effect of the policy influencing the enterprise's green innovation activities.

5. Empirical results and analysis

5.1 Descriptive statistics

Table 1: Variable descriptive statistics

Variable	Name	Mean Value	Standard Deviation	Maximum Value	Minimum Value
GreInvia	Number of green patent applications	0.2946	0.7236	11.0000	0.0000
GreInviaratio	Percentage of Green Patent Applications	0.1025	0.2465	0.9985	0.0000
Flow	Enterprise current ratio	1.563	2.6487	15.15	0.0235
Cap	Company Size	24.34	1.8855	35.15	10.64
Deb	Assets and Liabilities Ratio	0.4156	1.1654	186.15	-0.3175
Profit	Total Assets Net Profit Ratio	0.3455	0.2345	23.154	-16.4845
Wealth	Corporate Social Wealth Creativity	2.135	0.1654	4.644	0.000
Age	Enterprise maturity	3.258	0.3454	28.0000	1.0000

5.2 Regression results

The baseline regression model in Table 1 treats firms affected by the dual-pilot policy as the experimental group and firms not affected by either of the pilot policies as the control group. The control firm fixed effects and time fixed effects regression methods are used, and Trad*Crea is the two-policy cross-multiplier in Table 2, indicating that the firms are located in the area affected by the dual-pilot policy and take the time node as the time node of being affected by the dual-pilot policy shocks, and the variable Trad*Crea takes the value of 0 for the variable located prior to the time node, the value of 1 for the variable located after the node, and the value of 0 for all the rest of the cases.The model (1) does not incorporate the control variables and model (2) incorporates control variables.

Table 2: Regression results

	(1)		(2)	
	GreInvia	GreInviaratio	GreInvia	GreInviaratio
Trad* Crea	0.029*** (0.012)	0.074*** (0.010)	0.019** (0.019)	0.041** (0.015)
control variable	N	N	Y	Y
Individual fixed effects	Y	Y	Y	Y
Time fixed effects	Y	Y	Y	Y
R2	0.429	0.385	0.235	0.299
N	9373	9373	9373	9373

Note: ***, **, * denote significant at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

According to the regression results, regardless of whether the control variables are added or not, the green innovation activities of enterprises in regions where the dual pilot policy is implemented are enhanced compared to those of non-implemented enterprises: the estimated coefficients of the number and proportion of green patent applications are both significantly positive. This means that the joint implementation of the dual pilot policy has a facilitating effect on the green innovation of enterprises, and there is a crowding-out effect of green innovation on other innovations, and hypothesis H1 is valid.

5.3 Parallel trend hypothesis test

Drawing on the practice of Wang Xin (2021) to test the parallel trend, corresponding graphs are drawn to observe the parallel trend between the control group and the experimental group. Figures 1 and Figures 2 show the changes in the average number of green patent applications and the average number of green patents as a percentage of applications of listed enterprises in different policy pilot regions from 2007 to 2018, respectively, and the number of patents of enterprises in each region basically satisfies the condition of the same trend change.

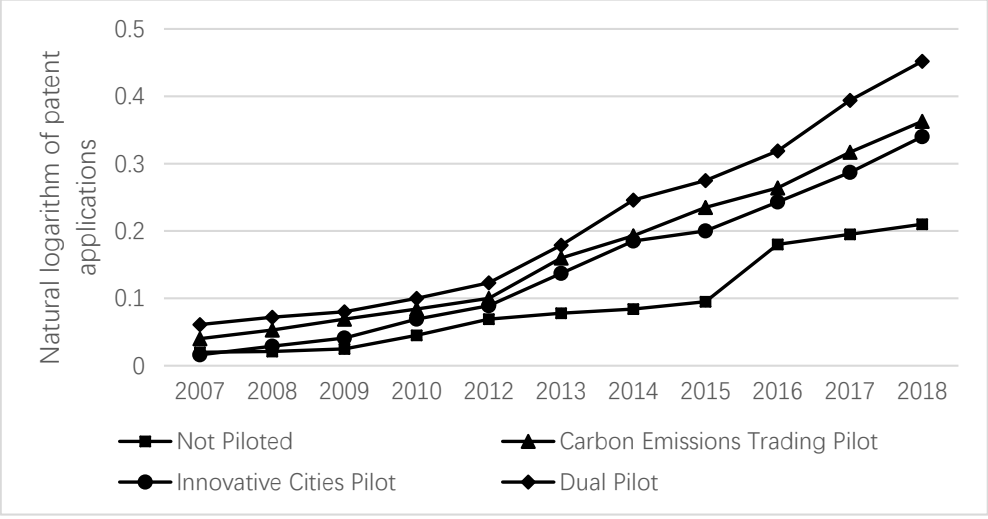

Figure 1: Average number of green patent applications in pilot regions with different types of policies

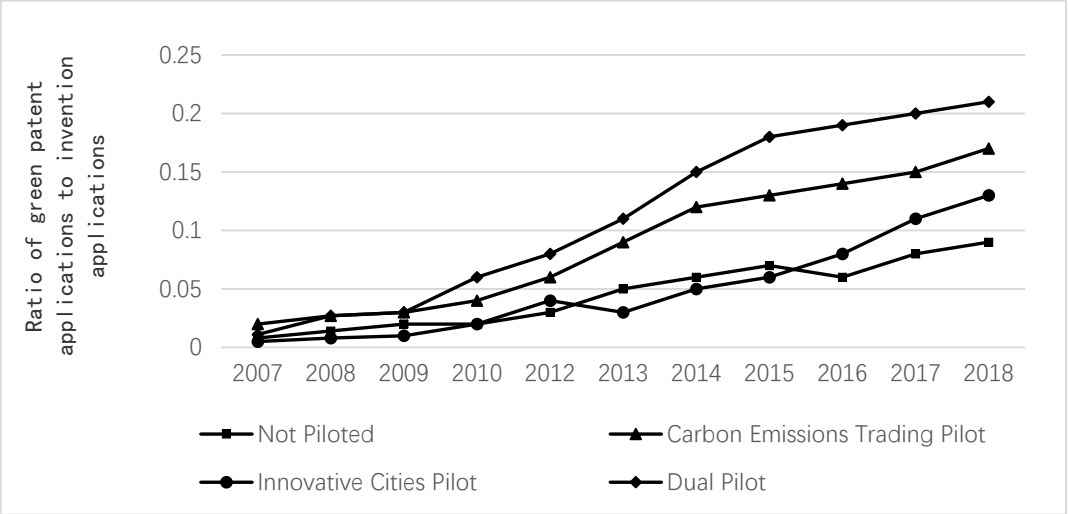

Figure 2: Average share of green patents in pilot regions with different types of policies

In addition, the parallel trend hypothesis is tested and the dynamic effects of policy are analyzed. The specific model is as follows:

$$\mathrm{GreInviaratio}_{it} = \beta_0 + \sum_{s=2}^{4} \beta_{pre_s}\, \mathrm{policy}_{pre_s} + \beta_{current}\mathrm{policy}_{current} + \sum_{s=1}^{5} \beta_{post\_s}\, \mathrm{policy}_{post\_s} + \sum \beta_2 \mathrm{control}_{it} + \eta_i + \gamma_t + \varepsilon_{it} \quad (2)$$

$\mathrm{GreInviaratio}_{it}$ is the proportion of enterprises' green patent applications, as the core explanatory variable, $\mathrm{policy}_{pre\_s}, \mathrm{policy}_{current}, \mathrm{policy}_{post\_s}$ respectively represent the cross-multiplication terms of the dummy variables of the years before the implementation of the dual-pilot policy, the year of the dual-pilot launch and the year after the implementation of the dual-pilot policy with the dummy variables of the corresponding policy, and the period before the policy is taken as a baseline, $\beta_{pre\_s}, \beta_{current}, \beta_{post\_s}$ are the corresponding coefficients of the policy. The regression results are shown in Figure 3. In the first few years of the dual pilot policy, the corresponding coefficient change was insignificant and negative, indicating that the trend of the green patent rate of enterprises in the first four years between the treatment group and the control group is a parallel trend. The coefficient of the year when the dual-pilot policy was implemented was significantly positive, and the coefficient of the following five years continued to increase, indicating that the promotion effect of the dual-pilot policy on enterprises' green innovation tends to increase year by year. The coefficient has become significantly positive in the year when the dual-pilot policy came into effect.

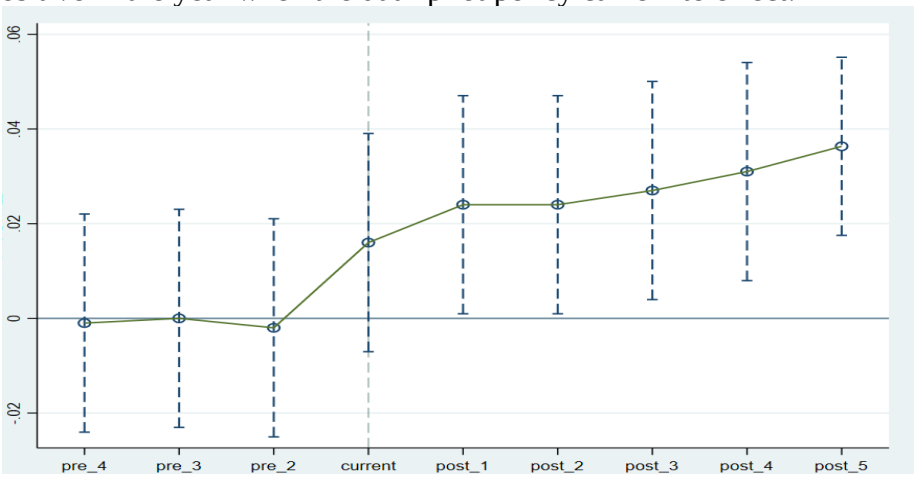

Figure 3: Parallel trend test and dynamic effects analysis

5.4 Robustness Tests

(1) In order to test whether the policy exogeneity of the regression results is obvious, a new explanatory variable is used in the model for verification. The specific approach is to artificially advance the policy implementation time by 1 year to form a new differential variable, i.e., the core explanatory variable ($policy_{it}$) of the time sub-variable assignment of the time node in advance, the new explanatory variable is named $policy_{t-1}$. (2) Replace the core explanatory variable of enterprise green innovation index in this paper, and change the calculation of the number of green patent applications of enterprises into the number of green patents including independent applications and joint applications, so as to exclude the number of green utility model applications of enterprises, and the corresponding percentage of green patents will be changed accordingly. In China's patent law, the innovativeness and strictness of the examination of invention patents are higher than that of utility model patents, so it can be assumed that the data after the exclusion of green utility model can better represent the level of green innovation of enterprises. As shown in table 3.

Table 3: Robustness test

	counterfactual test		Replacement data	
	GreInvia	GreInviaratio	GreInvia	GreInviaratio
Trad* Crea	0.009** (0.020)	0.047*** (0.018)	0.003* (0.016)	0.036* (0.011)
Trad* Creat-1	0.039 (0.012)	0.011 (0.010)	0.094 (0.021)	0.015 (0.014)
control variable	Y	Y	Y	Y
Individual fixed effects	Y	Y	Y	Y
Time fixed effects	Y	Y	Y	Y
R2	0.484	0.543	0.379	0.463
N	9373	9373	9373	9373

As shown in Figure 3, the results show that the coefficients of the original dummy multiple difference variables are still significant, while the regression coefficients of the newly constructed explanatory variables are not significant, suggesting that the core explanatory variables based on the original model are robust, and that the dual-pilot policy has a strong exogenous nature.

5.5 Mechanism test

According to the mechanism analysis above, the dual-pilot policy may work on enterprises' green innovation through the two mechanisms of increasing enterprises' R&D investment intensity and alleviating financing constraints. Therefore, the R&D investment intensity (RD) and cash flow ratio (Cashratio) of enterprises are selected to test the mechanism, and the two indicators selected above are used as explanatory variables and constructed to analyze the mediation effect model, the specific model is as follows:

$$Medac_{it}(RD,\ Cashratio) = \beta_0 + \beta_1 policy_{it} + \sum \beta_2 control_{it} + \eta_i + \gamma_t + \varepsilon_{it} \quad (3)$$

$$GreInviaratio_{it} = \beta_0 + \beta_1 Medac_{it}(RD,\ Cashratio) + \beta_2 policy_{it} + \sigma control_{it} + \eta_i + \gamma_t + \varepsilon_{it} \quad (4)$$

According to the results Table 4 results, the regression coefficient of the explanatory variable Trad* Crea in Column (2) is significantly positive, and the regression coefficient of RD in Column (3) is also significantly positive, which indicates that the simultaneous implementation of the dual-

pilot policy can enhance the intensity of enterprises' R&D investment, and at the same time, the coefficients of the explanatory variables are decreasing, implying that there is a part of the mediation effect, which suggests that the dual-pilot policy promotes the green enterprise by enhancing the intensity of enterprises' R&D inputs innovation activities. Similarly, columns (4) and (5) indicate that the dual-pilot policy can optimize enterprise cash flow, and the decrease in the coefficient of the differential explanatory variables also indicates the existence of mediation effect, which means that the dual-pilot policy promotes enterprise green innovation by optimizing the cash flow ratio. Therefore, hypotheses H2, H3 are valid.

Table 4: Mechanism tests

	(1)	(2)	(3)	(4)	(5)
	GreInviaratio	RD	GreInviaratio	Cashratio	GreInviaratio
Trad* Crea	0.013** (0.023)	0.005** (0.015)	0.009*** (0.0017)	0.138* (0.045)	0.004*** (0.016)
RD			0.24** (0.002)		
Cashratio					0.143** (0.0042)
control variable	Y	Y	Y		
Individual fixed effects	Y	Y	Y		
Time fixed effects	Y	Y	Y		
R2	0.108	0.147	0.092	0.113	0.099
N	9373	9373	9373	9373	9373

6. Further Discussion

In order to further test whether the carbon emissions trading pilot policy and the innovative city pilot policy have synergistic effects on the green innovation of enterprises, the samples of enterprises that are not affected by the carbon emissions trading pilot policy and the innovative city pilot policy during the study period are excluded, and the samples of enterprises that are only affected by the single-pilot policy of carbon emissions trading or the innovative city pilot policy as well as the samples that are affected by the dual-pilot policy are retained, and the values are assigned to the samples that are affected by the dual-pilot policy in the same way as above. In the same way as above, the regression coefficients of the differential explanatory variables DIDs test the net effect of the change from single pilot to dual pilot on the impact of enterprise green innovation. According to the results in Table 5, the regression coefficients of the explanatory variables are significantly positive, indicating that the dual-pilot policy has a synergistic effect on the promotion of enterprise green innovation.

Table 5: Comparative analysis of single pilot and dual pilot

	(1)	(2)
	GreInviaratio	GreInviaratio
DIDs	0.015*** (0.009)	0.008** (0.011)
control variable	N	Y
Individual fixed effects	Y	Y
Time fixed effects	Y	Y
R2	0.108	0.084
N	7761	7761

This paper further analyzes whether the sequence of carbon emissions trading pilot and innovative city pilot affects the effect of enterprises' green innovation. As shown in column (1) of Table 6, the regression coefficient of the difference variable DIDt is not significant in the case of the carbon emissions trading pilot followed by the innovative city pilot, as shown in column (1) of Table 5, the regression coefficient of the difference variable DIDt is not significant in the case of the carbon emissions trading pilot followed by the innovative city pilot, as shown in column (1) of Table 6, the regression coefficient of the difference variable DIDt is not significant in the case of the carbon emissions trading pilot followed by the innovative city pilot. As shown in column (1) of Table 5, the regression coefficient of the difference variable DIDt is not significant when the carbon emissions trading pilot is followed by the innovative city pilot, indicating that the effect of promoting firms' green innovation is not supported.

Table 6: Comparative analysis of the order of implementation of different pilot policies

	(1) Carbon emissions trading pilot before innovative city pilot	(2) Innovative city pilot before carbon emissions trading pilot
	GreInviaratio	GreInviaratio
DIDt	0.098 (0.027)	0.008** (0.013)
control variable	Y	Y
Individual fixed effects	Y	Y
Time fixed effects	Y	Y
R2	0.126	0.173
N	1190	5674

7. Conclusions and Policy Implications

7.1 Research Conclusion

This paper takes enterprise green innovation as the research center, and verifies the impact of carbon emissions trading pilot policy and innovative city pilot policy on enterprise green innovation. The study shows that: firstly, the carbon emissions trading pilot policy and innovative city pilot policy can effectively promote green innovation of enterprises, and at the same time have a "crowding out" effect on other innovative activities; secondly, the carbon emissions trading and innovative city pilot policy can promote green innovation of enterprises by enhancing the research and development intensity of enterprises and optimizing the cash flow ratio of enterprises; and thirdly, the double-pilot policy can be more effective in enhancing the level of green innovation of enterprises than the single-pilot policy and the two policies have a synergy effect.

7.2 Policy Implications

Enterprises are an important micro-unit of socio-economic development, and promoting green innovation in enterprises is an important initiative to realize green development. First, the synergistic effect between environmental regulatory policies and incentive policies should be fully emphasized. Second, the interaction and communication between "industry, academia and research" should be vigorously promoted to facilitate the full flow of innovation resources. Third, the government's role in promoting green innovation should be strengthened. The government can appropriately use subsidies and cost reductions to encourage enterprises to invest in scientific research and enhance

their green innovation output.

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