Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 9, No. 3, 2023

Carbon Trading Pilots and Firms' Green Innovation: Evidence from China's Listed Company

Langhua Zhang

BASIS International School Shenzhen, Shenzhen, 518067, China

Abstract: Firms' green innovation is important for their sustainable development. Determinants of firms' green innovation has been discussed by social scientists, among which, carbon trading is a significant perspective. However, the current literature has not obtained consistent findings on this issue, possibly because causality has been challenged by the issue of endogeneity. This is not conducive to efficient policy instruments from existing findings. Using the carbon trading pilots in China in 2011 and 16 as quasi-experiment, we constructed dataset of 9,998 listed companies from 2000-2021 to empirically test the effect of carbon trading pilots on firms' green innovation by using the staggered Difference-in-Differences (DID) method. The results show that carbon trading pilots increased the quantity of green innovation while had no effect on their quality, and remain robust after a series robustness tests. We also discuss the mechanism from the perspective of externalities. The paper thus highlights the necessity of piloting carbon trading and lowing externalities in fostering firms' green innovation.

Keywords: Carbon trading pilots, Firms' green innovation, China's listed company.

1. Introduction

Firms' green innovation is of great importance for their sustainable development and is of much concern in climate change [1] [2]. Therefore, there is a lot of literature dedicated to exploring the determinants of firms' green innovation, among which carbon trading is a significant perspective [4] [5] [6]. However, the causality between carbon trading and corporate green innovation has not been well tested empirically because of endogeneity problems such as facing some omitted variables [7] (Chen et al., 2021). Challenging studies have not yielded consistent findings, making it difficult to propose a targeted policy instrument. Some economists may argue that such regulations limited the options of firms, thus reducing their innovation [8]. Others argue that strict environmental regulations encourage enterprises to create more innovation to save costs and maintain profits [9]. In contrast with previous assertions, this claim is highly significant as it indicates that there is no tradeoff between environmental protection and economic development as it would stimulate dynamic efficiency [10]. The core issue behind this debate is whether environmental regulations trigger innovations. We use the carbon trading pilot in China's listed companies since 2011 as a quasi-experiment and empirically test the effect of carbon trading pilots on firms' green innovation.

China is the world's most populous country and the largest emitter of Carbon Dioxide[11]. To reduce carbon emissions, China initiated carbon trading pilot schemes since 2011. In 2011, Shanghai, Beijing, Hubei, Guangdong and Tianjin became carbon trading pilot provinces. In 2016, Fujian also became a carbon trading pilot province. Carbon trading refers to the trading of carbon emission rights. In essence, the government determines the total carbon emission target and then defines a carbon emission quota for the emitter. Due to the adjustment of the actual business situation, the emitter needs to trade the carbon quota freely in the market, which is carbon trading. Therefore, carbon emissions have become valuable assets that can be exchanged as commodities in the market. How to assess the impact of carbon trading pilots on corporate green innovation? To answer this question, we have collected and compiled a dataset covering 14 industrial industries with a total of 9,998 industrial A-shared listed companies in China from 2000-2021. We begin our analysis with a staggered Difference-in-Differences (DID) strategy. We compare changes in the quantity and quality of green innovation in firms located in piloted carbon trading provinces relative to no carbon trading provinces after the carbon trading pilots.

The results showed that carbon trading pilots increased the quantity of green innovation, while having no effect on their quality. After a series of robustness tests, this result remained robust. We conducted three sets of robustness checks to address omitted variables, use different constructing methods, and overcome sample selection bias, respectively. First, we included additional controls to show that the baseline results remain robust after considering some firms' characteristics. Second, we used both historical method and benchmark method of allocating the permit. There are two primary methods of allocating the permit. The historical method determines the number of permits allocated to a corporation based on their previous emission level. The benchmark method determines the number of permits allocated to a corporation based on the industry average emission level[12] . Last, we overcame the sample selection bias by conducting Propensity Score Matching. Results remained robust across all the checks.

The mechanism behind the influence of carbon trading on firms' green innovation is also difficult to explore. We discuss the potential influence mechanism of carbon trading on firms' green innovation from the perspective of externalities. Externalities are the spillover effects, either positive or negative, that arise from economic activities and affect individuals or entities not directly involved in those activities. We suggest that the greater the externality, the more it hinders the green innovation of enterprises. Therefore, we distinguish different industries, and there are differences in the degree of externalities of carbon emissions. An industry with high negative externalities is prone to hitchhiking, and the degree of innovation is low. We distinguished the manufacturing industry, the power production or supply industry and the construction industry, and tries to observe the changes of green innovation degree of firms in these industries after the implementation of carbon trading. The results in different industries show that the carbon trading pilots increased firms' green innovation in the power production or supply industry, and in the construction industry, but no in the manufacturing industry. This means that the manufacturing industry has high externalities, easy hitchhiking and low degree of innovation.

The mechanism behind the influence of carbon trading on firms' green innovation is also difficult to explore. We discuss the potential influence mechanism of carbon trading on firms' green innovation from the perspective of externalities. Externalities are the spillover effects, either positive or negative, that arise from economic activities and affect individuals or entities not directly involved in those activities. We suggest that the greater the externality, the more it hinders the green innovation of enterprises. Therefore, we distinguish different industries, and there are differences in the degree of externalities of carbon emissions. An industry with high negative externalities is prone to hitchhiking, and the degree of innovation is low. We distinguished the manufacturing industry, the power production or supply industry and the construction industry and tried to observe the changes of green innovation degree of firms in these industries after the implementation of carbon trading. The results in different industries show that carbon trading pilots increased firms' green innovation in the power production or supply industry and in the construction industry but not in the manufacturing industry. This means that the manufacturing industry has high externalities, easy hitchhiking and low degree of innovation.

This paper has two major contributions to this field of study. Firstly, this paper is the first to include the quality of green innovation into consideration. The majority of the previous studies used the quantity of green patents as the sole indicator of performance in green innovation, which could be misleading in cases where the quantity of green innovations increased while the quality decreased. In addition, this method also fails to differentiate innovations that contribute greatly to technological developments from innovations that do not. Therefore, in order to accurately measure the level of green innovation, it is essential to measure both the quantity and quality of green innovation as it is more comprehensive and holistic. To measure the quality of innovation, this paper referenced the methodology of Yang [13], where the quality of patents is calculated using an equation modeled after the equation of market concentration.

Secondly, this paper is also the first to give a perspective of externalities and measure the difference in the effect of carbon trading pilots on the level of green innovation in different industries. This paper categorized industrial firms into 3 large industries: The manufacturing industry, the electric power industry and the construction industry. By analyzing how the relationship between carbon trading pilots and the level of green innovation alters in these industries, this paper further contributes to the understanding of the structural differences between different industries as well as the suitability and effectiveness of carbon trading pilots in each industry.

The rest of the paper is organized as follows. We introduce the background of carbon trading pilots in Section 2. We introduce the data in Section 3. We present our empirical strategy and results in Section 4. We discuss the mechanism of externalities in Section 5. We conclude in Section 6.

2. Background

As greenhouse gas concentrations are at their highest level in 2 million years, countries are making various attempts to reduce CO2 emissions, the greatest contributor to greenhouse gas emissions, to prevent consequences such as droughts, rising sea levels and extinction. One of the most prominent international policies was the Kyoto Protocol, which laid the foundation of modern greenhouse gas (GHG) emission reduction schemes. Ratified in 2005 with the participation of 192 parties, the protocol targeted an average 5% emission reduction from 2008-2012 in comparison to the 1990 levels. The Kyoto Protocol was amended in 2012, which initiated the second commitment period starting from 2013 to 2020. In comparison to other GHG emission reduction schemes, the Kyoto Protocol was market-oriented with flexible market mechanisms[14] . Article 17 of the Kyoto Protocol allowed countries that have units of emission permitted but not used to sell those permits to countries that are over their capacity[15] . Such mechanism boosted the cost-effectiveness of greenhouse gas emission abatement while it also encouraged green investment in private sectors as well as the development of cleaner infrastructures. The world's first and largest carbon market was the Emission Trading System in the European Union[16].

China, being the world's most populous country and the largest emitter of carbon dioxide[11], also initiated carbon trading pilot schemes since 2011 to reduce carbon emissions. In 2011, the Chinese National Development and Reform Commission initiated carbon trading pilot schemes in six provinces: Shanghai, Beijing, Hubei, Guangdong, Shenzhen and Tianjin. In 2016, Fujian became a carbon trading pilot province. Carbon trading refers to the trading of carbon emission rights. In essence, the government determines the total carbon emission target and then defines a carbon emission quota for emitters. Due to adjustments in actual business situations, emitters need to trade carbon quotas freely in the market which is called carbon trading. Therefore, carbon emissions have become valuable assets that can be exchanged as commodities in the market.

3. Data

This study used the data of industrial A-shared listed companies in China from 2000-2021 to analyze the effect of carbon emission permit trading on green innovations. The data for green patents were taken from Chinese Research Data Service (CNRDS), while the data for the controlled variables were taken from CSMAR. In total, this dataset included 14 industrial industries with a total of 9,998 observed values.

3.1. Independent Variable: Participation in Carbon Trading Pilots

The independent variable used in this study was participation in carbon trading pilots. In 2011, Shanghai, Beijing, Hubei, Guangdong and Tianjin became carbon trading pilot provinces. In 2016, Fujian became a carbon trading pilot province. Companies in pilot cities that were included in carbon trading in 2011 or 2016 were coded as 1. Otherwise, companies were coded as 0. Figure 1 depicts the carbon trading pilots in provinces, which are randomly distributed.

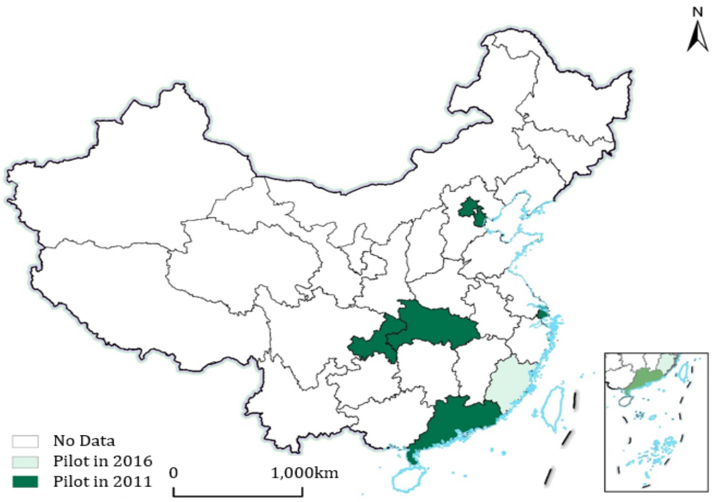

Figure 1. The Carbon Trading Pilots in Provinces

3.2. Dependent Variable: Quantity and Quality of Green Innovation

This study used the number of green patents attained to measure the quantity of innovation of companies. Using this variable as the dependent variable has several advantages. First, compared with financial investment and input in research and development, green patent is a much more specific and corresponding indicator of the level of corporations' innovation in green technology. Second, using the number of green patents attained rather than the number of green patents applied also filtered out green innovation with poor quality.

Nonetheless, the number of green patents attained did not holistically account for the effect on the level of corporate's green innovation since the relative quality of the patents was not considered. To measure the quality of green innovation, we referenced the method of Zhang [17], where the quality of patents is calculated using the equation of market concentration. The quality of green patents was measured based on the difference in the IPC (International Patent Classification) of patents of a company. The equation is as follows:

$$quality_{xt} = 1 - \sum \alpha^2$$

$$\alpha = the\ proportion\ of\ the\ number\ of\ patent\ in\ a\ category\ owned\ by\ company\ x\ in\ year\ t$$

The greater the value of quality, the more diverse a company's patent is, which indicates higher quality of innovation.

3.3. Controlled Variables

Several factors could affect the level of green innovation, which could be classified into 2 categories: the scale of a firm and its financial indicators. The size and the age of a firm are indicators of the scale of a company. The size of a firm often affects the availability of resources, thus affecting the development of new green technologies, while the age of a firm impacts their willingness and capability in innovating. The size of a firm is 22.214 in mean, and the age of a firm is 2.692 in mean.

Tobin Q, return on asset, and leverage reflected the finance of a company. The Tobin Q ratio of a corporation indicated its ability to create value, which is associated with its ability to innovate. The ability in which a company's assets were used to generate revenue reflected the efficiency and profitability of a company. The financial risks of a company also affected its ability to innovate. Therefore, this study controlled the size, age, Tobin Q, return on assets, and leverage of companies. Table 1 summarizes the definition of key variabl,

Table 1. Definition of Key Variables

Variable	Definition	Reference
Pilot	If a firm take parts in carbon permit trading, the value is 1. If it doesn't the value is 0	Xiao et al. (2022)
Scheme_bench mark	If permits are allocated by the benchmark method to a firm, the value is 1. Otherwise, it is 0.	Song et al. (2021)
Scheme_history	If permits are allocated by the historical method to a firm, the value is 1. Otherwise, it is 0.	Song et al. (2021)
Ind	If the firm is in the manufacturing industry, the value is 1. If the firm is power production or supply industry, the value is 2. If the firm is in the construction industry, the value is 3.	Li (2022)
ln number	Ln (the number of green patents attained by firms)	Du et al. (2021)
quality	The quality of green patents attained by firms	Zhang et al. (2022)
TobinQ	The ratio between physical assets market value and its replacement value	Shi and Wu (2022)
ROA	Return on Assets	Li (2022)
Lev	Leverage	Li (2022)
Size	Size of a firm	Tang et al. (2022)
FirmAge	The number of years since the firm was founded	Wang and Zhang (2022)

Table 2 provides the descriptive statistics of the dataset. The maximum number of green patents obtained by one company in one year was 61, while the minimum was 0, demonstrating the difference between the level of innovation of companies. In addition, the mean number of green patents was 0.155 while the mean quality of green innovation was only 0.107, showing an overall relatively poor innovation performance.

Table 2. Descriptive Statistics of Key Variables

Variable	Obs	Mean	Std. Dev.
Number	9555	0.155	1.603
Quality	9289	0.107	0.224
TobinQ	9433	1.697	1.071
ROA	9554	0.037	0.057
Lev	9555	0.480	0.204
Size	9555	22.214	1.380
Firm Age	9555	2.692	0.489

4. Empirical Strategy and Results

The empirical strategy of this paper follows the standard Difference-in-differences (DID) model to investigate the effect of carbon trading on corporates' green innovation. The model specification takes the following form:

$$Innovation\ (number, quality)_{xt} = \alpha + \beta Participation_{xt} + \delta C_{xt} + \delta_x + \sigma_t + \varepsilon_{xt} \quad (1)$$

The first model compared the relative changes in the quantity and quality of green innovation of companies participating in carbon trading with companies that didn't. Innovation_{xt} refers to the number and quality of green patents attained by company x in year t. The main explanatory variable is $\text{Participation}_{xt}$, the dummy variable that equals to 1 if the company participated in carbon trading and 0 otherwise. C_{xt} refers to all of the controlled variables, including Tobin Q, ROA, leverage, firm size, and firm age. As befits a fixed-effects model, δ_x captures the time-invariant regional characteristics for province x that may be associated with the reform, whereas σ_t controls for the temporal effects in our estimation. ε_{xt} is the error term.

We also use the main explanatory variable, $\text{Scheme\_benchmark}_{xt}$, the dummy variable that equals to 1 if the carbon permit was allocated by the benchmark method and 0 if otherwise, and $\text{Scheme\_history}_{xt}$, the dummy variable that equals to 1 if the carbon permit was allocated by the historical method and 0 if otherwise. We expect the coefficient β is positive.

4.1. Baseline Results

The empirical results of equation 1 is reported in Table 3. Column 1 represented the effect of participation in carbon trading on the quantity of green innovation without controlling any variable. Column 2 represented the effect of participation in carbon trading on the quantity of innovation after controlling the variables. Column 3 represented the effect of participation in carbon trading on the quanlity of green innovation without controlling any variable. Column 4 represented the effect of participation in carbon trading on the quanlity of innovation after controlling the variables.

Based on Table 3, without controlling covariates, carbon emission permit trading pilots had a significant positive impact on the number of green patents ($p<0.01$), indicating participation in carbon permit trading increased the number of green innovations. In column 2, both the independent and control variables were considered. After controlling Tobin Q, ROA, Leverage, Size, and Firm Age, participation in carbon emission permit trading still exerted a statistically significant and positive impact on the number of green patents. The strength of this relationship was stronger compared with column 1 as the coefficient increased. In addition, the age of the firm exerted a statistically significant effect on the number of patents, while the strength of this relationship also increased as the p-value decreased to below the 5% significance level.

Table 3. The Impact of Carbon Trading Pilots on Green Innovation: Baseline

	Quantity of green innovation		**Quanlity of green innovation**	
	(1)	(2)	(3)	(4)
Pilot	0.035***	0.038***	-0.017*	-0.015
	(0.010)	(0.010)	(0.010)	(0.010)
TobinQ		-0.004		0.003
		(0.003)		(0.003)
ROA		-0.059		-0.015
		(0.050)		(0.048)
Lev		0.031		-0.023
		(0.022)		(0.022)
Size		-0.006		0.043***
		(0.005)		(0.005)
FirmAge		0.039**		0.017
		(0.019)		(0.018)
Constant	0.041***	0.068	0.111***	-0.881***
	(0.003)	(0.121)	(0.003)	(0.118)
Observations	9,502	9,379	9,234	9,115
R-squared	0.551	0.554	0.367	0.375

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Based on Table 3, participation in carbon trading could significantly increase the level of green innovation of companies. In addition to the number of green patents attained, this paper also considered the quality of green patents. Without controlling covariates, involvement in carbon emission permit trading did have a significant and negative impact on the quality of green patents ($p<0.1$) obtained. However, after controlling Tobin Q, ROA, Leverage, Firm Age, and Firm Size, participation in carbon trading no longer exerted a statistically significant effect on the quality of green patents. This meant the quality of green innovation of companies that participated in carbon permit trading was not outstandingly better than companies that didn't.

In addition, this paper also analyzed the effect of different methods of allocating the permits on the quantity and quality of green innovation in Table 4. For this section, data from Chongqing were deleted as the methods of allocation were self-reported in Chongqing. Scheme_benchmark was the proxy variable for the benchmark method of allocation, while Scheme_history was the proxy variable for the historical method of allocation. Column 1 represented the effect of the benchmark method of allocating the permit on the quantity or quality of green innovation with controll variables. Column 2 represented the effect of the historical method of allocating the permit on the quantity or quality of green innovation with controll variables.

Column 1 and Column 2 in Table 4 analyzed the effect of different methods of allocating the permits on the quantity of green innovation. Based on column 1, the benchmark method of allocation did not have a statistically significant effect on the number of patents, indicating it does not account for the increase in patent. Nonetheless, according to column 2, the historical method of allocation had a statistically significant and positive effect on the number of patents, indicating companies whose permits were allocated by the historical method tend to obtain more patents. Column 3 and Column 4 in Table 4 analyzed the effect of different methods of allocating the permits on the quality of green innovation. Similarly, based on column 3, the benchmark method of allocation did not have a statistically significant effect on the quality of green patents, which was consistent with the overall relationship between pilot implementations and the quality of green patents. However, according to column 4, the historical method of allocation did have a statistically significant but negative effect on the number of patents, indicating companies whose permits were allocated by the historical method tend to obtain patents with lower quality.

Table 4. The Impact of Different Methods of Allocating the Permit on Green Innovation

	Quantity of green innovation		**Quality of green innovation**	
	(1)	(2)	(3)	(4)
Scheme Benchmark	-0.019		0.020	
	(0.021)		(0.020)	
Scheme_history		0.113***		-0.018
		(0.014)		(0.014)
TobinQ	-0.003	-0.004	0.002	0.003
	(0.003)	(0.003)	(0.003)	(0.003)
ROA	-0.022	-0.025	-0.013	-0.012
	(0.049)	(0.049)	(0.049)	(0.049)
Lev	0.046**	0.043*	-0.024	-0.023
	(0.022)	(0.022)	(0.022)	(0.022)
Size	-0.009	-0.008	0.042***	0.042***
	(0.005)	(0.005)	(0.005)	(0.005)
FirmAge	0.037*	0.049***	0.023	0.020
	(0.019)	(0.019)	(0.019)	(0.019)
Constant	0.125	0.059	-0.884***	-0.875***
	(0.121)	(0.120)	(0.119)	(0.119)
Observations	9,169	9,169	8,914	8,914
R-squared	0.559	0.563	0.375	0.375

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

4.2. Robustness Test

We also used PSM-DID analyses as a robustness test. Carbon pilot still significantly and positively affected the number of green patents (see Table 5). Therefore, this relationship remained robust. Similarly, the relationship between carbon trading pilot and the quality of green patents remained statistically insignificant after running the PSM-DID. After running the robustness test, all of the previous conclusions stand. In general, carbon trading pilot increased the number of green patents attained by companies. This was also confirmed by Song et al. [12], which also found how pilot implementation led to an increase in the number of green patents. In addition, this also validated Porter's hypothesis, as environmental policies indeed lead to an increase in innovations of firms. As Porter explained, there were multiple potential reasons behind this. Environmental regulations make companies aware of resource inefficiencies and room for technological improvements, reduce uncertainty in the necessity of environmental investment, and generate pressure that urges innovation and progress [18].

Table 5. The Impact of Carbon Trading Pilot on Green Patents: PSM

	Quantity of green innovation		Quanlity of green innovation	
	(1)	(2)	(3)	(4)
Pilot	0.030***	0.033***	-0.017	-0.015
	(0.010)	(0.010)	(0.010)	(0.010)
TobinQ		-0.004		0.003
		(0.003)		(0.003)
ROA		-0.031		-0.009
		(0.050)		(0.049)
Lev		0.044**		-0.025
		(0.022)		(0.022)
Size		-0.009		0.042***
		(0.005)		(0.005)
FirmAge		0.044**		0.019
		(0.019)		(0.019)
Constant	0.041***	0.105	0.112***	-0.876***
	(0.003)	(0.121)	(0.003)	(0.120)
R-squared	0.557	0.560	0.368	0.375
Observations	9,255	9,134	8,996	8,879

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

5. Discussion on Externalities

Innovation is the process of creating and implementing new ideas, technologies, or methods. It generates various externalities that can have both positive and negative effects on society. Green Innovation may have negative externalities with disruption and job losses. Technological advancements and automation can have negative externalities in the short term by displacing certain jobs and requiring workforce transitions. Also, green Innovation may lead to inequality. Socioeconomic disparities can arise if certain populations or regions lack the resources, skills, or infrastructure necessary to fully participate in and benefit from innovative advancements. An industry with high negative externalities is prone to hitchhiking, and the degree of innovation is low. We distinguish the manufacturing industry, the power production or supply industry and the construction industry according to the industry in which the enterprise is located, to test the negative externalities in different industries.

Based on Panel A in Figure 2, the relationship between carbon permit trading pilot and the number of green patents attained was highly positive and significant in the manufacturing industry. Similarly, according to Panel B, the relationship was also significantly positive and strong in the power production or supply industry. However, as illustrated by Panel C, this relationship between carbon permit trading pilot and the quantity of green patents was no longer statistically significant in the construction industry. The quality of the green patent was also examined. Based on Panel A, the relationship between carbon permit trading pilot and the quality of green patents attained was significant and positive in the manufacturing industry. However, according to Panel B, the relationship was significantly positive in the power production or supply industry. In addition, as illustrated by Panel C, this relationship between carbon permit trading pilot and the quality of green patents was also negative and statistically significant in the construction industry. This means that the manufacturing industry has high externalities, easy hitchhiking and low degree of innovation. Evidence of externalities showed that carbon permit trading pilots benefited the power production and supply industry the most. Carbon trading pilot policy effectively reduced the level of CO_2 emission in the power generation industry[19]. This was likely due to how technological breakthroughs in the power industry in recent years coincided with carbon trading pilots, which magnified the impact of green innovation.

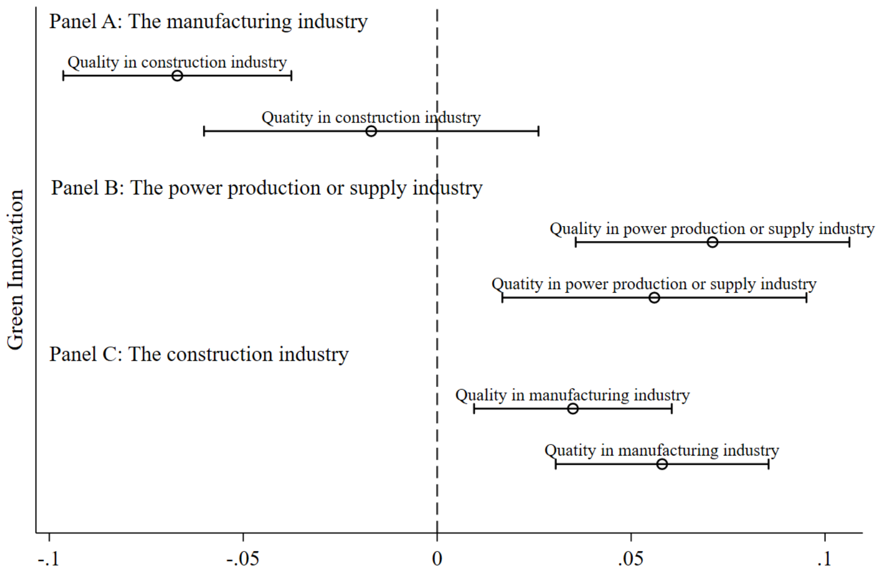

Figure 2. Effect of Green Innovation in Different Industries

6. Conclusions

Firms' green innovation is important for their sustainable development. Determinants of firms' green innovation has been discussed by social scientists, among which, carbon trading is a significant perspective. However, the current literature has not obtained consistent findings on this issue, possibly because causality has been challenged by the issue of endogeneity. This is not conducive to efficient policy instruments from existing findings. Using the carbon trading pilots in China in 2011 and 16 as quasi-experiment, we constructed dataset of 9,998 listed companies from 2000-2021 to empirically test the effect of carbon trading pilots on firms' green innovation by using the staggered Difference-in-Differences (DID) method. The results show that carbon trading pilots increased the quantity of green innovation while had no effect on their quality, and remain robust after a series robustness tests. We also discuss the mechanism from the perspective of externalities.

The paper thus highlights the necessity of piloting carbon trading and lowering externalities in fostering firms' green innovation. First, the government should widen the implementation of carbon trading pilot since it can effectively increase the number of green patents attained by companies. Second, the government should increase the level of activity in the secondary market. The primary economic efficiency of carbon trading arises from how the permits are tradeable[20]. Third, the government should increase the implementation of the historical method of allocation as the historical method could more effectively encourage green innovation. Fourth, the government should expand the implementation of carbon trading pilot in industries similar to the power production and supply industry.

However, there are various ways future studies can improve on the current studies. First, the current indicator of the quality of green innovation is modeled after the equation of market concentration. Nonetheless, this indicator is not accurate as it is possible for a company to specialize in one field and attain multiple high-quality innovations. Therefore, future studies could utilize other indicators of the quality of green innovation that tend to be more accurate. In addition, future studies can incorporate data sets that include non-industrial companies to analyze the carbon trading pilots more holistically in China.

References

[1] Paraschiv, D. M., Nemoianu, E. L., Langă, C. A., & Szabó, T. (2012). Eco-innovation, responsible leadership and organizational change for corporate sustainability. Amfiteatru Economic Journal, 14(32), 404-419.

[2] Zheng, C., Deng, F., Zhuo, C., & Sun, W. (2022). Green credit policy, institution supply and enterprise green innovation. Journal of Economic Analysis, 1(1), 20-34.

[3] Amore, M. D., & Bennedsen, M. (2016). Corporate governance and green innovation. Journal of Environmental Economics and Management, 75, 54-72.

[4] Yao, S., Yu, X., Yan, S., & Wen, S. (2021). Heterogeneous emission trading schemes and green innovation. Energy Policy, 155, 112367.

[5] Liu, M., & Li, Y. (2022). Environmental regulation and green innovation: Evidence from China's carbon emissions trading policy. Finance Research Letters, 48, 103051.

[6] Liu, M., Shan, Y., & Li, Y. (2022). Study on the effect of carbon trading regulation on green innovation and heterogeneity analysis from China. Energy Policy, 171, 113290.

[7] Chen, Z., Jin, J., & Li, M. (2022). Does media coverage influence firm green innovation? The moderating role of regional environment. Technology in Society, 70, 102006.

[8] Dechezleprêtre, A., & Sato, M. (2017). The Impacts of Environmental Regulations on Competitiveness. Review of Environmental Economics and Policy, 11(2), 183–206.

[9] Ambec, S., & Barla, P. (2005). Can Environmental Regulations be Good for Business? An Assessment of the Porter Hypothesis. Energy Studies Review, 14.

[10] Van Leeuwen, G., & Mohnen, P. (2017). Revisiting the Porter hypothesis: An empirical analysis of Green innovation for the Netherlands. Economics of Innovation and New Technology, 26(1–2), 63–77. https://doi.org/10.1080/10438599.2016.1202521

[11] Nancy, S. (2015). Carbon emissions in China. Main. https://energy.mit.edu/news/carbon-emissions-in-china/

[12] Song, D., Zhu, W., & Wang, B. (2021). Micro-empirical evidence based on China's carbon trading companies: Carbon emissions trading, quota allocation methods and corporate green innovation. China Population. Resources and Environment, 31.

[13] Yang, S., Jahanger, A., & Hossain, M. R. (2023). How effective has the low-carbon city pilot policy been as an environmental intervention in curbing pollution? Evidence from Chinese industrial enterprises. Energy Economics, 118, 106523.

[14] UNFCCC. (n.d.-a). Emissions Trading. Emissions Trading | UNFCCC. Retrieved January 14, 2023, from https://unfccc.int/process/the-kyoto-protocol/mechanisms/emissions-trading

[15] UNFCCC. (n.d.-b). What is the Kyoto Protocol? What Is the Kyoto Protocol? | UNFCCC. Retrieved January 14, 2023, from https://unfccc.int/kyoto_protocol

[16] European Commission. (n.d.). EU Emissions Trading System (EU ETS). Retrieved January 14, 2023, from https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en\

[17] Wang, W., & Zhang, Y. J. (2022). Does China's carbon emissions trading scheme affect the market power of high-carbon enterprises?. Energy Economics, 108, 105906.

[18] Ambec, S., Cohen, M. A., Elgie, S., & Lanoie, P. (2013). The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness? Review of Environmental Economics and Policy, 7(1), 2–22.

[19] Nie, Q. (2020). Analysis of policy effect of carbon emission trading on power generation industry. Energy Environmental Protection, 34(6). https://d.wanfangdata.com.cn/periodical/ChlQZXJpb2RpY2FsQ0hJTmV3UzIwMjMwMTEyEg9ta2hqYmgyMDIwMDYwMTIaCGR6M2RvZ2Uy

[20] Spash, C. (2010). The Brave New World of Carbon Trading. New Political Economy, 15(2).