The Impact of CO2 Emission Trade System on Firms’ Carbon Avoidance-motivated OFDI: Evidence from China

Gan LIN
Business School, University of Shanghai for Science and Technology

Yinuo ZHANG
Business School, University of Shanghai for Science and Technology

Ruyan TANG
Business School, University of Shanghai for Science and Technology

Le YANG
Business School, University of Shanghai for Science and Technology

他

https://doi.org/10.5109/7388812

出版情報：九州大学大学院農学研究院紀要. 70 (2), pp.137-146, 2025. 九州大学大学院農学研究院
バージョン：
権利関係：

J. Fac. Agr., Kyushu Univ., **70** (2), 137–146 (2025)

The Impact of CO2 Emission Trade System on Firms' Carbon Avoidance–motivated OFDI: Evidence from China

Gan LIN[1], Yinuo ZHANG[1], Ruyan TANG[1], Le YANG[1], Bingtao QIN[1], Yoshifumi TAKAHASHI* and Mitsuyasu YABE[2]

Laboratory of Fisheries Economics, Division of Agricultural and Resource Economics, Department of Agricultural and Resource Economics, Faculty of Agriculture, Kyushu University, Fukuoka 819–0395, Japan

(*Received May 6, 2025 and accepted May 16, 2025*)

This article analyzes the impact of China's CO2 Emission Trade System (ETS) on firms' carbon avoidance–motivated outward foreign direct investment (OFDI). The ETS is one of China's key market–based environmental policies aimed at controlling and reducing greenhouse gas emissions. Thousands of high–emission firms have been included in this system and now face the decision of either purchasing carbon credits or relocating production. The empirical application focuses on a manually compiled list of firms with carbon compliance obligations from 2013 to 2021, along with data from China's listed companies database. The study uses regional carbon trading pilot policies as a natural experiment for the analysis. The empirical results using Propensity Score Matching–Difference in Differences regression method indicate that: China's ETS have contributed to an increase in OFDI. We further incorporate carbon avoidance–motivated OFDI into the model, finding that the rise in OFDI may be motivated by the desire to avoid carbon reduction costs. This suggests that some firms, aiming to escape the costs associated with the carbon market, choose to relocate capital or production to other regions, leading to cross–border carbon leakage.

Key words: Carbon Avoidance, Emission Trade System, OFDI

INTRODUCTION

The CO2 Emission Trade System (ETS) is a widely adopted market–based environmental regulation designed to control emissions at the lowest cost by equalizing the marginal abatement costs of all emitters through market transactions. As the world's largest emitter of carbon dioxide, China implemented regional carbon trading pilot programs in 2013. Numerous studies have shown that carbon markets reduce overall emissions, but they impose additional abatement costs on emission–regulated firms. Beyond adjusting production levels or increasing investments in low–carbon technologies, firms may choose to invest in countries or regions with more lenient environmental regulations to avoid these extra costs. This paper explores this possibility.

To assess the impact of the carbon market on firms' outward foreign direct investment (OFDI) decisions, we first compiled a list of emission–regulated firms subject to compliance obligations in the regional carbon trading pilot programs from 2013 to 2021, across seven regions. This list was then matched with data from China's listed companies database, resulting in a panel dataset containing financial, investment, and other relevant firm information. Next, we treated the implementation of regional carbon markets as a quasi–natural experiment and employed a two–way fixed effect staggered Difference–in–Differences (DID) model to analyze the causal relationship between ETS and firms' OFDI decisions. Unlike traditional OLS methods, DID mitigates the influence of external factors and avoids significant endogeneity issues. To further reduce potential causal identification errors arising from firm heterogeneity, we conducted propensity score matching prior to the DID analysis, ensuring that each emission–regulated firm (Treatment group) was matched with a similar non–treated firm (Control group) from the same region, thus minimizing sample selection bias. Finally, to identify heterogeneous motives for firms' OFDI, we referred to the Environmental Performance Index (EPI) published by Yale and Columbia Universities. Using China's environmental regulation intensity as a benchmark, we classified OFDI to countries with weaker environmental regulations than China as motivated by carbon avoidance. By identifying OFDI driven by carbon avoidance, we further analyze whether firms seeking to evade domestic carbon reduction costs.

This study offers two key contributions: First, most studies on the impact of China's carbon trading pilot programs and OFDI have adopted a macro–level approach, often focusing on cities. This study bases on micro–level firm data and contributes to the literature on the effects of China's carbon emission trading policies. Second, by quantifying and comparing the environmental regulation intensity in both the home and host countries of OFDI, this study identifies carbon avoidance–motivated Outward FDI contributing to the literature on the causes of cross–border carbon leakage and offers policy recommendations to mitigate such leakage.

[1] Business School, University of Shanghai for Science and Technology, 516 Jungong Road, Yangpu District, Shanghai, 200093, P. R. China

[2] Professor Emeritus, Graduate School of Agriculture, Kyushu University

* Corresponding author (E–mail: gibun@agr.kyushu–u.ac.jp)

INSTITUTIONAL BACKGROUND AND LITERATURE REVIEW

Institutional Background

In 2011, China issued the "Carbon Emission Trading Pilot Work Notice", outlining a phased plan to incorporate seven regions–Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen–into carbon emission trading pilots between 2013 and 2014. Fujian was added to the pilot regions in 2016. As of 2013–2014, there were 2903 emission–regulated firms in the first seven pilot regions. After Fujian's inclusion in 2016, the number of firms in the pilot regions grew to 3180, and by 2023, the total number of emission–regulated firms exceeded 4000. According to data from the China Carbon Trading Network, by June 2019, the carbon markets in the pilot regions included nearly 3,000 major emission firms from industries such as power, steel, and cement, with a cumulative trading volume of over 330 million tons and a total transaction value of 7.1 billion yuan. With high contract compliance rates maintained, the pilot regions have developed local carbon markets characterized by comprehensive elements, distinctive features, and substantial scale. The pilot carbon markets are geographically dispersed and provide significant flexibility in policy design, with variations in allocation cycles, thresholds, and methods. Detailed information on regional policies is presented in Table 1.

Literature Review and Theoretical Development

Existing research widely agrees that the carbon emission trading market has stimulated OFDI. Most studies suggest that the establishment of China's CO2 ETS has facilitated OFDI (Liu *et al.*, 2022), particularly among high–pollution industries and carbon–intensive firms (Yu and Wu, 2022). With notable regional variation, the impact is more pronounced in eastern China compared to the western regions (Liu *et al.*, 2022). The mechanism through which the carbon market influences OFDI may involve factors such as firm innovation, profitability, and the stringency of local environmental penalties (Qi and Zhang, 2021). Based on these findings, we propose the following hypothesis:

H1: China's carbon emission trading pilot policies have stimulated firms' OFDI.

Theoretically, the "pollution haven" hypothesis explains the increase in OFDI driven by carbon emission trading, with most studies focusing on developed countries (Yu *et al.*, 2021). Additionally, many studies suggest that the theory is applicable to numerous developing economies, where firms seek countries with weaker environmental regulations for production. The location choice for OFDI depends not only on the environmental regulations of the home country but also on those of the host country. Therefore, this theory explains the "carbon avoidance" motivation behind firms' OFDI location choices, driven by the host country's environmental regulations.

The carbon emission quotas allocated to Chinese firms are based on their historical emissions, with these quotas gradually decreasing over time to achieve emission reductions. After the implementation of the carbon trading pilot policies, firms subject to carbon quota management have several options to meet their required emission limits: the first is reducing emissions. Firms can reduce their production scale to lower emissions, or they can innovate and upgrade equipment to improve energy efficiency and reduce emissions. Another option is to adjust the firm's industrial structure, shifting towards the tertiary sector and reducing high–carbon–emission activities. The second is trading carbon allowances: Firms can also meet their obligations by purchasing additional carbon allowances on the carbon trading

Table 1. Comparison of ETS in China's pilot regions

Pilot Regions	Beijing	Tianjin	Shanghai	Chongqing	Hubei	Guangdong	Shenzhen	Fujian
Start Time of Compliance	2014	2014	2013	2014	2014	2014	2013	2016
Threshold for emission–regulated firms	5000	20000	10000	20000	10000	20000	3000	20000
Number of Firms in the Initial Allocation	947	109	368	254	344	246	635	277
Allocation Method	The allocation is primarily based on free distribution, with the specific allocation amount determined according to the actual situation. The free allocation quota is around 95%.							
Penalty for Non–Compliance	A fine of 3–5 times the market average price	Order to correct within a specified period, and no preferential policies for three years	A fine of 50,000 to 100,000 yuan	Payment of three times the average quota price before the compliance deadline	A fine of 20% of the value of the subject matter	A fine of 50,000 yuan	A fine of three times the market average price to be paid in the following year	Deduction of two times the quota in the following year, and a fine of one to three times the market price

Notes: The unit for the total initial allocation is hundred million (tons), and the unit for the number of firms in the initial allocation is (firms) platform, thus increasing their emissions quota for the current period. However, this strategy is unsustainable, as the same issue will arise in the next compliance period. Additionally, purchasing carbon allowances raises environmental costs, placing financial pressure on firms. The third is investing abroad. Firms may opt to invest in countries with more lenient carbon policies to reduce costs. According to international factor mobility theory, carbon emission trading pilot policies may increase production costs, particularly carbon costs. Firms can use OFDI to seek more cost–effective production conditions in countries with less stringent environmental regulations. Based on the literature reviewed, we propose the second hypothesis:

H2: Firms may engage in "carbon avoidance motivated" OFDI to circumvent the carbon reduction costs imposed by the carbon market, making them more likely to increase OFDI to host countries with weaker environmental regulations than those in China.

DATA AND VARIABLES

Data

List of Listed Firms Subject to Compliance with China's Carbon Market

This study compiles lists of firms with compliance obligations, published annually by local governments, environmental bureaus, and development and reform commissions from 2013 to 2021. The list includes a variety of entities, including listed companies, limited liability firms, public institutions, and universities. Finally, we collected data covering over 4,000 emission–regulated firms.

The data was processed as follows: First, the carbon market includes both firms with compliance obligations (mandatory regulated firms) and non–compliant entities. Non–compliant firms are typically voluntary participants motivated by environmental or public welfare concerns, which are difficult to quantify economically. As a result, we excluded non–compliant entities from the sample. Second, as many banks are also included in the list of emission–regulated firms, their industry classification is used solely for categorization purposes and not for further data processing. Third, since not all firms in the pilot regions or specific industries are required to participate in the carbon trading system, using regions or industries as treatment groups could result in estimation bias. Therefore, we focused on the list of emission–regulated firms from the eight carbon markets and matched it with data from listed companies for analysis.

Basic Firm Information and OFDI Data

We constructed a panel dataset containing basic firm information using the China Stock Market & Accounting Research (CSMAR) database, a widely used micro–enterprise database in China. The CSMAR database provides detailed data on the financial, employment, and equity information of all listed firms in China. First, we manually matched the list of regulated firms with the CSMAR database from 2013 to 2021 based on firm names. Second, since the DID estimation requires data for at least three periods, we excluded firms with fewer than three periods of data. Finally, we compiled a panel dataset consisting of 250 listed regulated firms and other listed non–regulated firms.

We define a firm's OFDI as the behavior of its capital outflow from China, as well as the establishment and operation of local subsidiaries abroad. Based on this definition, we classify a firm's investment as OFDI if it has control over foreign companies. We determine whether a listed firm has made an OFDI by examining the information of affiliated companies (Liu *et al.*, 2015). The affiliation information is sourced from the CSMAR database, which includes attributes such as the affiliated firm's holding period, ownership percentage, location, registered capital and transaction currency code. The types of affiliated relationships include "subsidiaries", "associates", and "joint ventures" of listed companies. We calculate the total OFDI of the listed company by summing the yearly investment amounts. Since "tax havens" are commonly used for tax avoidance or as intermediary regions for FDI, this study excludes samples from tax havens such as Hong Kong, the British Virgin Islands, and the Cayman Islands (Dong and Chen, 2021; Li *et al.*, 2019).

Environmental regulation intensity data of host countries.

The Environmental Regulation Strength (ERS) data published by the OECD for 32 countries and the Environmental Performance Index (EPI) developed by Yale and Columbia Universities are the commonly used data on environmental regulation intensity. Compared to the ERS, the EPI covers more countries and offers a broader range of indicators. Therefore, we primarily use the EPI to measure the environmental regulation intensity in host countries. The EPI includes data for 180 countries, and even when excluding "tax havens", it covers all the destination countries of China's OFDI required for this study.

Table 2 shows the top 15 countries with the highest and lowest EPI scores. The average score across 182 countries is 42.85, with a standard deviation of 12.37. India has the lowest score at 18.9, while Denmark has the highest at 77.9. China's score is 28.4, placing it relatively low.

Descriptive Statistics

Table 3 shows the calculation method of all variables used in the empirical analysis. We selected several control variables based on existing literature, including firm age (*Age*), firm size (*Size*), investment expenditure ratio (*Inv*), equity capital (*Cap*), market–to–book ratio (*MBT*), cash asset ratio (*CAR*), and fixed asset ratio (*Fix*).

Table 4 shows the descriptive statistics. The OFDI of the treatment group (emission–regulated firms) is significantly higher than that of the control group (non–emission–regulated firms). This suggests that emission–

Table 2. EPI Scores of Countries Worldwide

Top 15 Countries	EPI Scores	Bottom 15 Countries	EPI Scores
Denmark	77.9	India	18.9
United Kingdom	77.7	Myanmar	19.4
Finland	76.5	Vietnam	20.1
Malta	75.2	Bangladesh	23.1
Sweden	72.7	Pakistan	24.6
Luxembourg	72.3	Papua New Guinea	24.8
Slovenia	67.3	Liberia	24.9
Austria	66.5	Haiti	26.1
Switzerland	65.9	Turkey	26.3
Iceland	62.8	Sudan	27.6
Netherlands	62.6	Ghana	27.7
France	62.5	Iraq	27.8
Germany	62.4	Madagascar	28.0
Estonia	61.4	Guatemala	28.0
Latvia	61.1	Chad	28.1

Table 3. Variable calculation method

Variable	Calculation method
OFDI	Logarithmic form of outward FDI amount
LERSOFDI	Logarithmic form of carbon avoidance–motivated OFDI amount
Age	Firm age, Year minus the year of listing
Size	Logarithmic form of total assets
Inv	Cash paid for fixed assets, intangible assets, and other long–term assets / total assets × 100%
Cap	Logarithmic form of share capital
MBT	Shareholders' equity / market value of the company × 100%
CAR	Cash and cash equivalents / current liabilities × 100%
Fix	Fixed assets / total assets × 100%

Table 4. Descriptive statistics

Variable	Overall		Treatment group		Control group	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
OFDI	2.684	6.252	6.120	8.885	2.474	5.991
LERSOFDI	0.164	0.371	0.339	0.473	0.154	0.361
Age	7.729	8.331	9.516	7.946	7.615	8.341
Size	22.138	1.564	23.475	2.365	22.049	1.453
Inv	0.049	0.051	0.059	0.053	0.048	0.050
Cap	20.060	1.202	21.008	1.787	19.998	1.125
MBT	0.616	0.253	0.698	0.267	0.611	0.251
CAR	0.174	0.146	0.148	0.129	0.176	0.147
Fix	0.205	0.163	0.264	0.179	0.201	0.162

regulated firms are more inclined to engage in outward FDI, implying that inclusion in the carbon market compliance list may drive firms to pursue international investments. Additionally, the OFDI driven by carbon avoidance motives is higher in the treatment group than in the control group. In the following sections, we will develop an empirical framework to test the hypotheses proposed earlier.

EMPIRICAL FRAMEWORK

We use the PSM–DID model for empirical analysis. First, we apply Propensity Score Matching (PSM) to match treatment group firms with control group firms that have similar characteristics, thereby mitigating potential causal identification errors arising from significant firm differences. Next, we construct a staggered DID model to evaluate the impact of the carbon market on firms' outward FDI decisions. Finally, we test Hypothesis 2 by identifying the outward FDI driven by carbon avoidance motives.

Propensity Score Matching

The basic idea of Propensity Score Matching (PSM) is to identify a comparable control firm (company j) from non–pilot enterprises, whose characteristics closely resemble those of the treatment firm (company i). Matching helps mitigate sample selection bias arising from significant differences between the treatment and control groups before the implementation of environmental regulations. In our case, the allocation of carbon emission quotas is not random but is based on the carbon emissions generated by listed companies' activities and regional differences. Therefore, we first use PSM to create a comparable control group for the treatment firms. We use radius matching as the primary matching method and perform robustness tests with several other methods.

According to the "Notice on the Implementation of Carbon Emission Trading Pilot Programs" issued by the National Development and Reform Commission (NDRC) in 2011, carbon emission control enterprises are identified based on the number of emissions exceeding specified limits during a given period. These enterprises are then included in the control list. The carbon emission control standards for each pilot region are provided in Table 1. Since eligibility for carbon emission control depends on total emissions, which are influenced by factors such as firm size, cash flow, and capital intensity. This study applies the propensity score matching (PSM) method, as proposed by Rosenbaum and Donald. We match the treatment group and the control group using seven observable characteristics: firm age (*Age*), firm size (*Size*), investment expenditure ratio (*Inv*), equity capital (*Cap*), market–to–book ratio (*MBT*), cash asset ratio (*CAR*), and fixed asset ratio (*Fix*).

Table 5 is the result of the radius matching. Before matching, there were notable differences between the carbon emission trading pilot firms and the non–pilot firms. Specifically, the pilot firms were older, larger in size, and had higher market–to–book ratios and fixed asset ratios. After matching, the treatment and control groups exhibited similar characteristics in these areas. The T–test results reveal no statistically significant differences, confirming the success of our matching process.

Staggered Difference–in–Differences Model

Based on the PSM–matched sample, we empirically examine the impact of the carbon market on firms' OFDI

Table 5. The results of propensity score matching

Variable	Unmatched (U) / Matched (M)	Mean: Treat	Mean: Control	Variation (%)	Variation reduction (%)	t–test	p–value
Age	U	11.180	9.739	19.300	97.900	8.490	0.000
	M	11.180	11.150	0.400		0.130	0.893
Size	U	23.275	22.138	68.300	99.100	36.180	0.000
	M	23.275	23.286	–0.600		–0.170	0.861
Inv	U	0.063	0.049	27.000	88.800	12.250	0.000
	M	0.063	0.061	3.000		0.880	0.381
Cap	U	20.847	20.043	63.900	97.000	32.340	0.000
	M	20.847	20.871	–1.900		–0.570	0.568
MBT	U	0.680	0.615	25.600	93.400	11.580	0.000
	M	0.680	0.675	1.700		0.530	0.597
CAR	U	0.149	0.173	–17.800	92.100	–7.410	0.000
	M	0.149	0.147	1.400		0.490	0.627
Fix	U	0.276	0.204	42.700	97.700	19.420	0.000
	M	0.276	0.274	1.00		0.270	0.786

decisions using a staggered difference–in–differences (Staggered–DID) model. The baseline regression model is as follows:

$$OFDI_{it} = \beta_0 + \beta_1 ETS_i \times Time_t + \boldsymbol{\beta X_{it}} + \lambda_i + \mu_t + \varepsilon_{it} \quad (1)$$

In the model, $OFDI_{it}$ represents the OFDI amount for firm i in year t; ETS_i indicates whether the firm is included in the carbon market's regulated list, with a value of "1" for regulated firms and "0" for non–regulated firms; $Time_t$ is a dummy variable, where it is "1" for the years following the introduction of the carbon market pilot program, and "0" for the years before; X_{it} includes a set of firm–level control variables; λ_i and μ_t represent firm and year fixed effects, respectively; ε_{it} is the error term. The coefficient β_1 of the interaction term $ETS_i \times Time_t$ is used to measure the impact of the carbon market on the firm's OFDI decisions.

To identify whether the carbon market has led firms to choose OFDI to avoid carbon reduction costs, we further distinguish the OFDI motivated by "carbon avoidance" and construct the following model for empirical testing:

$$LERSOFDI_{it} = \beta_0 + \beta_1 ETS_i \times Time_t + \boldsymbol{\beta X_{it}} + \lambda_i + \mu_t + \varepsilon_{it} \quad (2)$$

In this model, $LERSOFDI_{it}$ represents the amount of OFDI made by firm i at time t to countries with lower environmental regulatory intensity.

EMPIRICAL RESULTS

Baseline Results

Table 6 shows the baseline results for Eq. (1). Column 1 presents the results without control variables, indicating that the coefficient of the key interaction term $ETS_i \times Time_t$ is 3.383, statistically significant at the 1% level. This suggests that the carbon market has indeed stimulated overall OFDI. Column 2 includes control variables, with the coefficient of the key interaction term being 2.319, also significant at the 1% level, confirming the robustness of our conclusion. Specifically, on average, being included in the carbon market allows regulated firms to increase their OFDI by 2.319% compared to non–regulated firms.

Is It Driven by "Carbon Avoidance"

We analyze whether firms increase OFDI to avoid carbon costs by running a regression on Eq. (2). The results are shown in Table 7.

Columns (1) and (2) of Table 7 show the baseline results, with and without control variables, respectively. The results indicate that the coefficient of the key interaction term $ETS_i \times Time_t$ is significantly positive at the 1% level in both models. Specifically, the coefficient in column (2) is 1.644, suggesting that the implementation of the carbon market has led Chinese firms to increase their carbon avoidance–motivated OFDI by an average of 1.644%. This finding supports Hypothesis 2, validating our "pollution haven" hypothesis. It indicates that when environmental regulations tighten, firms are likely to shift capital to countries with more relaxed environmental regulations, thereby engaging in cross–border carbon leakage.

This result contrasts with findings in some developed countries, likely due to differences in the context of carbon market policies. In developed countries, economies are primarily service–oriented, with carbon–intensive industries comprising a smaller share of national output. In contrast, carbon–intensive industries, particularly manufacturing, are central to China's economy. This makes Chinese firms more vulnerable to carbon

Table 6. Baseline results of ETS's impact on firms' OFDI

	(1)		(2)	
Variables	*OFDI*		*OFDI*	
$ETS_i \times Time_t$	3.383***	(0.360)	2.319***	(0.353)
Age			–0.021	(0.0151)
Size			0.866***	(0.154)
Inv			1.518*	(0.797)
Cap			0.709***	(0.119)
MBT			–1.566***	(0.398)
CAR			–0.912*	(0.430)
Fix			–1.603***	(0.518)
Cons.	3.289***	(0.014)	–28.560***	(3.909)
λ_i (firm fixed effect)	Controlled		Controlled	
μ_t (year fixed effect)	Controlled		Controlled	
Observations	37,292		37,292	
Within R^2	0.060		0.118	

Notes: T–value in parentheses, clustered at the firm level. ***p < 0.01; **p < 0.05; *p < 0.1

Table 7. The impact of ETS on carbon avoidance motivated OFDI

	(1)		(2)	
Variables	*LERSODFI*		*LERSOFDI*	
$ETS_i \times Time_t$	2.496***	(0.403)	1.644***	(0.378)
Age			–0.0238	(0.0157)
Size			0.748***	(0.148)
Inv			0.448	(0.685)
Cap			0.557***	(0.0923)
MBT			–1.465***	(0.337)
CAR			–0.869**	(0.328)
Fix			–1.448***	(0.377)
Cons.	2.364***	(0.0153)	–23.83***	(3.615)
λ_i (firm fixed effect)	Controlled		Controlled	
μ_t (year fixed effect)	Controlled		Controlled	
Observations	37,292		37,292	
Within R^2	0.060		0.116	

Notes: T–value in parentheses, clustered at the firm level. ***p < 0.01; **p < 0.05; *p < 0.1

cost pressures. Moreover, the high level of fixed asset investment in these industries raises the cost of technological transformation. The entrenched, carbon–intensive manufacturing supply chains further slow the adoption of new technologies. Consequently, Chinese firms need more time to transition to low–carbon operations. As a result, firms are more likely to relocate capital or production to regions with less stringent environmental regulations.

Robustness

Parallel trend test

The key assumption in the DID regression is the parallel trends assumption. If a pre–existing time trend difference exists between the treatment and control groups, the observed difference in outward FDI may not result from the carbon market implementation but from other factors. To test the parallel trends assumption, we constructed a difference–in–differences model incorporating interactions between policy periods (three periods before and after the policy implementation) and the carbon market. The results are displayed in Figure 1. The vertical solid lines represent the 95% confidence intervals for the estimated coefficient of $ETS_i \times Time_t$. Prior to the implementation of the carbon emission trading pilot policy, the estimated coefficient of $ETS_i \times Time_t$ lies within the 95% confidence interval, including 0. This indicates no significant differences in OFDI between the treatment and control groups before the policy, satisfying the parallel trends assumption. Furthermore, after policy implementation, the estimated coefficient of $ETS_i \times Time_t$ is significantly positive, suggesting that the carbon emission trading pilot policy has a lasting effect on firm's OFDI.

Placebo Test

The fictitious treatment group is a common placebo test in DID analysis. If the policy effect of the fictitious treatment group is not significant, it suggests that the carbon market's impact on firms' outward FDI is not random. This indicates that the carbon market's influence on firms' OFDI is a genuine effect. Following Li *et al.* (2016), we perform a placebo test by randomly assigning a treatment group. Specifically, we randomly select 2000 observations as the fictitious treatment group, with the remaining data serving as the control group. Next, we repeat the experiment 500 times, performing regression analysis based on Eq. (1) to estimate the policy effect. Finally, we examine the changes in the coefficient of the core interaction term.

Figure 2 presents the kernel density distribution of the placebo test. As shown, the absolute values of the t–statistics for the estimated coefficients in the random sampling are all below 2.25, with p–values exceeding 0.1. This indicates that the results are not statistically signifi-

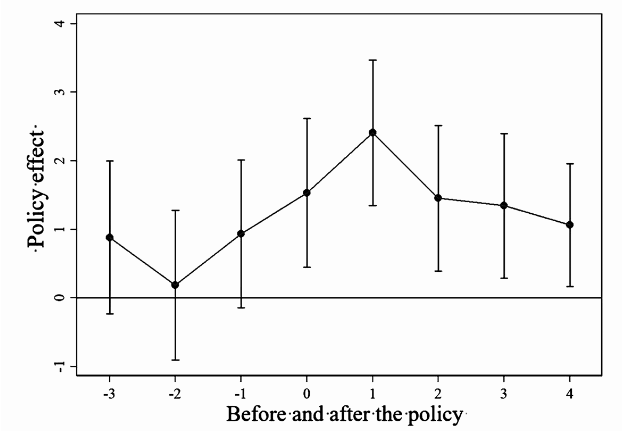

Fig. 1. The results of the parallel trend test.

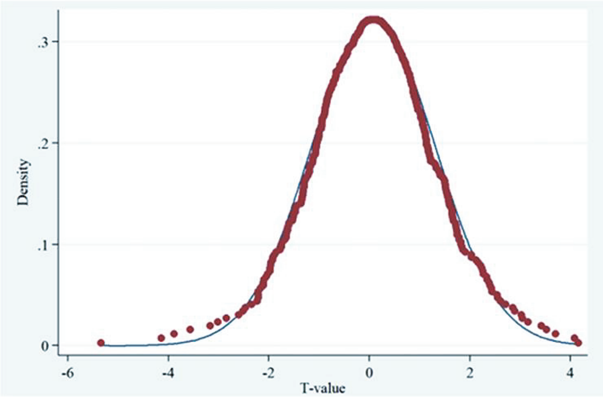

Fig. 2. Kernel Density Distribution Plot of Placebo Test Results.

cant. These findings suggest that, across the 500 random samples, the carbon emission trading pilot policy did not significantly affect firms' OFDI decisions. Therefore, this provides strong statistical evidence that our conclusions are unlikely to be due to chance.

Change the PSM matching method

The main regression uses kernel matching as the matching method. To further validate the robustness of our conclusions, we performed Propensity Score Matching (PSM) with a 1:1 nearest neighbor matching approach, followed by a DID regression based on the matched sample. The results are shown in Table 8.

As shown in Column (1) of Table 8, after changing the matching method, the coefficient of the key interaction term remains significantly positive, confirming the robustness of our conclusions. Column (2) presents the results with LEROFDI as the dependent variable. The coefficient is significantly positive, indicating that the carbon market in China has indeed increased firms' Carbon avoidance–motivated Outward FDI.

Replace the environmental regulation data

In our main regression, we identified firms' carbon avoidance–motivated OFDI by comparing China's EPI score to those of other countries. Given the subjectivity in index construction, we also used a comparison based on countries' inherent environmental advantages to identify firms' carbon avoidance motives for OFDI. Specifically, we followed the approach of (Deng *et al*, 2015), using the number of international environmental agreements (IEAs) each country is a party to as a measure of environmental regulations. These agreements include "Convention on Wetlands of Importance Especially as Waterfowl Habitat", "The United Nations Framework on the Convention for Climate Change", "The Kyoto Protocol", "Vienna Convention on the Law of Treaties", "The Stockholm Convention on Persis–tent Organic Pollutants", "The Convention on Biological Diversity", and "Convention on Migratory Species". If a country has signed any of these international environmental agreements, its environmental regulation score is assigned to a value of 1; otherwise, it is assigned a value of 0. The total score for each country is then calculated. We manually compiled the data for each country that signed an agreement and scored them accordingly. After matching, we obtained a composite score for 163 countries. Using this scoring system, we identified firms' carbon avoidance–driven OFDI and re–estimated Eq. (2). The results are presented in Table 9.

As shown in Table 9, after re–selecting the method to assess the host country's environmental regulation intensity, the results remain consistent. The coefficient of the core interaction term is significantly positive at the 1% level, indicating that after the implementation of the carbon emission trading pilot policy, the treatment group is more likely to engage in carbon avoidance–motivated outward FDI than the control group. This further supports Hypothesis 2.

CONCLUSIONS

To combat climate change and achieve the "carbon neutrality" goal through carbon emission reductions, China has implemented carbon emission trading pilot policies, in line with global trends. These policies aim to encourage manufacturing companies to reduce emissions by upgrading industries and increasing productivity. However, some companies have relocated capital or production to avoid the costs of the carbon market, lead-

Table 8. The results after changing the matching method

	(1)		(2)	
Variables	*ODFI*		*LERSOFDI*	
$ETS_i \times Time_t$	1.081*	(0.577)	0.702*	(0.331)
X_{it}	Controlled		Controlled	
λ_i (firm fixed effect)	Controlled		Controlled	
μ_t (year fixed effect)	Controlled		Controlled	
Observations	4,375		4,375	
Within R^2	0.313		0.311	

Notes: T–value in parentheses, clustered at the firm level. ***p < 0.01; **p < 0.05; *p < 0.1

Table 9. The results after replacing the method for evaluating the intensity of environmental regulation

	(1)
Variables	*LERSODFI*
$ETS_i \times Time_t$	2.247*** (0.350)
X_{it}	Controlled
λ_i (firm fixed effect)	Controlled
μ_t (year fixed effect)	Controlled
Observations	37,292
Within R^2	0.121

Notes: T–value in parentheses, clustered at the firm level. ***p < 0.01; **p < 0.05; *p < 0.1

ing to cross–border carbon leakage. This study aims to verify this claim using a large enterprise dataset and rigorous econometric methods.

Specifically, China's carbon emission trading pilot policy creates a quasi–natural experimental environment for this study. Using data from mandatory carbon control enterprises across regions and detailed information on listed companies, we employ the PSM–DID method to analyze the causal relationship between China's carbon market policy and corporate OFDI. The results show that China's carbon market policy has led to an increase in corporate OFDI. After comparing the environmental regulatory intensity between China and other countries, we incorporate carbon avoidance–motivated OFDI into the model for further analysis. The results suggest that the increase in corporate OFDI is driven by the desire to avoid carbon–related costs. Our findings remain robust after several robust tests.

The conclusions of this study suggest that China's implementation of the carbon market may have led to some unintended shifts that do not align with the policy's original objectives. Therefore, the findings offer valuable insights for the future improvement of China's carbon market policies. First, the design of environmental regulation policies should place more emphasis on preventing carbon leakage. Secondly, the government should improve the methodology for third–party carbon emission assessments. For example, incorporating the ownership networks of companies into carbon emission calculations could help prevent high–emission companies from evading regulation by relocating production. Finally, the government should increase incentives for corporate green innovation. When reducing carbon emissions through green innovation becomes more profitable, companies will be more inclined to enhance green productivity rather than relocating capital or production abroad.

AUTHOR CONTRIBUTIONS

G. Lin designed the study. Y. Zhang analyzed the data and wrote the paper. R. Tang, L. Yang, B. Qin and M. Yabe participated in the design of the study and supervised the work. Y. Takahashi assisted in editing the manuscript and approved the final version.

ACKNOWLEDGEMENTS

This work is supported by Youth Project of Shanghai Philosophy and Social Science Planning [Grant No. 2021EGL007]. We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

REFERENCES

Albrizio, S., T. Kozluk and V. Zipperer 2017 Environmental policies and productivity growth: Evidence across industries and firms. *J. Environmental Economics and Management*, **81**: 209–226

Cai, X., Y. Zhao, X. Wu, *et al*. 2023 The green halo effect of China's OFDI: Evidence from countries along the Belt and Road. *J. Environ. Sci. Pollut. Res. Int*., **30**(26): 68290–68312

Dong, Y., and B. Chen 2021 Financing constraints, outward foreign direct investment, and corporate R&D expenditure. *J. World Econ. Res*., **325**(03): 121–133

Dou, J., and X. Han 2019 How does industry mobility affect pollution industry transfer in China: Empirical test on Pollution Haven Hypothesis and Porter Hypothesis. *J. Cleaner Prod*., **217**: 105–115

Dong, Y., J. Tian and J. Ye 2021 Environmental regulation and foreign direct investment: Evidence from China's outward FDI. *J. Finance Res. Lett*., **39**: 101611

Gao, Y., M. Li, J. Xue, *et al*. 2020 Evaluation of effectiveness of China's carbon emissions trading scheme in carbon mitigation. *J. Energy Econ*., **90**: 104872

Guo, L. L., Y. Qu, and M. Tseng 2017 The interaction effects of environmental regulation and technological innovation on regional green growth performance. *J. Cleaner Prod*., **162**: 894–902

Galeotti, M., S. Salini, and E. Verdolini 2020 Measuring environmental policy stringency: Approaches, validity, and impact on environmental innovation and energy efficiency. *J. Energy Policy*, **136**: 111052

He, L., and K. Chen 2023 Does China's regional emission trading scheme lead to carbon leakage? Evidence from conglomerates. *J. Energy Policy*, **175**: 113481

Hu, J., Q. Fang, and W. Long 2023 Carbon emission regulation, enterprise emission reduction incentives, and total factor productivity: A natural experiment based on China's carbon emission trading mechanism. *J. Econ. Res*., **58**(04): 77–94

Hu, J., N. Huang, and H. Shen 2020 Can market–based environmental regulation promote enterprise technological innovation? A natural experiment based on China's carbon emission trading mechanism. *J. Financ. Res.*, **475**(01): 171–189

Liu, L., Z. Zhao, M. Zhang, *et al*. 2021 The effects of environmental regulation on outward foreign direct investment's reverse green technology spillover: Crowding out or facilitation? *J.*

Cleaner Prod., **284**: 124689

Ma, G., J. Qin, and Y. Zhang 2023 Does the carbon emissions trading system reduce carbon emissions by promoting two–way FDI in developing countries? Evidence from Chinese listed companies and cities. *J. Energy Econ.*, **120**: 106581

Nasir, M. A., T. L. Duc Huynh, and H. T. Xuan Tram 2019 Role of financial development, economic growth & foreign direct investment in driving climate change: A case of emerging ASEAN. *J. Environ. Manag.*, **242**: 131–141

Pan, X., M. Li, M. Wang, *et al.* 2020 The effects of outward foreign direct investment and reverse technology spillover on China's carbon productivity. *J. Energy Policy*, **145**: 111730

Panhans, M., L. Lavric, and N. Hanley 2017 The Effects of Electricity Costs on Firm Re–Location Decisions: Insights for the Pollution Havens Hypothesis? *J. Environ. Resour. Econ.*, **68**(4): 893–914

Ramanathan, R., Q. He, A. Black, *et al.* 2017 Environmental regulations, innovation and firm performance: A revisit of the Porter hypothesis. *J. Cleaner Prod.*, **155**: 79–92

Verde, S. F. 2020 The Impact of the EU Emissions Trading System on Competitiveness and Carbon Leakage: The Econometric Evidence. *J. Econ. Surv.*, **34**(2): 320–343

Xin, D., and Y. Zhang 2020 Threshold effect of OFDI on China's provincial environmental pollution. *J. Cleaner Prod.*, **258**: 120608

Yu, P., Z. Cai, and Y. Sun 2021 Does the emissions trading system in developing countries accelerate carbon leakage through OFDI? Evidence from China. *J. Energy Econ.*, **101**: 105397

Yang, T., Q. Dong, Q. Du, *et al.* 2021 Carbon dioxide emissions and Chinese OFDI: From the perspective of carbon neutrality targets and environmental management of home country. *J. Environ. Manag.*, **295**: 113120

Yirong, Q. 2022 Does environmental policy stringency reduce CO2 emissions? Evidence from high–polluted economies. *J. Cleaner Prod.*, **341**: 130648

Zhang, Z., Y. Zhao, H. Cai, *et al.* 2023 Influence of renewable energy infrastructure, Chinese outward FDI, and technical efficiency on ecological sustainability in Belt and Road node economies. *J. Renewable Energy*, **205**: 608–616