

Do Carbon Markets Create Jobs? Evidence from China's Regulated Listed Enterprises

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Abstract

The coordinated development of the economy, environment, and people's livelihood is fundamental to sustainable national progress. The carbon emissions trading policy (CET), a market-based instrument for environmental governance, is crucial to emission reduction and green transformation. Therefore, it is vital to investigate how it affects employment, which determines whether ecological preservation and full employment can be accomplished simultaneously. Using panel data of A-share listed companies in Shanghai and Shenzhen from 2011 to 2023, this study employs a multi-period difference-in-differences (DID) model to examine whether China's carbon trading market generates an "employment dividend". The findings demonstrate that CET considerably boosts employment among pilot enterprises, with an average increase of almost 21.9%, as compared to non-pilot firms. The conclusion is supported by a range of robustness tests, such as PSM-DID, staggered DID, two-stage DID, and placebo tests. Mechanism analysis reveals that the policy boosts employment by encouraging company innovation, but total factor productivity exert a negative impact due to labor-substitution effects. Moreover, provincial green finance development significantly strengthens the positive employment effect. Heterogeneity analysis further indicates that the policy impact is more pronounced among small firms, manufacturing enterprises, competitive industries, and capital- or technology-intensive sectors, with more significant effects observed in eastern regions compared to central and western regions. By integrating carbon markets and employment into a unified analytical framework, this study provides empirical evidence and policy insights for achieving carbon neutrality alongside high-quality employment growth.

Keywords

Carbon Emissions Trading; Employment; Multi-period DID; Innovation; Total Factor Productivity; Green Finance.

1. Introduction

Climate change has intensified environmental risks and triggered a global commitment to curbing greenhouse gas (GHG) emissions [1, 2]. The carbon emissions trading scheme (CET) designates greenhouse gas environmental capacity as a limited resource by establishing property rights and internalizing the external costs of emissions, thereby achieving GHG emission reduction and optimal resource allocation within the market framework [3]. China, the world's foremost carbon emitter, is committed to reaching carbon peaking by 2030 and obtaining carbon neutrality by 2060 [4, 5]. As a crucial instrument in achieving the "dual control of carbon emissions", China has initiated pilot programs for carbon trading across several regions since 2013, including Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Hubei Province, and Shenzhen [6]. The national carbon market was formally launched in 2021, initially encompassing the electricity sector, which accounts for around 40% of domestic emissions,

thereby establishing itself as the largest carbon market globally [7]. Employment is a cornerstone of stability, and in China-with its population of 1.4 billion-it represents the most significant livelihood issue [8]. Theoretically, carbon markets may influence employment through two opposing mechanisms. Rising carbon costs and stricter regulations may elevate production expenses, decrease output, and lead to job losses, particularly in carbon-intensive sectors [9, 10, 11]. Conversely, carbon pricing has the potential to promote green innovation, enhance industrial upgrading, and attract investment in clean production, ultimately generating new job opportunities in emerging sectors like renewable energy and low-carbon manufacturing [12]. These dynamics suggest that the effects of CET on employment may be structural: short-term job losses may occur, while labour reabsorption could be realized through a green transformation in the medium to long term. Against this backdrop, this study addresses the following questions: Does CET significantly affect firm-level employment? Are these effects driven by firms' technological upgrading and efficiency improvements and conditioned by regional green finance development? Finally, are there heterogeneous effects across different types of enterprises and regions?

There are three main contributions to this paper. First, it improves identification accuracy by using actual emission-regulated firms rather than firms located in pilot provinces, avoiding potential misclassification. Second, it examines the employment effect of carbon trading through firm-level mechanisms-specifically innovation and productivity-providing new micro-level evidence. Third, it explores the moderating role of green finance and the heterogeneity across firms and regions, offering targeted policy implications for aligning environmental regulation with employment stability.

2. Literature Review

The carbon emissions scheme has been extensively implemented globally as a primary policy instrument for controlling GHG emissions. A substantial body of research indicates that CET can harmonize environmental and economic goals [13, 14]. Cap-and-trade systems have proven effective in reducing pollution levels [15] and improving air quality when implemented alongside supportive policies [16]. Using provincial-level panel data, Dong et al. [17] and Tian et al. [18] further confirm that CET significantly reduces both total carbon emissions and emission intensity. Moreover, Liu et al. [19], using the TermCO₂ model, find that CET in Hubei effectively reduced emissions by approximately 10%, with only a modest negative impact on GDP.

At the micro level, some scholars have examined how CET influences firm behavior. Zhou and Wang [20] contended that the internalization of carbon prices motivates firms to increase their investments in green R&D, hence corroborating the Porter hypothesis. Wu and Wang [21] found a significant positive correlation between increasing carbon prices and total factor productivity (TFP). They predicted that if China's carbon pricing reached the level of the EU ETS, firm-level TFP would rise by approximately 22.73%. Oestreich and Tsiakas [9] proposed that the distribution of free allowances could improve enterprises' financial stability. Nonetheless, several studies have also emphasized the potential detrimental consequences of CET. Lyu et al. [22] noted that policy uncertainty during the early implementation phase may hinder corporate innovation. Clarkson et al. [23] contended that expenditures associated with environmental compliance could diminish long-term corporate value. Furthermore, Ma et al. [24] found that CET indirectly increases labour expenses by enhancing the human capital structure within organizations.

Carbon trading has increasingly drawn scholarly attention for its potential labour market effects. In terms of employment scale, most studies suggest that CET exhibits a pattern of short-term suppression but long-term promotion through mechanisms such as production upgrading

and green transformation [25]. According to Cui et al. [26], employment across enterprises decreased by around 6.6% during the quota allocation phase, and this decline further expanded to 11.8% in the trading phase. Yang et al. [27] show with provincial data that China's CET yields an employment dividend and supports the Porter effect. Studies by Yu and Li [28], taking a spatial spillover perspective, suggest that carbon trading pilots have generated net job growth, with effects intensifying over time. Moreover, Peng et al. [29] find that quota allocation methods influence employment outcomes-benchmarking provides stronger incentives for green job creation than historical allocation. Conversely, Cui et al. [26] report a decline in employment during both the quota allocation and trading stages. At the industry level, sectors such as mining and energy-intensive manufacturing face significant contraction in labour demand [30], whereas low-carbon and service industries tend to benefit. Additionally, Qiang et al. [31] examined the relationship between carbon price levels and employment, revealing an inverted U-shaped relationship: moderate carbon prices enhance employment, whereas extremely high costs may hinder it. Internationally, drawing on evidence from the EU and Quebec, Dechezleprêtre et al. [33] and Hanoteau and Talbot [32] provide consistent evidence that carbon markets can reduce emissions without negatively impacting employment or firm-level economic performance. Spatially, CGE simulations suggest that regions with lower carbon prices may experience job growth while others face the risk of job loss [34].

Regarding employment structure, carbon trading facilitates labour reallocation from high-carbon industries to low-carbon sectors or green services. Bu et al. [35] point out that while some employment in high-emission industries contracts, new green jobs are gradually emerging. The policy also reshapes the skill structure of employment, as firms tend to substitute energy and low-skilled labor with capital and high-skilled workers, thereby exacerbating skill inequality [36].

Overall, a well-designed carbon market mechanism, supported by complementary policies, can help achieve both emission reduction and improvement in employment quality. However, existing studies often suffer from coarse data granularity, inaccurate identification of regulated firms, and simplified empirical strategies, limiting the precision of policy evaluation. In addition, the firm-level mechanisms through which CET affects employment remain underexplored, and the moderating role of external institutional conditions is rarely addressed. To fill these gaps, this study utilizes micro-level data on verified emission-regulated enterprises and applies a multi-period DID model to systematically assess the employment effects of carbon trading and its underlying mechanisms.

3. Research Design

3.1. Theoretical Framework

This paper builds upon the Partial Static Equilibrium Model (PSEM) established by Berman and Bui [37], incorporating CET into firms' production decision frameworks to analyze its impact on employment. The compliance costs related to the carbon market-such as abatement investments and pollution control expenditures-are classified as quasi-fixed inputs influenced by institutional variables. At the same time, labour, raw materials, and capital are considered variable production inputs. In a perfectly competitive market, firms allocate their inputs to minimize total costs. The variable cost function is represented as:

$$CV = F(Y, P_L, Z) \quad (1)$$

Where CV represents the variable cost, Y is output, P_L is the price of labour, and Z denotes environmental compliance costs. According to Shephard's lemma, the firm's labor demand function can be derived as:

$$L = \alpha Y^\rho P_L^\gamma Z^\beta \quad (2)$$

In Equation (2), the parameter β elucidates the correlation between environmental compliance costs and labour input, determining whether they function as replacements or complements. Letting R represent the carbon trading scheme, the first-order derivative of labour demand L for R is given by:

$$\frac{dL}{dR} = \frac{\partial L}{\partial Y} \cdot \frac{dY}{dR} + \frac{\partial L}{\partial P_L} \cdot \frac{dP_L}{dR} + \frac{\partial L}{\partial Z} \cdot \frac{dZ}{dR} \quad (3)$$

This framework reveals that CET impacts labour demand through three distinct mechanisms:

(1) Output Effect: CET may impact businesses' output (Y) and subsequently change labour input (L). If the regulation substantially increases compliance costs, firms may opt to reduce production capacity or halt operations to avoid expenses, leading to decreased output ($dY/dR < 0$) and constrained labour demand [23]. Conversely, if the policy encourages enterprises to pursue technical innovation and resource efficiency, it may result in output growth ($dY/dR > 0$), thereby augmenting labour demand. Some firms may enhance their production capacity through innovation, leading to the "innovation compensation" effect, which further promotes employment [38, 51].

(2) Price Effect: If the input factor markets are sufficiently competitive, the CET policy is unlikely to influence input prices ($dP_L/dR \approx 0$).

(3) Input Substitution Effect: Existing studies widely suggest that carbon trading increases firms' environmental compliance costs ($dZ/dR > 0$), prompting a reallocation of inputs between labour and capital. Suppose compliance efforts are capital-intensive, such as through the setup of automated pollution control systems. In that case, corporations may decrease their reliance on labour, thereby suppressing employment ($\beta < 0$), indicative of a substitution effect. Conversely, if compliance processes require substantial human input—such as equipment operation and maintenance or environmental monitoring—firms may increase labour demand, reflecting a complementarity effect ($\beta > 0$) [39].

Drawing upon the preceding model estimation, the impact of CET on employment is primarily shaped by the trade-off between output variations and input substitution responses [40]. Given the advancing maturity of China's carbon market, the rapid green transformation among enterprises, the constrained technological advancements in high-carbon industries, and the labour-intensive nature of environmental compliance activities, CET is likely to have a positive impact on employment. While advancements in TFP indicate increased operational efficiency, they may result in worker displacement in practice. In high-carbon industries, TFP gains are often achieved through capital substitution for labour—such as automation and process optimisation—rather than through labour-creating innovations. Conversely, in the face of carbon limits, some firms enhance their technical innovation capabilities to improve output and product value, thereby broadening their business operations and generating employment. This illustrates the phenomenon known as the "innovation compensation" effect. This study posits the following hypotheses:

H1: Carbon trading significantly increases employment in regulated enterprises.

H2a: Carbon trading suppresses employment by increasing firms' total factor productivity.

H2b: Carbon trading promotes employment by enhancing firms' innovation capacity.

3.2. Data and Sample

This study utilizes data from A-share listed firms in Shanghai and Shenzhen from 2011 to 2023. Based on the list from CSMAR, we identify and retain firms that are officially included in CET and construct treatment and control groups by tracing the year of their initial inclusion. Employment data are obtained from the Wind database, while other firm-level indicators are sourced from CSMAR. The provincial-level green finance development index is calculated using data from the National Bureau of Statistics. To ensure data quality, we exclude ST, *ST firms, those listed after 2013, firms with fewer than three years of observations, and those with substantial changes in industry classification. Observations with missing key variables are removed, and all continuous variables are winsorized at the 1% level. The final unbalanced panel dataset includes 161 regulated firms and 1,701 unregulated firms, totalling 21,933 observations.

3.3. Variables

(1) Dependent variable (Employee)

Firm labor demand is quantified by the total annual number of employees. To alleviate the impact of scale effects, the natural logarithm of the employment variable is used in the analysis.

(2) Independent variable (did)

The primary explanatory factor (did) is the participation of companies within the carbon trading scheme. Specifically, the key DID_{it} interaction term, defined as $DID_{it} = treatment_i \times post_{it}$, captures the average treatment effect of the carbon trading policy on firm-level employment. Here, $Treatment_i$ identifies whether the firm is treatment group, taking a value of 1 if the firm is classified as an emission-control enterprise and 0 otherwise. $Post_{it}$ denotes the policy implementation period, taking a value of 1 for years that are equal to or after the firm's initial inclusion in the carbon market and 0 otherwise.

(3) Mediator Variables

This study measures firms' total factor productivity (TFP) using the Olley-Pakes (OP) method. Under environmental regulation, firms face dual pressures of resource reallocation and operational efficiency improvement. TFP provides a comprehensive measure of efficiency, capturing both technological advancement and factor utilization [41]. To reduce compliance costs, firms typically increase investment in green or low-carbon technologies, thereby enhancing their innovation capacity. The number of patents granted is used as a proxy for firm-level innovation (INNO).

(4) Moderating variable (GFI)

A higher level of green finance development provides firms with stronger financial support, helping to mitigate the transitional costs associated with carbon trading. It fosters low-carbon technological innovation and facilitates industrial upgrading [42]. The measurement approach follows established methodologies [43] and is constructed using seven primary indicators: green credit, green investment, green insurance, green bonds, green fiscal support, green funds, and green equity.

(5) Control Variables

Referencing the studies of Wang et al. [25] and Yu & Li [28], key factors include firm scale (Size), firm age (Age), gearing ratio (Lev), profitability (ROA), employee wage level (Wage), fixed asset ratio (Fixed), cash flow ratio (Cashflow) and investment potential (TibinQ). Due to space constraints, variable definitions and calculations are available from the authors.

3.4. Model Design

Given the staggered adoption of CET across provinces-starting with Beijing, Shanghai, Tianjin, and Guangdong in 2013, followed by Chongqing and Hubei in 2014, Fujian in 2016, and most others after 2021-this study adopts a multi-period DID model with two-way fixed effects, following Bertrand et al. [44], to identify the policy effect. The model is specified as follows:

$$\text{Employee}_{it} = \beta_0 + \beta_1 \text{did}_{it} + \beta_x \text{control}_{it} + u_{it} + \lambda_t + \epsilon_{it} \quad (4)$$

In Equation (4), Employee_{it} denotes the natural logarithm of the number of employees in firm i during year t . The key explanatory variable, did_{it} , takes the value of 1 if firm i is a regulated enterprise under the CET and the policy is in effect in year t , and 0 otherwise. The coefficient of interest, β_1 , captures the net impact of the CET on firm-level employment. A vector of control_{it} variables is included to account for firm-specific characteristics that may affect employment. Year fixed effects (λ_t) are introduced to control for time-varying shocks that affect all firms uniformly, while firm fixed effects (u_{it}) account for time-invariant unobserved heterogeneity across firms. And ϵ_{it} represents a randomized disturbance term. Descriptive statistics are reported in Table 1.

Table 1. Descriptive Statistics

Variables	N	Mean	Std.Dev.	Min	Median	Max
Employee	21933	7.922	1.255	4.997	7.854	11.313
did	21933	0.052	0.222	0.000	0.000	1.000
TFP	21933	6.931	0.911	5.100	6.832	9.432
INNO	21933	1.478	1.565	0.000	1.099	6.038
GFI	21933	0.384	0.100	0.099	0.394	0.632
Size	21933	22.497	1.330	20.056	22.325	26.440
Age	21933	2.968	0.329	1.946	2.996	3.611
Lev	21933	0.440	0.205	0.054	0.435	0.894
Wage	21933	9.513	1.103	5.627	9.621	11.929
SOE	21933	0.442	0.497	0.000	0.000	1.000
Fixed	21933	0.222	0.160	0.002	0.190	0.691
Board	21933	2.144	0.195	1.609	2.197	2.708
CashFlow	21933	0.046	0.066	-0.149	0.045	0.232
TobinQ	21933	1.928	1.207	0.820	1.526	7.726

4. Results and Discussions

4.1. Baseline Model

Table 2 reports the impact of CET on enterprise employment. Columns (1) to (4) progressively incorporate control variables and fixed effects. Across specifications, CET exhibits a significantly positive effect on employment. Specifically, the DID coefficient in Column (4) is 0.198, significant at the 1% level, indicating that, ceteris paribus, firms participating in the carbon market experience an average increase in total employment of approximately 21.9% ($\exp(0.198)-1$) compared to non-participating firms. This finding suggests that CET has generally promoted employment expansion in regulated enterprises.

4.2. Robustness Checks

4.2.1. Parallel Trend Test

To address potential biases arising from the non-random assignment of the pilot policy and significant differences in firm characteristics, this study conducts a parallel trend test [46]. An event-study model is constructed using a series of time dummy variables, with the year before CET implementation set as the reference period. The data from the six years preceding and succeeding the policy are categorized into boundary intervals. The parallel trends test model is specified as follows:

$$Employee_{it} = \beta_0 + \sum_{k=-6, k!=-1}^{k=6} \beta_k D_{it}^k + \beta_x control_{it} + u_{it} + \lambda_t + \epsilon_{it} \quad (5)$$

In Equation (5), where D_{it}^k is a set of event-time dummies, with $k < 0$ indicating years before CET and $k > 0$ indicating years after. Each coefficient β_k captures the change in firm-level employment between the treatment and control groups in the k -th year relative to the baseline. Other variables are defined as in Equation (1).

Table 2. DID Results

Variables	Employee	Employee	Employee	Employee
	(1)	(2)	(3)	(4)
did	0.998*** (0.096)	0.444*** (0.085)	0.185*** (0.067)	0.198*** (0.067)
Size		0.719*** (0.017)	0.645*** (0.018)	0.657*** (0.019)
Age		-0.237*** (0.046)	-0.190*** (0.044)	0.356*** (0.105)
Lev		-0.003 (0.087)	0.327*** (0.062)	0.280*** (0.063)
Wage		-0.193*** (0.016)	-0.149*** (0.013)	-0.140*** (0.013)
SOE		-0.007 (0.037)	0.046 (0.033)	0.051 (0.033)
Fixed		0.745*** (0.123)	0.524*** (0.082)	0.497*** (0.083)
Board		0.238*** (0.079)	0.017 (0.040)	0.012 (0.040)
CashFlow		1.821*** (0.156)	0.167** (0.067)	0.140** (0.066)
TobinQ		0.055*** (0.010)	0.020*** (0.004)	0.019*** (0.006)
_cons	7.870*** (0.028)	-6.607*** (0.381)	-4.973*** (0.331)	-6.921*** (0.506)
Firm FE	No	No	Yes	Yes
Year FE	No	No	No	Yes
r2_a	0.0311	0.5918	0.9231	0.9239
N	21933	21933	21933	21933

Notes: Standard errors clustered at the firm-level are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The following tables are annotated as in Table 2.

The relevant outcomes are depicted in Figure 1. During the pre-treatment period ($t \leq -1$), the estimated coefficients fluctuate around zero, and the 95% confidence intervals include zero across all periods. This indicates no systematic differences in employment trends between the treatment and control groups before the policy intervention, thereby supporting the validity of the parallel trends assumption. In contrast, in the post-treatment period ($t \geq 0$), the coefficients increase significantly, and in the majority of years, the confidence intervals exclude zero. This indicates that CET has greatly facilitated employment growth among enterprises, aligning with the results from the baseline regression.

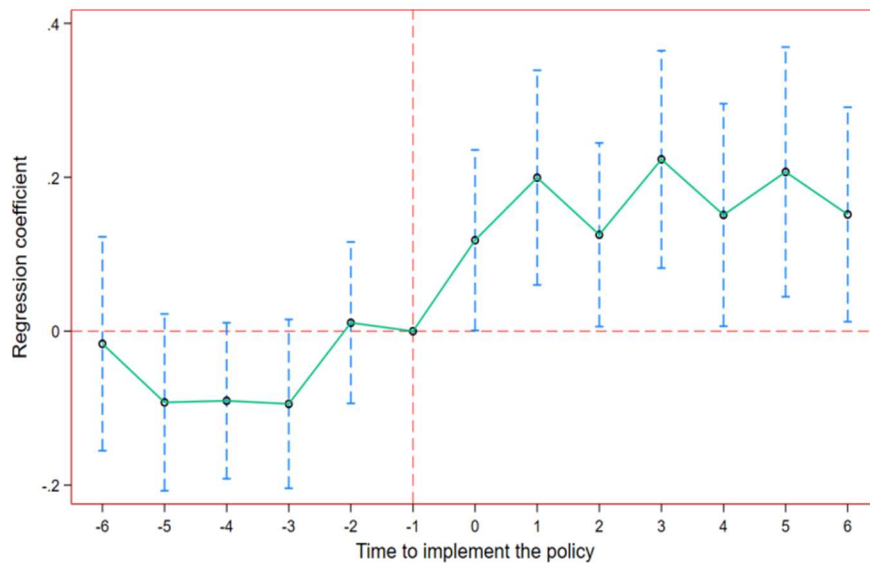


Figure 1. The Parallel Trend Test

4.2.2. Placebo Test

This study conducts a placebo test to mitigate potential bias stemming from unobserved confounding factors. Specifically, a random subset of enterprises is designated as pseudo-treatment firms, and policy implementation years are randomly reassigned to provinces, following the methodology of Irfan et al. [45]. Based on 500 simulations, the computed coefficients are centred near zero, predominantly statistically insignificant, and approximately normally distributed. As illustrated in Figure 2, the actual policy effect lies in the far right tail of the distribution, suggesting that the observed effect is unlikely to be driven by random shocks, unobserved factors, or model misspecification.

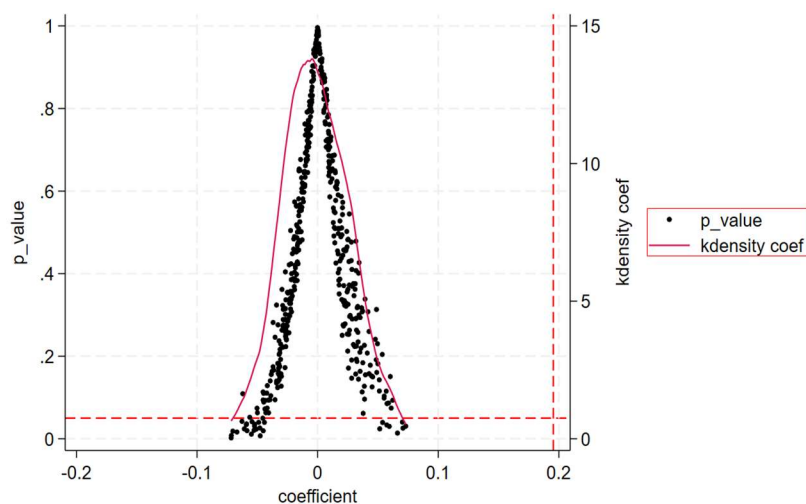


Figure 2. The Placebo Test

4.2.3. Narrowing the Sample Scope

To further substantiate the baseline estimation, robustness tests are implemented by narrowing the sample scope. Column (1) of Table 3 excludes enterprises participating in the national carbon market, retaining only those in regional pilots. The DID coefficient of 0.162 passes the 5% significance threshold, reaffirming the policy's employment effect. Column (2) removes post-pandemic observations to control for the COVID-19 impact, yielding a similar estimate of 0.160. This indicates that, even when considering anticipated disruptions from the pandemic on enterprises' operations and labour demand, the CET policy continues to exert a stable and favourable influence on employment.

4.2.4. Alternative DID Specification

This study additionally evaluates robustness by redefining the DID treatment variable. The baseline identifies treated firms through direct participation in the carbon market. In contrast, an alternative specification classifies all firms within the eight pilot provinces as treated, so capturing potential spillover and demonstration effects. Under this broader definition, the DID coefficient remains positive and statistically significant (0.0788), as shown in Column (3) of Table 3. These results indicate that the positive employment effect of CET persists even when treatment is defined at the provincial level.

Table 3. Robustness Test Results I

Variables	Change Sample Interval		Alternative DID
	Exclude National CET	Exclude Post-Pandemic Years	
	(1)	(2)	
did	0.162** (0.070)	0.160** (0.071)	0.078*** (0.022)
_cons	-6.855*** (0.533)	-6.754*** (0.547)	-6.950*** (0.506)
Control	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
r2_a	0.9338	0.9368	0.9236
N	16,986	15,372	21,933

4.2.5. Eliminate Other Policy Interference

During the sample period, the employment effect of CET may have been influenced by other overlapping policy interventions, notably the NDRC's low-carbon pilot program initiated in 2010 and the State Council's air pollution control policy introduced in 2013 [46]. To mitigate this issue, the study integrates two policy dummy variables into the regression analysis. The first dummy (did1) identifies firms located in low-carbon pilot cities during their active years, while the second dummy (did2) captures firms exposed to the national air pollution control strategy. These factors are incorporated individually to isolate their possible confounding influences. According to Table 4, the incorporation of did1 and did2 does not significantly modify the predicted effect of CET. The DID coefficients remain consistent, signifying that concurrent environmental policies do not drive the observed employment effects.

4.2.6. Lagged Controls

To further alleviate potential endogeneity concerns and avoid possible reverse causality between dependent and control variables within the current period, this study incorporates one-period-lagged control variables into the model. Column (3) of Table 4 shows a DID coefficient of 0.211, which remains significant at the 1% level and consistent with the baseline results.

Table 4. Robustness Test Results II

Variables	Eliminate Other Policy Interference		Controlling for Lagged Controls
	Low-Carbon City	Air Pollution Control	
	(1)	(2)	(3)
did	0.195*** (0.0687)	0.194*** (0.0687)	0.213*** (0.0672)
did1	0.00183 (0.0194)		
did2		0.0310** (0.0131)	
_cons	-6.983*** (0.535)	-6.968*** (0.535)	-6.053*** (0.496)
Control	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
r2_a	0.9257	0.9257	0.9211
N	19667	19667	19300

4.2.7. Propensity Score Matching (PSM)

To further mitigate sample selection bias, this study adopts a PSM-DID approach, employing nearest neighbour matching (1:1 without replacement, calliper = 0.05), radius matching (calliper = 0.01), and kernel matching. Propensity scores are calculated via a logit model based on firm-level control variables as covariates and DID regressions are performed on the matched samples. Table 5 demonstrates that the DID coefficients maintain a considerably positive value at the 1% level throughout both matching methodologies. The results align with the baseline, supporting the policy's substantial beneficial effect on employment.

Table 5. PSM-DID

Variables	PSM-DID		
	nn1	radius	kernel
	(1)	(2)	(3)
did	0.160*** (0.060)	0.159*** (0.058)	0.159*** (0.058)
_cons	-6.949*** (0.505)	-3.186*** (1.234)	-3.188*** (1.234)
Control	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
r2_a	0.9236	0.8381	0.8381
N	21,933	21,868	21,880

4.2.8. Two-Stage DID

Drawing on Gardner [47], this study uses a Two-stage DID approach to identify the heterogeneous effects of the policy intervention. The first stage removes group and time fixed effects, while the second stage assesses the treatment effects, thereby facilitating a more rigorous identification of the average treatment effects across different subgroups-especially appropriate for staggered policy implementations. The DID coefficient of 0.189 ($p < 0.01$) reported in Column (1) of Table 6 indicates that the beneficial effect of CET on employment remains, hence affirming the credibility of the empirical results.

Table 6. Robustness Test Results III

Variables	Two-Stage DID	CSDID	
		driwp	reg
	(1)	(2)	(3)
did	0.189***	0.217**	0.201*
	(0.073)	(0.107)	(0.107)
Control	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

4.2.9. Staggered DID (CSDID)

This work adopts the group-time average treatment effect estimator developed by Callaway and Sant’Anna [48] to address potential estimation bias and reversed causal inference resulting from non-random policy timing in MP-DID settings [49]. Two estimation approaches are utilised: the doubly robust estimator (dripw) and the regression-based method (reg). The last two columns in Table 4.7 validate the strong favourable effect of CET on employment through various DID methodologies, even with staggered treatment timings.

5. Further Analysis

5.1. Mechanism Analysis

Table 7. Mediation and Moderation Analysis

Variables	Mediating				Moderating
	TFP	Employee	INNO	Employee	Employee
	(1)	(2)	(3)	(4)	(5)
did	0.080***	0.216***	0.147**	0.195***	0.167***
	(0.025)	(0.067)	(0.073)	(0.068)	(0.062)
TFP		-0.226***			
		(0.023)			
INNO				0.022***	
				(0.005)	
GFI					0.583*
					(0.329)
did_GFI					0.729**
					(0.316)
_cons	-4.237***	-7.880***	0.083	-6.923***	-6.934***
	(0.410)	(0.499)	(1.022)	(0.504)	(0.506)
Control	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Sobel test	-0.0181 (0.0036)		0.0032 (0.0010)		
Bootstrap test (ind_eff)	-0.0181 (0.0034)		0.0032 (0.0010)		
r2_a	0.8950	0.9267	0.7619	0.9240	0.9240
N	21933	21933	21933	21933	21933

This study introduces total factor productivity (TFP) and innovation capability (INNO) as mediating variables. Table 7 reports all the relevant results. The results indicate that CET significantly enhances TFP. However, the effect of TFP on employment is negative, suggesting that efficiency gains may trigger labour-saving technologies and organizational restructuring,

thereby weakening the policy's employment-promoting impact. That said, TFP may also generate demand for skilled labour through technology-induced job creation, partially offsetting its crowding-out effect. In contrast, CET markedly stimulates firms' innovation efforts, and INNO exerts a positive influence on employment, indicating that innovation may enable firms to expand production capacity and explore new business opportunities, thus increasing labour demand. Both Sobel and bootstrap tests confirm the statistical significance of these two mediating pathways. Overall, TFP exhibits a "suppressing" mediation effect, whereas INNO reflects a "facilitating" mechanism, underscoring the dual tension and balance between efficiency and employment during CET-driven green transformation.

5.2. Moderating Effect Analysis

This study incorporates the Green Finance Index (GFI) as a moderating variable in Column (5) of Table 7. The analysis reveals that GFI not only promotes employment directly but also significantly moderates the link between CET and employment. The interaction term (*did_GFI*) is positive and significant (0.729, $p < 0.05$), indicating an amplifying effect of GFI. In regions or enterprises with more advanced green financing, the employment-enhancing impact of CET is more pronounced, underscoring a notable synergy between carbon markets and green finance.

5.3. Heterogeneity Analysis

5.3.1. Heterogeneity based on Firm Size

Columns (1) to (3) of Table 8 illustrate the varied impacts of CET among enterprises of differing sizes. The strategy greatly enhances employment in small enterprises, although its impact on medium and large firms is positive yet insignificant. This suggests that small firms are more responsive to CET, likely due to their greater flexibility and quicker adaptation to market dynamics. By actively engaging in carbon trading, small firms may expand production and drive job creation.

5.3.2. Heterogeneity based on Industry Competition

Following Ke et al. [50], firms are categorised into competitive and regulated industries. This classification is based on the notion that firms in competitive markets encounter heightened market pressures and exhibit greater responsiveness to policy signals. In contrast, regulated firms typically operate under more lenient budget constraints or policy safeguards, which may diminish their motivation to adjust production or employment in response to CET. Columns (4) and (5) of Table 8 substantiate this point.

5.3.3. Heterogeneity based on Manufacturing

Table 8. Heterogeneity Analysis I

Variables	Firm Size			Competition		Manufacturing	
	Small	Medium	Big	Competitive	Regulated	Mfg.	Non-Mfg.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>did</i>	1.261***	0.009	0.019	0.197**	0.199	0.182***	0.348
	(0.318)	(0.056)	(0.042)	(0.077)	(0.147)	(0.0641)	(0.249)
<i>_cons</i>	-8.163***	-6.315***	-5.693***	-7.499***	-5.004***	-7.748***	-5.267***
	(0.949)	(0.932)	(0.916)	(0.541)	(1.141)	(0.534)	(1.046)
Control	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES
<i>r2_a</i>	0.8147	0.8877	0.9405	0.9120	0.9458	0.9185	0.9341
<i>N</i>	7165	7135	7392	16004	5806	15017	6874

Table 8 explores the heterogeneous effects of CET within the Manufacturing sector. Column (6) shows that CET considerably improves employment in manufacturing enterprises, but its impact on non-manufacturing firms, as presented in Column (7), is statistically insignificant. This discrepancy likely arises from the imposition of stricter environmental regulations on industrial businesses, which also hold heightened duties for emission reductions. These pressures could prompt companies to invest in cleaner technology and increase production, thereby enhancing employment opportunities.

5.3.4. Heterogeneity based on Firms' Factor Intensity

According to the industry classification technique outlined in the 2012 CSRC guidelines, this study categorises all sample firms by factor intensity. Table 5.3 presents the regression results in the initial three columns. CET significantly increases employment in capital-intensive and technology-intensive firms, indicating that organisations with superior financial and technological resources are more adept at adapting to carbon trading. Capital-intensive enterprises with abundant financial resources can more efficiently manage the costs of emissions reduction. The introduction of CET has diminished high-energy, obsolete capacity, while technology-intensive enterprises might exploit their technological advantages to secure a greater market share. Conversely, labour-intensive enterprises that depend on cheap labour face greater cost pressures from carbon quotas. As a result, these firms may reduce capacity or lay off workers, as the financial burden outweighs the incentives provided by CET.

5.3.5. Heterogeneity based on Region

Columns (4) and (5) of Table 9 reveal regional heterogeneity. CET boosts employment exclusively in the eastern region. This suggests that firms in the East, which benefit from stronger economic and technological infrastructures, exhibit greater responsiveness to carbon market incentives. In contrast, the constrained resources and limited governmental backing in the middle and Western regions diminish the efficacy of the CET policy. The findings correspond with the analysis in Section 5.2, indicating that the higher degree of GFI in the eastern region enables enterprises to utilise green financial instruments and policy support more effectively, thereby enhancing the impact of the CET policy. These findings underscore the necessity for region-specific assistance to facilitate the inclusive advancement of the carbon market.

Table 9. Heterogeneity Analysis II

Variables	Factor Intensity			Region	
	Labor	Capital	Technology	East	Mid-West
	(1)	(2)	(3)	(4)	(5)
did	0.187	0.216**	0.226**	0.247***	0.0709
	(0.154)	(0.087)	(0.109)	(0.0895)	(0.0734)
_cons	-4.619***	-7.388***	-8.714***	-6.046***	-8.698***
	(0.964)	(0.572)	(0.678)	(0.655)	(0.716)
Control	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
r2_a	0.9407	0.9285	0.9228	0.9185	0.9412
N	7783	17535	9527	14891	7038

6. Conclusion and Policy Implications

6.1. Conclusion

While implementing CET, governments and corporations encounter a critical challenge: how to prevent "carbon reduction" from becoming "job reduction". The resolution of this issue directly affects the policy's social acceptance and long-term sustainability. This study employs the pilot CET as a quasi-natural experiment, analyzing data from A-share listed companies in Shanghai and Shenzhen covering the period from 2011 to 2023. It utilizes a multi-period DID methodology to investigate employment effects and transmission mechanisms of CET. The findings for this study are:

(1) The carbon market has not adversely affected firms' employment levels; instead, it has substantially increased the labor demand of participating enterprises. Compared to non-participating enterprises, those engaged in the carbon market experienced an average employment scale growth of around 21.9%. This result remains robust after a series of robustness tests. These findings suggest that CET has generated substantial "employment dividends", with the "substitution effect" driven by technological upgrading and green investment outweighing the potential adverse "output effect".

(2) The mechanism analysis reveals that CET affects employment by TFP and INNO. TFP exerts a negative impact on employment, suggesting that firms can improve efficiency and reduce emissions through technological advancements, which may involve labour-saving adjustments such as automation, thereby weakening employment expansion. In contrast, innovation activities increase firms' demand for human capital. These two mediation paths reflect a dual mechanism of "efficiency suppression" and "innovation promotion," generating offsetting effects on employment and highlighting the structural nature of the policy's impact. Similarly, the moderation analysis further shows that the employment effect of CET is approximately 72.9% higher in financially developed regions than in less developed ones.

(3) The employment-promoting effect of CET demonstrates structural heterogeneity. The policy benefits are primarily observed among small enterprises, which exhibit greater flexibility in transformation and heightened responsiveness to policy signals. Manufacturing firms demonstrate stronger employment growth than non-manufacturing sectors, which experience a more constrained impact. Along the dimension of market competition, employment gains are larger in competitive industries, underscoring the essential function of market mechanisms in labor resource allocation. Capital-intensive and technology-intensive enterprises benefit more substantially from factor intensity, whereas labor-intensive industries show weaker responses. The policy effect is more pronounced in eastern China, which capitalizes on its financial and industrial strengths, while the central and western regions still require further supportive policies to get the advantages of the carbon market fully.

6.2. Policy Implications

Based on the empirical findings, this study offers the following policy recommendations:

(1) The government must persist in promoting the advancement of CET to realise its potential "employment dividend" fully. Under the dual-carbon policy, the scope of the carbon market should be progressively broadened according to the emission characteristics and reduction capabilities of different industries. This strategy prevents sudden, uniform implementation that may lead to irrational capacity cutbacks and job losses. Simultaneously, greater emphasis should be placed on policy stability and expectation management to enhance firms' adaptability to carbon market regulations and strengthen their confidence in low-carbon transformation. This would provide a more stable institutional environment for both green transition and sustained employment.

(2) The government should remain alert to the risk of structural unemployment arising from efficiency gains. Establishing early-warning systems for job displacement and enhancing reskilling and workforce transition programs might alleviate immediate labour market disruptions. As the green transition progresses, it is imperative to augment policy incentives and fiscal support for enterprise-level innovation, encouraging firms to invest carbon revenues in R&D and the development of high-skilled human capital, thus unlocking the inherent potential of innovation-driven employment growth. Enhancing regional green financing systems is crucial, especially in underdeveloped regions. Measures such as the introduction of green credit schemes, carbon funds, and carbon-related financial derivatives can expand access to low-cost financing, improve firms' capacity to participate in the carbon market and enhance their resilience-ultimately amplifying the employment and economic benefits of the carbon trading system.

(3) It is crucial to consider firm-specific and regional variability and to avoid uniform rules. Tailored support measures such as sector- or firm-specific strategies should be considered. Given that manufacturing, capital-intensive, and technology-intensive firms benefit more from carbon trading, their green transition should be prioritized. For labour-intensive and regulated industries, promoting energy-saving technologies, green supply chains, and workforce reskilling can help reduce transition costs and maintain employment. As the policy's effects remain concentrated in eastern regions, greater support is needed in central and western areas. Region-specific policies should be introduced to strengthen carbon market development, industrial upgrading, and green finance in lagging regions, ensuring balanced and effective nationwide implementation.

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