Analysis of the carbon emission reduction mechanism in the textile industry under the dual control of carbon emissions and carbon trading prices

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ABSTRACT – REZUMAT

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Abstract: The textile industry, as a high-energy consumption and high-emission traditional sector, faces significant challenges in its emission reduction efforts. This paper, based on the dual control targets for carbon emissions, employs a panel regression model to empirically examine the impact of carbon trading prices in China's pilot carbon markets on carbon emissions and carbon emission intensity in the textile industry. The paper also explores the role of energy structure and energy efficiency in this process through a mediation effect model. The findings reveal that carbon trading prices have a significant negative impact on carbon emission intensity in the textile industry, with every 1% rise in carbon trading prices leading to a 0.005% drop in carbon emission intensity, while their effect on overall carbon emissions is comparatively weaker. Further analysis indicates that energy efficiency plays a fully mediating role in promoting carbon emission reductions, whereas adjustments to the energy structure have only a partial mediating effect. The study suggests that there should be substantial development of carbon trading markets, improvement of the price formation mechanism, and enhancement of energy efficiency through technological innovation and management optimisation, thereby facilitating the green and low-carbon transformation of the textile industry. This would provide policy recommendations and practical guidance for achieving the dual control targets for carbon emissions.

Keywords: *textile industry, carbon emission intensity, carbon trading prices, mediation effect*

Analiza mecanismului de reducere a emisiilor de carbon în industria textilă sub controlul dual al emisiilor de carbon și al prețurilor tranzacționării carbonului

Industria textilă, ca sector tradițional cu consum ridicat de energie și emisii ridicate, se confruntă cu provocări semnificative în eforturile sale de reducere a emisiilor. Această lucrare, bazată pe obiectivele duble de control al emisiilor de carbon, utilizează un model de regresie panel pentru a examina empiric impactul prețurilor tranzacționării carbonului pe piețele pilot de carbon din China asupra emisiilor de carbon și intensității emisiilor de carbon în industria textilă. Lucrarea explorează, de asemenea, rolul structurii energetice și al eficienței energetice în acest proces printr-un model de efect de mediere. Rezultatele arată că prețurile tranzacționării carbonului au un impact negativ semnificativ asupra intensității emisiilor de carbon în industria textilă, fiecare creștere de 1% a prețurilor tranzacționării carbonului ducând la o scădere de 0,005% a intensității emisiilor de carbon, în timp ce efectul lor asupra emisiilor totale de carbon este comparativ mai slab. O analiză mai aprofundată indică faptul că eficiența energetică joacă un rol de mediere deplină în promovarea reducerii emisiilor de carbon, în timp ce ajustările structurii energetice au doar un efect de mediere parțial. Studiul sugerează că ar trebui să existe o dezvoltare substanțială a piețelor de comercializare a carbonului, o îmbunătățire a mecanismului de formare a prețurilor și o sporire a eficienței energetice prin inovare tehnologică și optimizarea managementului, facilitând astfel transformarea ecologică și cu emisii reduse de carbon a industriei textile. Acest lucru ar oferi recomandări de politică și îndrumări practice pentru atingerea obiectivelor duble de control al emisiilor de carbon.

Cuvinte-cheie*: industria textilă, intensitatea emisiilor de carbon, prețuri de comercializare a carbonului, efect de mediere*

INTRODUCTION

Against the backdrop of deepening integration between global climate change and sustainable development, the Chinese government, in 2024, proposed a dual-control carbon emission system focused primarily on intensity control and supplemented by total volume control. This initiative aimed to accelerate the comprehensive transition of the economy and society towards green and low-carbon development [1, 2]. As a traditional pillar industry of the national economy and an important industry for people's livelihood, the textile industry employs over 20 million people and has an annual export value of more than 300 billion US dollars. Its production process involves multiple high-energy-consuming and high-emission links, such as fibre processing, dyeing and finishing, and is highly dependent on resources such as water, electricity, and steam. According to data from the *United Nations Environment*

Programme, the textile and apparel industry accounted for approximately 10% of global carbon emissions, making it the second-largest source of pollution after the petroleum industry.

Carbon trading markets, as market-based economic instruments, have emerged as vital policy tools used by governments to incentivise carbon reduction among market entities. They have offered new pathways for emission reduction within the textile industry [3]. Carbon trading prices, as a core element of these markets, played a critical role in guiding enterprises to optimise resource allocation and adjust production behaviours. Understanding how fluctuations in carbon trading prices influenced emission reduction decisions and actual outcomes among textile enterprises held significant implications not only for the industry's green transformation but also for the attainment of national dual-control carbon emission targets [4–6]. Analysing the effects of carbon trading prices on emission reduction within the textile industry addressed a pressing practical challenge and contributed both theoretical insights and practical guidance towards improving the carbon market mechanism and implementing the dual-control strategy effectively [7, 8].

In recent years, the issue of carbon emissions within the textile industry has garnered increasing scholarly attention. Liang et al. found that electricity, heat, and coal consumption were the primary sources of carbon emissions in the textile sector, with economic development level identified as the strongest positive driving factor [9]. Haseeb et al. highlighted that low energy efficiency within the industry was a major reason for excessive emissions [10]. Leal Filho et al. argued that enhancing energy and environmental performance was crucial to achieving green and low-carbon development in the textile sector and to improving pollution and emission reduction synergy [11]. Other studies also noted that the application of AI technology could help reduce material waste and improve energy efficiency (Akter & Masood). Peng et al. examined the integration of the textile and logistics industries and found that such convergence generally contributed to lower carbon emission intensity [12]. Wei et al. (2023) explored the effects of heterogeneous environmental regulations on carbon emissions in the textile sector, revealing that command-and-control regulations had an inverted U-shaped effect on carbon emission intensity, market-based incentives induced emissions reduction within a certain threshold, and public participation regulations presented a green paradox effect on total emissions [13].

With the rapid development of carbon trading markets, researchers increasingly investigated the emission reduction effects of carbon trading prices [14, 15]. Fleschutz et al. suggested that appropriate carbon pricing, combined with an active and large-scale carbon market, was essential for achieving energy savings and emissions reductions [16]. Hernandez et al., focusing on the Californian carbon market, found that its operation reduced industrial carbon and air pollutant emissions by 3–9% annually and narrowed industrial air pollution disparities by 6–10% per year [17]. Goldemberg (2020) noted that carbon prices reflected regional carbon abatement costs and quota supply-demand dynamics; therefore, it was reasonable for developing countries to exhibit lower carbon prices than developed nations [18]. Wu and Wang argued that there existed a threshold effect in carbon pricing, whereby only once prices surpassed a certain level would trading activities significantly drive carbon reduction [19].

The existing literature confirmed the general recognition of the emission reduction effect of carbon trading prices. However, limited research had specifically addressed their impact on the textile industry. As the world's largest producer, consumer, and exporter of textiles, China's textile sector faced severe challenges related to energy consumption, pollution, and emissions [20]. How to achieve green and low-carbon development in this industry has thus become a topic of extensive academic and industrial interest. Following the proposal of the dual-control carbon emission strategy, the focus had shifted to not only the total volume of emissions but also changes in emission intensity [21–23]. Unlike the "dual control of energy consumption", which focuses on controlling the total volume and intensity of energy consumption, the "dual control of carbon emissions" relaxes the regulation of energy consumption and emphasises a direct shift from energy consumption to carbon emissions control. Its core is to force the industry to undergo low-carbon transformation through total volume constraints, while guiding technological upgrading through intensity standards, forming a collaborative constraint mechanism of "total volume cap + intensity reduction". Cao and Zhang pointed out that achieving a shift from "dual-control of energy consumption" to "dual-control of carbon emissions" required the expansion of national carbon trading markets in both scale and impact. Based on this, this paper will take the textile industry as the research object to explore how carbon trading prices simultaneously affect the total volume and intensity of carbon emissions, in response to the new requirements of the dual control objectives for "collaborative control of total volume and intensity", providing theoretical and practical insights to support the industry's green development [24].

The marginal contributions of this paper were twofold: first, it examined carbon trading prices, as a core tool for carbon mitigation, as explanatory variables to analyse their impact on emission reduction in the textile sector, and further explored the underlying mechanisms through a mediation model; second, it addressed both carbon emissions and carbon emission intensity as dependent variables under the dual-control framework, thus offering a more comprehensive analysis of the reduction effects of carbon trading prices.

The remainder of this paper is organised as follows: 2nd section presents the theoretical analysis, 3rd section introduces the model specification, 4th section conducts the empirical analysis, and the final section concludes with key findings and policy recommendations.

LITERATURE REVIEW AND THEORETICAL ANALYSIS

As carbon trading markets became increasingly mature, the influence of carbon trading prices on enterprises became more pronounced. High-emission firms were required to pay for their excess carbon emissions, while low- or zero-emission firms could generate economic returns by selling their surplus carbon allowances. Fluctuations in carbon trading prices guided enterprises to reallocate resources from high-carbon energy sectors to low-carbon alternatives [25]. Higher carbon trading prices incentivised firms to increase their investment in low-carbon technologies and clean energy, allocating more resources towards research and development. This process facilitated innovation and advancements in low-carbon technologies, thereby reducing emissions and contributing to carbon mitigation [26].

Green (2021) argued that carbon pricing policies had a significant suppressive effect on carbon emission intensity, namely, the higher the carbon price, the lower the emissions required to generate the same economic output [27]. Similarly, Huisingh et al. found that increases in carbon prices were associated with reductions in emission intensity, driven by technological improvements that promoted decarbonisation [28]. Based on this, the following hypothesis was proposed.

Hypothesis 1: Increases in carbon trading prices contributed to reductions in both carbon emissions and carbon emission intensity in the textile industry.

Fossil fuels, particularly coal, remained the primary source of carbon emissions in China [29]. Jiang et al. observed that the dual-control carbon strategy encouraged industries to proactively optimise their energy structures [30]. In response to changes in carbon trading prices, enterprises, driven by cost control and profit maximisation objectives, strategically adjusted their energy portfolios. They gradually reduced the share of high-carbon energy sources in their energy consumption structures while increasing reliance on relatively low-carbon alternatives [31].

In this process, carbon trading prices served as a key market-based regulatory mechanism, playing a crucial role in promoting the optimisation of energy structures. Rational and scientific adjustments in energy composition guided consumption patterns towards cleaner, more efficient, and lower-carbon trajectories. The energy structure, therefore, functioned as an intermediary, translating the price signals from carbon trading markets into tangible shifts in energy use, and became an important conduit through which carbon prices promoted emissions reduction [32].

On the other hand, in order to reduce the cost of carbon emissions, firms engaged in technological innovation and process improvements to enhance energy efficiency. This improvement in efficiency not only directly lowered emissions per unit of output but also strengthened firms' capacity to respond to fluctuations in carbon prices. Wang and Wang empirically demonstrated that improvements in energy efficiency were a key driver of decoupling carbon emissions from economic growth [33]. Under the carbon trading mechanism, firms reduced carbon emission intensity through more efficient energy use, without significantly compromising economic performance.

Based on the above analysis, the following hypothesis was proposed.

Hypothesis 2: Energy structure and energy efficiency acted as mediating variables in the relationship between carbon trading prices and emission reduction in the textile industry.

MODEL SPECIFICATION

This study focused on regions in China where carbon trading markets had been established. The dependent variables were the carbon emissions and carbon emission intensity of the textile industry within those regions. The core explanatory variable was the regional carbon trading price. A panel regression model was constructed as follows:

$$emi_{i,t} = a_0 + a_1 price_{i,t} + a_2 control_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$int_{i,t} = b_0 + b_1 price_{i,t} + b_2 control_{i,t} + \varepsilon_{i,t} \quad (2)$$

In the above equation, *emi* is the carbon emission of the textile industry. *i* is different individuals, *t* is time, and a_j and b_j are the coefficients of each variable. *int* is the carbon emission intensity, which is defined as carbon emission/principal business income with reference to Bolton et al. [34]. *price* is the carbon trading price, which is measured by the average price of the yearly transaction, because both carbon emission and carbon emission intensity are annual data. *control* is the control variable. Based on the data availability and referring to the existing literature, the total assets and the annual number of employees in the textile industry are selected to represent the capital input and labour input, respectively, and are expressed as ASSET and LABOUR [35]. The total assets of an enterprise exert dual effects on carbon emissions through scale and technological effects: asset expansion may reduce carbon emission intensity due to economies of scale and technological upgrading, but it may also lead to an increase in total emissions due to increased production; the number of employees affects carbon efficiency through the scale and skill structure of the labour force. An increase in the proportion of high-skilled labour helps achieve higher efficiency and lower carbon emissions with fewer human inputs, while an inefficient expansion may exacerbate emissions.

To further explore the underlying mechanisms through which carbon trading prices influence energy transition, this study, based on theoretical analysis, introduced two new indicators, energy structure and energy efficiency, as mediating variables in the panel regression model. A mediation effect model was constructed to perform the regression estimation. The mediation effect model for carbon emissions was specified as follows:

$$M_{i,t} = c_0 + c_1 price_{i,t} + c_2 control_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$emi_{i,t} = d_0 + d_1 price_{i,t} + d_2 M_{i,t} + d_3 control_{i,t} + \varepsilon_{i,t} \quad (4)$$

M is the mediating variable. In this paper, energy structure and energy efficiency are selected as mediating variables, which are denoted by estr and ee, respectively. Coal is the main source of carbon emissions in China, and changes in the proportion of coal consumption are more sensitive to the response of carbon trading price, which can be a better change in the energy structure. Therefore, referring to Guo et al., the energy consumption structure is defined as the proportion of coal in the total energy consumption [36]. Energy efficiency, on the other hand, is defined as the total amount of energy consumed per unit of GDP with reference to Hu [37]. In equation 3, c_1 represents the effect of price on the mediating variable; in equation 4, d_1 represents the effect of *price* on *emi* after the addition of the mediating variable, and d_2 represents the effect of the mediating variable *M* on *emi*. In equation 1 a_1 is significant is the premise for analysing the mediating effect, based on which, if c_1 and d_2 are significant, it represents the existence of a mediating effect. Where d_1 is not significant, it represents the existence of a complete mediation effect of variable *M*; otherwise, it is a partial mediation effect. The mediation effect model on carbon emission intensity is basically similar and will not be repeated here.

EMPIRICAL ANALYSIS

Data description

Since the initiation of China's pilot carbon emissions trading scheme, the government has established eight regional carbon markets in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, Shenzhen, and Fujian. Among these, the markets in seven regions, excluding Fujian, were launched between June 2013 and June 2014, while the Fujian carbon market was launched in December 2016. Due to the lack of accurate statistical data on energy consumption structure in Fujian Province and the administrative status of Shenzhen as a prefecture-level city, both regions were excluded from the analysis. As a result, this study focused on the remaining six provinces and municipalities, covering the period from 2015 to 2021.

Carbon emissions data were obtained from the China Carbon Emission Accounts and Datasets (CEADs), while the remaining variables were sourced from the China Industrial Statistical Yearbook and the China Economic Census Yearbook, among others. A small number of missing values were supplemented using interpolation methods. Given the substantial variation across variables, except for carbon trading prices, all variables were log-transformed to reduce skewness. Descriptive statistics are presented in table 1.

Table 1

DESCRIPTIVE STATISTICS OF VARIABLES

Variable	Min	Max	Mean	Median	S.d.
emi	0.704	3.102	2.068	1.876	0.718
int	–1.404	0.381	–0.309	–0.296	0.463
price	2.253	49.95	25.85	24.55	14.76
estr	0.365	3.985	3.292	3.720	1.015
ee	–0.400	1.754	0.643	0.744	0.667
asset	2.802	7.229	5.330	5.054	1.356
labour	–2.040	3.340	0.962	0.672	1.791

The dependent variable *emi* ranged from 0.704 to 3.476, with a mean of 2.089, a median of 1.876, and a standard deviation of 0.753, indicating relatively low overall variability. The textile industry in Beijing exhibited the lowest level of carbon emissions, averaging approximately 10,000 tonnes per year, whereas Guangdong Province recorded the highest emissions, reaching 840,000 tonnes in 2021. Except for Chongqing, all other provinces and municipalities experienced varying degrees of decline in carbon emissions, suggesting that the low-carbon transition within the textile industry had yielded tangible results. In terms of carbon emission intensity, Hubei Province recorded the lowest intensity, while Shanghai exhibited the highest. Beijing had the highest average carbon trading price, reaching 64 yuan per tonne. In contrast, Guangdong, Tianjin, and Chongqing all reported average prices below 20 yuan per tonne, with Chongqing as low as 13 yuan per tonne.

Furthermore, the textile industries in Guangdong and Hubei were relatively large in scale, each generating over 200 billion yuan in annual main business revenue, with total assets exceeding 100 billion yuan and employing around 200,000 people. Conversely, Beijing had the smallest textile industry, with an annual main business revenue of approximately 2 billion yuan and only 1,300 employees in 2021.

Subsequently, Pearson correlation analysis was employed to examine the relationships among the variables. The results are presented in table 2. As shown, *price* was significantly negatively correlated with *emi*, indicating that higher carbon trading prices were associated with lower carbon emissions. Additionally, *price* was significantly negatively correlated with *estr* and positively correlated with *ee*, preliminarily indicating that carbon trading prices reduce the proportion of coal consumption and improve energy efficiency.

To avoid the issue of spurious regression, this study conducted unit root tests prior to model estimation to assess whether the core variables were stationary. The results are presented in table 3. The key variables, *emi*, *int*, and *price*, rejected the null hypothesis of a unit root at the 1% significance level, indicating

Table 2

CORRELATION ANALYSIS RESULTS							
emi	emi	int	price	estr	ee	asset	labor
	1						
int	0.298*	1					
price	–0.369**	0.0340	1				
estr	0.513***	–0.120	–0.755***	1			
ee	–0.660***	0.375**	0.519***	–0.601***	1		
asset	0.809***	–0.280*	–0.346**	0.545***	–0.921***	1	
labor	0.809***	–0.299*	–0.395***	0.576***	–0.889***	0.974***	1

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 3

UNIT ROOT TEST RESULTS			
Variable name	**emi**	**int**	**price**
p value	0.0001	0.0000	0.002

that these variables were stationary. Therefore, it was appropriate to proceed with the construction of the regression model.

Baseline regression analysis

In panel data regression analysis, three primary models were considered: the Random Effects (RE) model, the Pooled Ordinary Least Squares (POOL) model, and the Fixed Effects (FE) model. Table 4 presents the results of the model selection tests.

The F-test produced a statistic of 2.62 with a corresponding p-value of 0.0674. As this value exceeded the 0.05 significance threshold, the POOL model demonstrated a relative advantage over the FE model. Subsequently, the Breusch–Pagan (BP) test yielded a chi-square statistic of $\chi^2(1) = 85.55$ with a p-value of 0.000, indicating that the RE model outperformed the POOL model. Furthermore, the Hausman test produced a statistic of $\chi^2(3) = 1.73$ with a p-value of 0.63, which also exceeded the 0.05 significance level, suggesting that the RE model was preferable to the FE model.

Based on the results of these tests, this study ultimately adopted the Random Effects model as the baseline model for subsequent regression analysis.

Table 5 presents the results of the panel regression analysis. Columns (1) and (2) report the regression outcomes for carbon emissions. In column (1), only the core explanatory variable, carbon trading price, was included. Its coefficient was −0.0047 and was statistically significant at the 10% level, suggesting that higher carbon trading prices contributed to a reduction in carbon emissions in the textile industry. However, in column (2), after the inclusion of control variables, the coefficient of carbon trading price was no longer statistically significant, indicating that its effect on carbon emissions was not robust.

Columns (3) and (4) display the regression results for carbon emission intensity, with column (4) incorporating control variables. In both specifications, the coefficient for carbon trading price remained statistically significant at the 10% level, demonstrating that an increase in carbon trading prices can significantly reduce the carbon emission intensity of the textile industry, with every 1% rise in carbon trading prices leading to a 0.005% drop in carbon emission intensity. Taken together, the findings suggested that the impact of carbon trading prices was more pronounced in reducing carbon emission intensity than in reducing absolute carbon emissions. This may be because carbon emission intensity directly reflects the emission efficiency per unit of output. Enterprises

Table 4

PANEL MODEL SELECTION RESULTS		
Type of test	**Purpose of the test**	**Value of test**
F test	Comparative selection of FE and POOL models	F-statistic = 2.62, p = 0.0674
BP test	Comparative selection of RE and POOL models	$\chi^2(1) = 85.55$, p = 0.0000
Hausman test	Comparative selection of FE and RE models	$\chi^2(3) = 1.73$, p = 0.63

Table 5

BASELINE REGRESSION RESULTS				
Variables	**(1)**	**(2)**	**(3)**	**(4)**
	emi	**emi**	**int**	**int**
price	–0.0047*	–0.003	–0.0020*	–0.005*
	(–1.95)	(–1.14)	(–1.77)	(–1.90)
asset		–0.085		–0.249
		(–0.52)		(–1.51)
labour		0.138		–0.071
		(1.39)		(–0.70)
Constant	2.2218***	2.496***	–0.2463	1.250
	(6.96)	(2.84)	(–1.09)	(1.40)
Observations	42	42	42	42
Number of provinces	6	6	6	6

Note: z-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively..

Table 6

RESULTS OF THE MEDIATION EFFECT MODEL					
Variables	(1)	(2)	(3)	(4)	(5)
	int	estr	int	ee	int
price	–0.0055*	–0.0223***	–0.0052*	0.0037***	–0.0009
	(–1.90)	(–4.84)	(–1.65)	(2.93)	(–0.26)
asset			0.0728		
			(0.64)		
labour					–1.4159***
					(–3.57)
Constant	–0.2486	0.2903	–0.3511*	0.0229	–0.0515
	(–1.51)	(1.24)	(–1.81)	(0.32)	(–0.30)
Observations	–0.0708	0.0156	–0.0883	–0.3668***	–0.6450***
Number of provinces	(–0.70)	(0.09)	(–0.87)	(–7.41)	(–3.41)

Note: z-statistics are reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

can quickly respond to price signals by adopting low-cost measures such as replacing energy-saving equipment and optimising processes to reduce intensity. However, carbon emissions are the product of intensity and production scale. As a labour-intensive industry, the production scale of the textile industry is constrained by factors such as market demand and supply chain, and reducing production capacity incurs high costs. Therefore, enterprises are more inclined to maintain production, making total emissions less sensitive to carbon prices.

Mediation effect analysis

Based on the results of the baseline regression, carbon trading prices primarily reduced carbon emissions in the textile industry by lowering carbon emission intensity, with a comparatively weaker effect on absolute carbon emissions. To further examine the specific pathways through which carbon trading prices contributed to carbon reduction, this study employed a mediation model using energy structure and energy efficiency as mediating variables, as shown in table 6 [38].

In table 6, columns (2) and (3) present the mediation effects via energy structure, while columns (4) and (5) display the mediation effects via energy efficiency. For comparison, column (1) includes the regression results without any mediating variables.

In column (2), the coefficient of *price* was −0.0223 and statistically significant at the 1% level, indicating that carbon trading prices had a significant negative impact on the energy structure. Specifically, a one-unit increase in the carbon trading price was associated with a 2.23% reduction in the share of coal consumption. In column (3), the coefficient of *price* was −0.0052, slightly lower than in column (1), yet still significant at the 10% level. The coefficient of *estr* was positive, suggesting that a higher proportion of coal consumption corresponded to higher carbon emissions. However, this coefficient was not statistically significant, implying that the direct effect of carbon trading prices on carbon emission intensity was dominant, and that energy structure only partially mediated the relationship.

In column (4), the coefficient of *price* was 0.0037 and significant at the 1% level, indicating that higher carbon trading prices were associated with improved energy efficiency. In column (5), the coefficient of *price* declined to −0.0009 and lost its statistical significance, while the coefficient of *ee* was significantly negative. This result suggested that energy efficiency fully mediated the effect of carbon trading prices on reducing carbon emission intensity in the textile industry.

Moreover, examining columns (1), (3), and (5) collectively revealed that although the significance levels of asset and labour varied slightly, both variables were consistently negatively associated with int. That is, higher total assets and a larger workforce were linked to lower carbon emission intensity. Total assets represented capital investment, while the number of employees reflected labour input; greater input in either dimension typically resulted in reduced energy consumption, thereby lowering carbon emission intensity.

To further verify the robustness of the results, this study applied 10% level winsorisation to all variables and re-estimated the equations presented in table 6 [39–41]. This method effectively mitigated the potential influence of outliers on the regression outcomes [42–44]. The results remained consistent, confirming the robustness of the conclusions.

CONCLUSION AND POLICY RECOMMENDATIONS

This study investigated the impact of carbon trading prices on carbon emissions in China's textile industry, focusing on regions covered by the national carbon market pilots. Using a panel regression model, it was found that carbon trading prices had a significant negative effect on carbon emission intensity, while the effect on absolute carbon emissions was relatively modest. Further analysis, based on a mediation model, revealed that improvements in energy efficiency constituted the primary mechanism through which carbon trading prices reduced emissions. Adjustments in the energy structure played only a partial mediating role. Based on these findings, the following policy recommendations are proposed:

Vigorously develop the carbon trading market

First, expand the coverage of the carbon market, include enterprises along the industrial chain in quota management, formulate differentiated standards based on production processes and carbon emission intensity, set stricter emission reduction targets for high-energy-consuming enterprises, and force them to carry out technological transformation. Second, improve the price formation mechanism, introduce a "carbon price - emission reduction cost" linkage model, dynamically adjust the carbon price according to the industry's emission reduction costs, and enrich financial instruments such as carbon futures to enhance market liquidity. Third, strengthen policy support, provide tax incentives, financial subsidies, and other rewards to enterprises that exceed emission reduction targets, use the Internet of Things and blockchain technology to strengthen energy consumption monitoring, establish a data sharing platform, crack down on data fraud, and ensure a fair and effective market.

Improve energy efficiency

Focus on the dual upgrade of technology and management, promote energy-saving technologies such as waste heat recovery and intelligent control in printing and dyeing and chemical fibre processes, and deploy energy management systems to achieve dynamic control of energy consumption. Construct industry energy efficiency standards, set energy efficiency benchmarks for product categories, and guide enterprises in strategic energy conservation. Build a technology sharing platform, organise technical exchanges and demonstration observations, implement contract energy management models, lower the threshold for enterprise technological transformation, and accelerate the implementation of energy-saving technologies.

Adjust the energy structure and reduce coal consumption

Advance energy transformation through a two-pronged approach. On one hand, encourage enterprises to apply distributed photovoltaic, biomass energy, and other renewable energy sources, and promote the elimination of coal-fired boilers or their replacement with clean energy. On the other hand, implement total coal consumption control, promote clean combustion technologies and support environmental protection facilities for enterprises that retain coal-fired equipment. Through financial subsidies, quota rewards, and price transmission mechanisms, reduce the cost of using clean energy for enterprises, enhance its economic substitutability for coal, and achieve a clean energy structure.

This paper only covers the textile industry in regions where China's pilot carbon markets are located, excluding enterprises in non-pilot regions, which may limit the generalizability of conclusions. Moreover, it does not distinguish the heterogeneous impacts among different sub-sectors (such as clothing and home textiles). The mediating effect analysis only focuses on energy efficiency and energy structure, without covering other potential paths such as the application of carbon capture technology and industrial structure adjustment. In the future, the sample can be expanded to the national textile industry to conduct a comparative analysis of emission reduction differences between pilot and non-pilot regions as well as among different sub-sectors, so as to reveal the regional and industrial heterogeneous impacts of carbon trading policies. Meanwhile, more mediating variables (such as carbon capture technology and industrial concentration) can be included to construct a more comprehensive framework of emission reduction path mechanisms.

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