Carbon trading pilot and low-carbon development of China’s textile industry

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ABSTRACT – REZUMAT

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To explore whether a carbon trading pilot (CTP) can promote the low-carbon development of China's textile industry (CTI), this paper used a difference-in-difference model to study the impact of CTP on the carbon emissions in CTI and further analysed its regional heterogeneity. The research results showed that the impact coefficient of CTP on the carbon emissions in CTI was significantly negative, indicating that CTP could reduce the carbon emissions in CTI. Robustness tests such as the Placebo test, replacing the explained variable and the estimation method and excluding the interference of other policies verified the robustness of the research results. The dynamic regression results revealed the carbon reduction effect of CTP became stronger as the time of its implementation increased. At the regional level, CTP could also significantly lower the carbon emissions in the textile industry both in the eastern and western regions, and the reduction effect in the western region was greater than that in the eastern.

Keywords: *carbon emissions, carbon trading pilot, China's textile industry, difference-in-difference model, low-carbon development*

Program pilot de comercializare a certificatelor de emisii de carbon și dezvoltarea industriei textile din China cu emisii scăzute de carbon

Pentru a explora dacă programul pilot de comercializare a certificatelor de emisii de carbon (CTP) poate promova dezvoltarea industriei textile din China (CTI) cu emisii scăzute de carbon, acest studiu a folosit modelul de „diferență în diferență” pentru a studia impactul CTP asupra emisiilor de carbon în CTI și a analizat în continuare eterogenitatea sa regională. Rezultatele cercetării au arătat un coeficient de impact al CTP asupra emisiilor de carbon în CTI semnificativ negativ, indicând faptul că CTP ar putea reduce emisiile de carbon în CTI. Teste precum testul Placebo, care înlocuieşte variabila explicată și metoda de estimare și exclude interferența altor politici au verificat validitatea rezultatelor studiului. Rezultatele regresiei dinamice au arătat că efectul de reducere a emisiilor de carbon al CTP a devenit mai puternic pe măsură ce timpul de implementare al acestuia a crescut. La nivel regional, CTP ar putea, de asemenea, să reducă semnificativ emisiile de carbon din industria textilă atât în regiunile de est, cât și de vest, iar efectul de reducere în regiunea de vest a fost mai intens decât cel din est.

Cuvinte-cheie: *emisii de carbon, program pilot de comercializare a certificatelor de emisii de carbon, industria textilă din China, model de diferență în diferență, dezvoltare cu emisii scăzute de carbon*

INTRODUCTION

Global climate warming is a common problem faced by all countries worldwide, and reducing CO_2 emissions is a key initiative to combat it. The textile industry is one of the traditional pillar industries of China's economy and also a major source of CO_2 emissions in China's manufacturing industry. Its total carbon emissions in 2020 were close to 13 million tons [1], and still ranked high in the manufacturing sectors. Lowering CO_2 emissions has become a key issue in promoting the low-carbon development of China's textile industry (CTI).

Environmental regulation (ER) is an important tool for cutting CO_2 emissions. It can be categorized into command-based, market-based and public-based ER. Among them, market-based ER (MER) means the government guides enterprises to make environment-friendly decisions through economic incentives including carbon tax and carbon trading. Carbon trading aims to push enterprises to take measures such as technological innovation etc. to mitigate carbon emissions by internalizing their emission costs. Because of its non-mandatory, market-based and tradable advantages, carbon trading has rapidly become a widely used tool for cutting carbon emissions in major carbon-emitting countries around the world. The European Union established the world's earliest and largest carbon trading market in 2005, which now covers all EU countries. In 2023, a new, separate emissions trading system (ETS) was created: Emissions Trading System 2 (ETS 2), covering fuel combustion in buildings, road transport and additional sectors (mainly small industries not covered by the existing EU ETS). In China, Beijing, Shanghai, Tianjin, Guangdong, Shenzhen, Hubei, and Chongqing were selected as pilot regions for carbon trading by the Chinese National Development and

Reform Commission in 2011 and the ETS was piloted successively in the second half of 2013. Then the national unified carbon trading market was officially put into operation in July 2021. So far, can the carbon trading pilot (CTP) promote the low-carbon development of CTI? In other words, has CTP helped mitigate the carbon emissions of the industry?

Answering these questions is essential to assess the effectiveness of CTP, and also provide empirical evidence of how the government uses MER tools to achieve the low-carbon development of CTI.

Carbon trading is becoming a hot topic in academia with the establishment of ETS around the world. Extensive research has been conducted on the operation of ETS in various countries [2–4], with a focus on the carbon reduction effect and low-carbon technological innovation effect of carbon trading, and its impact on economic development. In the study of the carbon reduction effect, most scholars believed that carbon trading helped reduce CO_2 emissions [5, 6]. However, some scholars doubted the reduction effect. For example, Dalia [7] found that ETS had a weak effect on carbon reduction in Baltic countries. Regarding the low-carbon technological innovation effect, Liu [8] confirmed that China's CTP could promote low-carbon technological innovation at the regional level. Mo's [4] research on South Korea's manufacturing industry reached a similar conclusion. In terms of the impact on economic development, Jing [9] proved that CTP played an important role in promoting high-quality economic development in China, and its promotion effect in the eastern region was greater than that in other regions. Wang [10] obtained the same results in China's manufacturing industry, but there was a time lag in the effect of the pilot.

At the industry level, most literature evaluated the impact of CTP on carbon emissions in high energy-consuming industries such as power [11] and transportation [12]. As to CTI, the existing literature mainly focused on the estimation of carbon emissions and its determinants [13, 14], and studies on the impact of CTP on CTI's carbon emissions have not yet been found. Therefore, it is still unclear whether CTP can promote the low-carbon development of CTI so far.

To explore the relationship between CTP and low-carbon development in CTI, this paper constructed a difference-in-difference (DID) model to study the impact of CTP on carbon emissions in CTI using the provincial panel data from 2004 to 2019. Then it divided China into eastern and western regions to further analyse the regional heterogeneity. The contribution of this paper is that for the first time, policy evaluation methods are used to evaluate the carbon reduction effects of CTP on the textile industry in China and its various regions. The findings of this paper also help to answer the above questions, make up for the research shortages and provide decision-making reference for China to promote textile enterprises to participate in carbon trading.

This paper is organized as follows. 2nd section explains the DID model and its key variables. The empirical results and analysis of CTP's impacts on the carbon emissions in CTI are provided in 3rd section. Finally, the conclusions and policy recommendations are discussed in the 4th section.

METHODOLOGY AND DATA SOURCES

DID Model

The DID approach has been widely used to evaluate the effectiveness of policy. The study is designed as a quasi-experiment by setting up two sample groups, a treatment group and a control group. Compared with other policy evaluation methods, the DID approach can effectively solve the possible endogenous problems and assess the net effect of policy. Therefore, to study whether CTP could promote the low-carbon development of CTI, according to Wang's [10] study, this paper constructed the following DID model to empirically analyse the impact of CTP on carbon emissions in CTI:

$$\ln CE_{it} = \beta_0 + \beta_1 Pilot_i * Time + \beta_n Control_{it} + \\ + \delta_i + \gamma_i + \varepsilon_{it} \quad (1)$$

where β_1~β_n are the estimated coefficients. β_1 is used to evaluate the impact of CTP on the carbon emissions in CTI, which is the most concerned coefficient in this study. If β_1 is significantly negative, it means that CTP can lower the carbon emissions in CTI.

Pilot*Time is the core explanatory variable and it's the intersection of policy dummy variable $Pilot_i$ and year dummy variable *Time*, indicating the implementation of CTP in province *i*, year *t*. $Pilot_i$ equals 1 if province *i* is a pilot province, otherwise 0. Beijing, Shanghai, Tianjin, Chongqing, Hubei, Guangdong and Shenzhen officially launched CTP in the second half of 2013. As Shenzhen City belongs to Guangdong Province, this paper takes Beijing, Shanghai, Tianjin, Chongqing, Hubei, and Guangdong six provinces as the carbon trading pilot provinces and the treatment group. The remaining 24 provinces (excluding Hong Kong, Macao, Taiwan, and Tibet due to data availability) are in the control group. Time is defined as a year dummy variable. Typically if the pilot policy is implemented in the first half of the year, the current year is considered to be the starting year for the execution of the policy. If it is in the second half, the following year is the starting year. By common practice, this paper uses 2014 as the starting year since CTP was practised in the second half of 2013 and assigns a value of 1 to the years 2014 and after, and 0 to the years before 2014.

CE_{it} is the explained variable and represents the carbon emissions of the textile industry in province *i*, year *t*. $Control_{it}$ is the control variable. δ_i and γ_i represent the province-fixed-effect and year-fixed-effect, respectively. $\varepsilon_{i,t}$ is the residual.

Variables

Explained variables

Carbon emissions (CE) refer to the total amount of carbon dioxide emitted by CTI. It's directly obtained from China Emission Accounts and Datasets (CEADs).

Explanatory variables

Pilot*Time is the intersection of policy dummy variable $Pilot_i$ and year dummy variable *Time*. It shows whether CTP was implemented in a specific province and at a specific time.

Control variables

According to Li's [6] research, this paper chose economic development (PGDP, measured by GDP per capita), urbanization (URB, measured by the ratio of the urban population to the total population), energy structure (ES, measured by the ratio of coal consumption to the total energy consumption) and foreign direct investment (FDI, measured by the total amount of foreign direct investment) as the control variables.

Data sources

In this study, data on carbon emissions is retrieved from CEADs. Data on control variables is collected from the China Statistical Yearbook and China Industrial Statistical Yearbook. The national carbon trading market officially started operating in 2021 and by then the CTP ended in the six provinces mentioned above. In addition, the CEADs have not yet published carbon emissions data of the textile industry for 2020, with the latest available data ending in 2019. So the research periods cover from 2004 to 2019.

EMPIRICAL RESULTS AND DISCUSSION

Main regression results

Equations 1 and 2 of table 1 presented the main regression results of CTP on carbon emissions in CTI without and with the control variables in the DID model, respectively. It could be seen that the impact coefficients of Pilot*Time were both negative at the 1% significance level, –0.732 and –0.825 (table 1), respectively. It showed that compared with the control provinces, CTP could significantly lower carbon emissions in the textile industry of pilot provinces and it helped achieve the green development of CTI. The result was also similar to the findings of most scholars [5–6] i.e. CTP can effectively reduce carbon emissions in CTI.

Parallel trend test

The precondition for using the DID model is that the trend of carbon emissions in the treatment and control groups must satisfy the parallel trend assumption. That is, there is no significant difference between

Table 1

RESULTS OF MAIN REGRESSION, DYNAMIC EFFECTS, REPLACING VARIABLE & METHOD, EXCLUSION OF OTHER POLICY EFFECTS

Equation	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Explained variable	Ln(CE)	Ln(CE)	Ln(CE)	Ln(CE)	Ln(CI)	Ln(CE)	Ln(CE)
Pilot*Time	-0.732^{***} [–6.84]	-0.825^{***} [–6.61]			-0.807^{***} [–4.99]	-0.478^{***} [–3.04]	-0.648^{***} [–5.44]
P1			-0.590^{**} [–2.89]	-0.628^{***} [–3.72]			
P2			-0.665^{**} [–2.92]	-0.660^{**} [–3.08]			
P3			-0.771^{**} [–3.17]	-0.719^{**} [–3.42]			
Low-carbon							-0.430^{***} [–3.72]
Ln(PGDP)		1.150^{**} [3.12]		1.050 [1.24]	–0.751 [–1.82]	–0.260 [–0.26]	1.150^{**} [3.22]
Ln(URB)		-2.287^{**} [2.90]		–1.463 [–0.99]	-3.271^{***} [–3.60]	-0.206^{*} [–1.72]	-2.180^{**} [–2.81]
Ln(FDI)		0.065 [0.55]		0.006 [0.04]	–0.017 [–0.11]	–0.216 [–0.88]	0.084 [0.72]
Ln(ES)		0.336^{*} [2.16]		0.386 [1.99]	–0.196 [–1.15]	0.754^{**} [2.57]	0.420^{*} [2.57]
Obs.	480	480	480	480	480	125	480
R^2	0.928	0.930	0.925	0.927	0.797	0.992	0.932
Adj-R^2	0.920	0.922	0.917	0.919	0.773	0.987	0.924

Note: ***, **, * represent significance levels of 1%, 5% and 10%, respectively. *t* values are shown in parentheses. Obs. is the number of observation data sets.

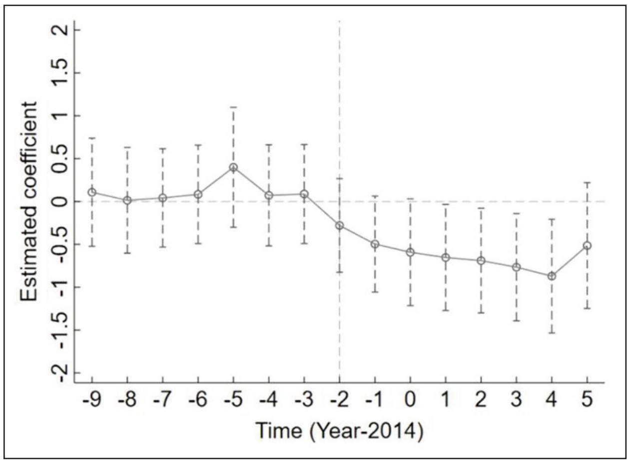

Fig. 1. Results of parallel trend test

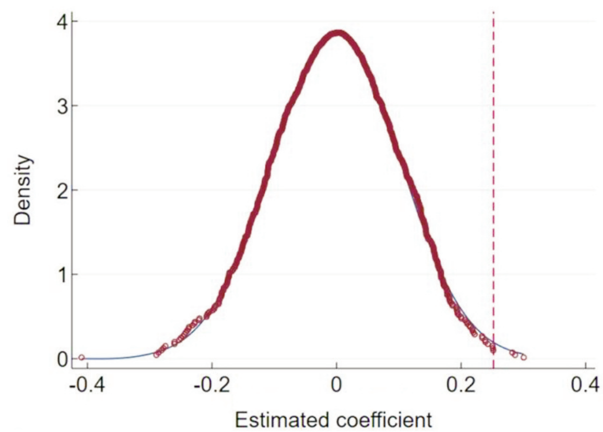

Fig. 2. Kernel density of estimated coefficients

the trends of the two groups before the implementation of CTP and there is a significant difference after the implementation. Referring to Thorsten's [15] research, the event study method was used to conduct the parallel trend test and the results are shown in figure 1. Before the implementation of CTP, the estimated coefficients were all around 0, indicating that there was no significant difference in the trend of carbon emissions between the treatment and control groups. After its implementation, the corresponding coefficients were far less than 0. The results were in line with the parallel trend assumption, so it was appropriate to use a DID model in this study. Meanwhile, the coefficients were significantly negative after the implementation, suggesting that CTP had a negative impact on the carbon emissions and helped mitigate the carbon emissions in CTI.

Dynamic effects of CTP

To study the dynamic impact of CTP on the carbon emissions in CTI, this paper further constructed the following dynamic regression model 2 to evaluate the policy effect of CTP over three years' implementation.

$$\ln CE_{it} = \beta_0 + \beta_1 P_1 + \beta_2 P_2 + \beta_3 P_4 + \beta_n Control_{it} + \delta_i + \gamma_i + \varepsilon_{it} \quad (2)$$

where P_1, P_2, and P_3 were also the intersection of policy dummy variable $Pilot_i$ and year dummy variable *Time*, denoting the dummy variables for the 1st (2015), 2nd (2016) and 3rd (2017) years after CTP was practised, respectively. Time was equal to 1 when the year was one of the three mentioned above. The estimation coefficients of P_1, P_2, and P_3 were used to assess the dynamic effects of CTP. The other indicators and coefficients had the same meanings as above.

Equations 3 and 4 of table 1 listed the dynamic regressions results when control variables were not added versus when they were added in the DID model. As could be seen from the regression results, the coefficients of P_1, P_2, and P_3 were all significantly negative and gradually became smaller with time. This revealed that as the time of CTP implementation increased, its carbon reduction effect got stronger.

Robustness test

Placebo test

To test the robustness of the main regression results, a placebo test was performed by randomly selecting samples as the treatment group. Specifically, the first six provinces were randomly selected from the 30 provinces in China (excluding Hong Kong, Macao, Taiwan, and Tibet due to data availability) as the treatment group and the remaining as the control group. The implementation year of CTP remained unchanged. Pilot*Time was taken as a "pseudo-policy dummy variable" and again the DID model was used for regression. In the study, the random sampling and regression were repeated 1000 times and the kernel densities of the estimated coefficients were plotted (figure 2), where the dashed line represented the coefficient of Pilot*Time in the true main regression. Figure 2 showed the coefficients were normally distributed, concentrated around 0, and significantly different from the true main regression coefficient. This reflected that the difference in regression results between the treatment and control groups as discussed resulted from the CTP, not from other unobservable factors. Therefore it could be concluded the main regression results in the previous section were robust.

Replacing the explained variable and the estimation method

To eliminate the possible disturbances and biases in the estimation results due to the selection of variables and models, the paper further conducted robustness tests by replacing the explained variable and the estimation method.

In terms of replacing the explained variable, as the carbon emissions (CE) and carbon intensity (CI) in the textile industry had the same trend generally, this paper chose CI as the new explained variable to replace CE, then re-ran the DID regression to test the robustness. The test results are shown in equation 5 of table 1. The coefficient of Pilot*Time remained significantly negative after the replacement, indicating

Table 2

REGRESSION RESULTS IN VARIOUS REGIONS				
Region	**Eastern**		**Western**	
Equation	(8)	(9)	(10)	(11)
Explained variable	Ln(CE)	Ln(CE)	Ln(CE)	Ln(CE)
Pilot*Time	-0.996^{***} [–7.74]	-0.765^{***} [–5.46]	-0.821^{***} [–5.41]	-1.063^{***} [–5.06]
Ln(PGDP)		1.051^{*} [2.07]		1.740^{**} [3.26]
Ln(URB)		–0.733 [–0.98]		–0.985 [–0.72]
Ln(FDI)		0.011 [0.08]		0.099 [0.59]
Ln(ES)		0.531^{***} [2.90]		0.424 [1.17]
Obs.	160	160	320	320
R^2	0.974	0.979	0.872	0.879
Adj-R^2	0.969	0.975	0.856	0.861

Note: ***, **, * represent significance levels of 1%, 5% and 10%, respectively. *t* values are shown in parentheses. Obs. is the number of observation data sets.

CTP could also promote the CI reduction of China's textile industry and the main regression results were robust.

In terms of replacing the estimation method, to eliminate the interference of the self-selection effect, this paper used propensity score matching and difference in difference (PSM-DID) method to re-evaluate the impact of CTP on the carbon emissions in CTI. The self-selection effect is that the government may consider the economic development and carbon emissions of different provinces when selecting pilot provinces, which in turn leads to non-randomness in the pilot province selection. As shown in equation 6 of table 1 the coefficient of Pilot*Time was still significantly negative and it verified the robustness of the main regression results of this study again.

Excluding the interference of other policy

In parallel with the execution of CTP, other policies might also influence the carbon emissions in CTI. Considering the period and objective of the study, this paper focused on the impact of the low-carbon city pilot policy practised in 2010 on the carbon emissions in CTI to test if the main regression results were biased. The pilot areas for the policy included five provinces (Guangdong, Liaoning, Hubei, Shaanxi and Yunnan) and eight cities (Shenzhen, Hangzhou, Xiamen, Tianjin, Baoding, Nanchang, Guiyang and Chongqing). As the data used in this paper were all provincial panel data, seven provinces (Guangdong, Tianjin, Liaoning, Hubei, Shaanxi, Chongqing and Yunnan) were taken as pilot areas and included in the treatment group, while the rest were in the control group. Similarly, the DID model was used to study the impact of CTP on the carbon emissions in CTI after including the low-carbon city pilot policy (Low-carbon) in the regression model, and the regression results were presented in equation 7 of table 1. The coefficient of Pilot*Time was still significantly negative, which indicated that even considering this policy, CTP also could promote the carbon emissions reduction of CTI. The main regression results of this study were still robust.

Regional heterogeneity analysis

As the development and CO_2 emission of the textile industry varied across regions in China, so this paper further investigated whether there was any difference in the impact of CTP on the carbon emissions in the textile industry across different regions. This paper divided China into the eastern region and the western region. The western region includes the central, western and northeastern regions according to the regional division standard of the State Council of China, while the eastern region remains unchanged. Then this paper also used the DID model to evaluate the impacts of CTP on the carbon emissions in the eastern and western textile industries respectively, and analysed the regional heterogeneity. In the eastern region, Beijing, Shanghai, Tianjin and Guangdong were the pilot provinces and then included in the treatment group. In the western region, Chongqing and Hubei were classified to be the treatment group, while the other provinces were in the matched control group. The regression results are shown in table 2.

As can be seen from table 2 all regression coefficients of Pilot*Time were significantly negative. This meant that CTP both exerted a significantly negative impact on the carbon emissions in the eastern and western textile industries, which was in line with the regression results for CTI. It was also noted that when control variables were added, the coefficient of Pilot*Time on the eastern textile industry was –0.765, greater than that of the western (–1.063). This suggested that CTP's carbon reduction effect in the western textile industry was stronger than that in the eastern. The reason may be that there was a big gap between the western and eastern textile industries in terms of green technology innovation and industrial structure upgrading. The western textile industry was more sensitive to the cost caused by CTP and then more greatly cut its carbon emissions, therefore showing a stronger carbon reduction effect.

CONCLUSIONS

This paper constructed the DID model to study the impact of CTP on the carbon emissions in CTI and then analysed its regional heterogeneity. The research results are as follows:

(1) At the national level, the main regression results demonstrated that CTP could significantly reduce carbon emissions. Further dynamic regression results revealed that the reduction effect of CTP became stronger as the time of its implementation increased. (2) At the regional level, CTP could also significantly cut the carbon emissions of the textile industry in the eastern and western regions, and the reduction effect in the western region was significantly larger than that in the eastern region.

Based on the findings above, this paper put forward the following policy suggestions to promote the low-carbon development of CTI: (1) At the national level, China should accelerate the development of a national unified carbon trading market, increase market activity, and gradually include the textile industry into the market. (2) At the regional level, it's recommended to optimize the regional structure of carbon emissions in CTI through market-based ER, especially to reduce carbon emissions in the eastern textile industry, which is the most critical. (3) At the enterprise level, China also needs to strengthen the regulation of carbon emissions from textile companies, set carbon accounting standards and improve the mandatory disclosure system for textile enterprises. Finally, this paper has some limitations. Due to data availability, this study only covered the period from 2004 to 2019. Future studies can expand the sample range to the most recent years e.g., 2020–2022 to improve the accuracy and validity of the conclusions. Moreover, this paper investigated the impact of CTP on carbon emissions in CTI but did not further analyse the mechanism and path of the impact, which suggests future research directions.

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