The impact of heterogeneous environmental regulations on China's textile industry CO_2 emissions

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ABSTRACT – REZUMAT

The impact of heterogeneous environmental regulations on China's textile industry CO_2 emissions

Environmental regulation is an important tool to reduce CO_2 emissions. To investigate the relationship between heterogeneous environmental regulations and CO_2 emissions of China's textile industry (CTI), this paper uses the threshold model and panel model to study the impacts of command-based, market-based and public-based environmental regulations (CER, MER and PER) on the total carbon emissions and carbon emission intensity of CTI from 2004 to 2019. Then it further explores their regional heterogeneity. The results show that: at the national level, CER has a forced emission reduction effect and a green paradox effect on CTI's total carbon emissions and carbon emission intensity, respectively. And MER shows a forced emission reduction effect on carbon emission intensity. But the coefficients of PER are not significant. At the regional level, the result verifies a U-shaped relationship between CER and CO_2 emissions in the eastern textile industry. And CER shows a forced emission reduction effect in the central and western regions. The impact of MER on the carbon emission intensity of the eastern textile industry is N-shaped, which means MER can lower carbon emission intensity only within a certain range. And its impacts on the central and western regions are also the forced emission reduction effect. There is an inverted U-shaped relationship between PER and the total carbon emission in the eastern textile industry. While PER has always had a green paradox effect on carbon emission intensity in the eastern region. Other coefficients are not significant. Finally, this paper puts forward the policy suggestions to mitigate the CO_2 emissions of CTI.

Keywords: *China's textile industry, CO_2 emissions, heterogeneous environmental regulations, green paradox effect, forced emission reduction effect*

Impactul reglementărilor eterogene de mediu asupra emisiilor de CO_2 din industria textilă a Chinei

Reglementările de mediu reprezintă un instrument important pentru reducerea emisiilor de CO_2. Pentru a investiga relația dintre reglementările eterogene de mediu și emisiile de CO_2 ale industriei textile din China (CTI), această lucrare utilizează modelul de prag și modelul panoului pentru a studia impactul reglementărilor de mediu bazate pe comandă, pe piață și pe bază publică (CER, MER și PER), privind emisiile totale de carbon și intensitatea emisiilor de carbon ale CTI din 2004 până în 2019. Apoi explorează în continuare, eterogenitatea lor regională. Rezultatele arată că: la nivel național, CER are un efect de reducere forțată a emisiilor și un efect de paradox verde asupra emisiilor totale de carbon și, respectiv, intensității emisiilor de carbon ale CTI. Și MER arată un efect de reducere forțată a emisiilor asupra intensității emisiilor de carbon. Dar coeficienții PER nu sunt semnificativi. La nivel regional, rezultatul verifică o relație în formă de U între CER și emisiile de CO_2 din industria textilă de est. Și CER arată un efect de reducere forțată a emisiilor în regiunile centrale și vestice. Impactul MER asupra intensității emisiilor de carbon din industria textilă de est este în formă de N, ceea ce înseamnă că MER poate reduce intensitatea emisiilor de carbon doar într-un anumit interval. Iar impactul său asupra regiunilor centrale și vestice este și reducerea forțată a emisiilor. Există o relație în formă de U inversă între PER și emisiile totale de carbon în industria textilă de est, în timp ce PER a avut întotdeauna un efect de paradox verde asupra intensității emisiilor de carbon în regiunea de est. Alți coeficienți nu sunt semnificativi. În cele din urmă, această lucrare prezintă sugestii de politici pentru atenuarea emisiilor de CO_2 din CTI.

Cuvinte-cheie*: industria textilă din China, emisii de CO_2, reglementări de mediu eterogene, efectul paradoxului verde, efect de reducere forţată a emisiilor*

INTRODUCTION

The textile industry is one of the traditional pillar industries of China's economy and also an important source of China's carbon (CO_2) emissions. Since the beginning of the 21st century, CO_2 emission in China's textile industry (CTI) has experienced a trend of growth followed by a decline. At present, CTI is still facing great pressure to reduce CO_2 emissions. The total CO_2 emissions in 2020 were still large at about 13 million tons. In the meantime, China set a green development goal in the "14th Five-Year Plan for the Development of Textile Industry" that the amount of CO_2 emissions per unit of CTI's industrial value-added decrease by 18% from 2021 to 2025. Cutting down CO_2 emissions is an important pathway to achieve the goal of CTI's green development.

Environmental regulation (ER) is an important tool to curb CO_2 emissions. According to existing studies, it can be divided into three heterogeneous regulations: command-based environmental regulation (CER), market-based environmental regulation (MER) and public-based environmental regulation (PER). There are different views on the relationship between ER and CO_2 emissions. The green paradox effect posits that ER cannot curb CO_2 emissions, but will push CO_2 emissions to increase instead [1]. But forced emission reduction effect insists that a well-designed ER can motivate an enterprise to carry out technological innovation to compensate for the cost induced by ER and reduce CO_2 emissions [2,3]. New studies argue green paradox effect and forced emission reduction effect coexist between ER and carbon emission and the influence of ER on CO_2 emissions depends on which is dominant. Thus, there is a dynamic, nonlinear relationship between them. Wang [4] proves that there is an inverted U-shaped relationship between ER and CO_2 emissions using the data from 282 cities in China. So, what is the role of each of the three ER tools in reducing CO_2 emissions in CTI? How do they influence CTI's CO_2 emissions? As there are significant differences in the development of textile industries in different regions of China, is there regional heterogeneity in the impact of these three ER tools? Therefore, it has great empirical significance to study the heterogeneous effects of different ERs on CTI's CO_2 emissions.

In the study of the impact of ER on CO_2 emissions, existing research is mainly carried out at the regional level, less at the industrial level. Moreover, most researches focus on the impact of CER. The literature on the impact of MER is relatively little and that of PER is rare. In terms of research on a single ER tool, Yang [5] concluded that the CER can significantly reduce China's CO_2 emissions from both temporal and spatial perspectives. Neves's [6] research on 17 EU countries also showed that MER could reduce CO_2 emissions in the long run. Zhang [7] proved that environmental information disclosure could help reduce CO_2 emissions, but there was regional heterogeneity.

Concerning multi-ER tools, the relevant literature mostly compared the impacts of CER versus MER or CER versus PER on CO_2 emissions. Few scholars performed a comparative study of the effects of all three ER tools together. Wu's [8] results demonstrated there was an inverted U-shaped relationship between CER, MER and PER and CO_2 emissions in China's iron and steel industry. The above results show that there is a wide divergence among academics regarding the mechanism of how ER affects CO_2 emissions. As for the study of carbon emissions in CTI, most scholars discussed the estimation of CTI's CO_2 emissions and its determinants [9,10]. But few literatures on the impact of ER on CTI's CO_2 emissions were found. Due to the lack of relevant literature, the relationships between the three ER tools and CTI's CO_2 emissions and whether there is regional heterogeneity are not clear. Therefore, it's of high theoretical value to study the impacts of heterogeneous ERs on CTI's CO_2 emissions.

To address the practical problems and fill the theoretical gaps as described above, this paper uses the threshold model and panel model to study the impacts of CER, MER and PER on CTI's total carbon emissions and carbon emission intensity from 2004 to 2019, then it further explores their regional heterogeneity. The contribution of this paper is that it investigates in detail the differences between these three ER tools in terms of their impact mechanisms on CTI's CO_2 emissions at national and regional levels, respectively. The results will also provide the basis for the Chinese government to make policy decisions on how effectively utilizes ER tools to mitigate carbon emissions for CTI's green development.

METHODOLOGY AND DATA SOURCES

Estimation model

This paper first uses a threshold model to study the impact of CER, MER and PER on the total carbon emissions and carbon emission intensity of CTI from 2004 to 2019. Compared with the traditional static panel model, the threshold model can be used to analyse whether the impact of ER on CTI's CO_2 emissions is dynamically nonlinear. If the threshold effect is significant, it means that this ER tool has a nonlinear relationship with CTI's CO_2 emissions. If not, it indicates a linear relationship between them. Then the paper further investigates whether the impact mechanism is a green paradox effect or a forced emission reduction effect using the panel model.

Referring to the method proposed by Hansen [11], this paper takes CER, MER and PER as the threshold variables and explanatory variables, CTI's total carbon emissions (TCE) and carbon emission intensity (CEI) as the explained variables. It constructs the following threshold model to investigate whether there is a nonlinear relationship between heterogeneous ERs on CTI's CO_2 emissions:

$$LnY_{it} = C_{it} + \beta_1 LnER_{it} \cdot I(ER_{it} \le \gamma_1) + \beta_2 LnER_{it} \cdot I(\gamma_1 < ER_{it} \le \gamma_2) + \cdots + \beta_n LnER_{it} \cdot I(\gamma_{n-1} < ER_{it} \le \gamma_n) + \beta_{n+1} LnER_{it} \cdot I(ER_{it} > \gamma_{n+1}) + \theta LnX_{it} + \varepsilon_{it} \quad (1)$$

where Y represents the total carbon emissions ($TCE_{i,t}$) and carbon emission intensity ($CEI_{i,t}$) of the textile industry of province i in year t, respectively. $ER_{i,t}$ represents the command-based, market-based and public-based environmental regulation (CER, MER and PER) of province i in year t. $X_{i,t}$ is the control variable and $\varepsilon_{i,t}$ is the residual. $I(*)$ is the indicator function that takes the value of 1 if the condition in brackets holds, and 0 otherwise. γ is the threshold value. $\beta_1 - \beta_n$ denote the estimation coefficients in different ranges of threshold variables. The paper can determine whether the threshold effect exists by testing if the estimation coefficients of $\beta_1 - \beta_n$ are significantly different or not. If the threshold effect is

significant, the impact mechanism is nonlinear. Otherwise, it's linear. Then the following panel model need to be constructed for further study:

$$LnY_{it} = C_{it} + \beta_1 LnER_{it} + \theta LnX_{it} + \varepsilon_{it} \quad (2)$$

The meaning of each indicator is the same as above. To explore the regional heterogeneity of *ER*, this paper first divides China into four regions: East, Central, West and Northeast according to the regional division standard of the State Council of China. Then it employs the threshold model and panel model to study the impacts of heterogeneous ERs on CO_2 emissions of the textile industry in each region of China.

Variables and data source

Explained variables

Total carbon emissions (TCE) refer to the amount of carbon dioxide emitted by CTI and are directly obtained from Carbon Emission Accounts & Datasets (CEADs).

Carbon emission intensity (CEI) measures the carbon emission efficiency of CTI and is calculated as the ratio of CTI's total carbon emissions to its gross output.

Core explanatory variables

Command-based environmental regulation (CER) regulates corporate environmental behaviours through administrative orders, including laws, policies and development plans. CER is measured by the ratio of investment completed in the treatment of industrial pollution in each province to the gross industrial output of industries above the designated size.

Market-based environmental regulation (MER) guides enterprises to make environment-friendly decisions through economic incentives including carbon tax and carbon emissions trading. Referring to Wu [8], MER is measured by the ratio of each province's sewage charges to the gross industrial output of industries above the designated size.

Public-based environmental regulation (PER) is a non-statutory agreement established between enterprises, governments, or non-profit organizations and it depends on public environmental awareness, public opinions and supervision. According to Pargal [12], it is measured by residents' income, population density and education level in each province. The objective weight-based entropy method is adopted to calculate the comprehensive index of PER.

Control variables

Economic development (PGDP) is usually accompanied by high CO_2 emissions and it's measured by GDP per capita. Urbanization (URB) is an important determinant of environmental problems and it's measured by the proportion of urban population in the total population. Energy structure (ES) is also the determinant of environmental pollution and it's reflected by the ratio of coal consumption to total energy consumption. Foreign direct investment (FDI) also affects the ecological environment of the host country and it's expressed by the total amount of foreign direct investment.

Data sources

The data on CO_2 emissions used in this paper are collected from CEADs. The data of ERs and the control variables are taken from China Statistical Yearbook and China Industrial Statistical Yearbook. The time series of data is 2004–2019.

THE TOTAL CARBON EMISSIONS AND CARBON EMISSION INTENSITY OF CTI

The total carbon emissions of CTI showed an increase first and then a decrease from 2004 to 2019, reaching its maximum (25.10 million tons) in 2008. The eastern region had always been the main source of CTI's CO_2 emissions, accounting for about 3/4. The western region ranked second, followed by the central and northeastern regions. In 2019, eastern total carbon emissions accounted for 76.89%, even higher than its proportion in CTI's total gross output (70.42%), which shows that cutting eastern CO_2 emissions was the key to achieving CTI's green development.

Unlike the trend of total carbon emissions, the carbon emission intensity of CTI has been decreasing from 1.781 kilotons/billion CNY in 2004 to 0.564 in 2019 with a drop of 68.33%. Meanwhile, those of all the regions were also on a downward trend. Eastern carbon emission intensity in 2019 was 1.09 times (0.616 kilotons/billion CNY) the national average, which means that it still had much room for decline. Central carbon emission intensity had dropped from 1.28 times (2.284 kilotons/billion CNY) the national average in 2004 to 0.42 times (0.238 kilotons/billion CNY) in 2019 and only it was lower than the national level. This shows that the central region has been the most productive in reducing CEI.

THE IMPACTS OF HETEROGENEOUS ERS ON CTI'S CO_2 EMISSIONS

This paper firstly tests the threshold effects of three ER tools on CTI's total carbon emissions and carbon emission intensity. The test results (table 1) show that only the threshold effect of CER on carbon emission intensity is significant and it's a single threshold effect. Then, this paper uses a panel model to do further research. The Hausman test results of the panel model (not presented here due to the limited space, similarly hereinafter) show that the fixed effect model is appropriate. The regression results are shown in table 2.

The impact coefficient of CER on CTI's total carbon emissions is significantly negative (–0.143, table 2). CER has a single threshold effect on carbon emission intensity. Only when CER is less than the threshold, the coefficient is significant (0.144). This implies that CER has the forced emission reduction effect and green paradox effect on CTI's total carbon emissions and carbon emission intensity, respectively. Formal government environmental regulation can

Table 1

THE THRESHOLD EFFECT TEST RESULTS						
Region	**Explained variables**	**Explanatory variables**	**Number of thresholds**	**Threshold**	**Lower**	**Upper**
China	CEI	CER	Single	3.269	3.240	3.274
Eastern	TCE	CER	Single	–0.364	–1.165	0.267
	CEI	CER	Single	–0.364	–1.165	–0.267
	CEI	MER	Double	–3.459	–3.466	–3.408
				–0.856	–0.948	–0.844
	TCE	PER	Single	–0.857	–0.883	–0.856
Northeastern	TCE	MER	Single	–1.067	–1.122	–1.059

Table 2

THE REGRESSION RESULTS OF CTI						
Coefficient	**TCE**			**CEI**		
CER	-0.143^{***}			0.144^{**} (ER≤3.269)		
				0.002 (ER>3.269)		
MER		–0.107			-0.303^{***}	
PER			0.211			0.254
PGDP	–0.035	0.059	0.039	-0.746^{***}	-0.845^{***}	-0.930^{***}
URB	–0.594	–0.544	–0.640	0.367^{*}	-1.772^{***}	-1.766^{***}
FDI	-0.236^{***}	–0.212	-0.216^{***}	0.142^{***}	0.042	0.045
ES	0.611^{***}	0.598^{***}	0.611^{***}	0.160^{***}	-0.309^{**}	-0.252^{*}
Model	FE	FE	FE	Single threshold	FE	FE

Note: ***, **, * represent significance levels of 1%, 5% and 10%, respectively.

significantly decrease CTI's total carbon emissions, but not the carbon emission intensity. The coefficients of MER on the total carbon emissions and carbon emission intensity both are negative, but only the latter is significant (–0.303). This means that MER's impact on the carbon emission intensity is the forced emission reduction effect. The use of market-based tools such as carbon tax and carbon emissions trading effectively pushes textile enterprises to improve carbon emission efficiency and reduce carbon emission intensity. Both coefficients of PER are positive, but neither is significant.

THE IMPACTS OF HETEROGENEOUS ERS ON CO_2 EMISSIONS OF THE REGIONAL TEXTILE INDUSTRY

Based on the above research, this paper further investigates the regional heterogeneity of the impacts of the three ER tools on CTI's CO_2 emissions. First, the threshold effect test results (table 1) show that in the eastern region, the impacts of CER and PER on the total carbon emissions and CER and MER on carbon emission intensity are all the single threshold effect. In the northeastern region, MER has a single threshold effect on total carbon emissions. The others are not significant. Further, the Hausman test results show that the fixed effect model is more appropriate for most regression analyses except for a few that require a random effect model. The regression results are shown in table 3. Due to the limited space, table 3 only presents the estimation coefficients of the core explanatory variables (ER).

In the eastern region, the impacts of CER on the total carbon emissions and carbon emission intensity both present a single threshold effect. When CER is less than the threshold, the coefficients (table 3) are negative and the forced emission reduction effect plays a dominant role. After it exceeds the threshold, the green paradox effect is dominated. The results show a significant U-shaped relationship between CER and CO_2 emissions in the eastern textile industry. The reason is that the agglomeration of the eastern textile industry is the highest. And when CER exceeds the threshold, it will further increase environmental protection costs and cause a crowding-out effect on the green R&D investment of textile enterprises, which is not conducive to the carbon emission reduction of the eastern textile industry. A significant

Table 3

THE REGRESSION RESULTS ACROSS REGIONS

Region	ER	TCE			CEI		
Eastern	CER	–1.656*** (ER≤–0.364) 0.164*** (ER>–0.364)			–1.479*** (ER≤–0.364) 0.417*** (ER>–0.364)		
	MER		–0.032			0.165* (ER≤–3.459) –0.254** (–3.4590<ER≤–0.856) 0.571*** (ER>–0.856)	
	PER			0.467** (ER≤–0.857) –0.655 (ER>–0.857)			0.835***
Central	CER	–0.239**			–0.017		
	MER		–0.424**			–0.710***	
	PER			–0.485			–0.416
Western	CER	–0.354***			–0.342***		
	MER		–0.443**			–0.526**	
	PER			0.177			0.247
Northeastern	CER	–0.182			0.056		
	MER		–0.404 (ER≤–1.067) 0.218 (ER>–1.067)			–1.395***	
	PER			0.484			–0.630

Note: ***, **, * represent significance levels of 1%, 5% and 10%, respectively.

double-threshold effect is observed between MER and carbon emission intensity. The impact is N-shaped, with coefficients successively positive, negative and positive, which means that only within a certain range can MER play a role in reducing carbon emission intensity. PER shows a single threshold effect on total carbon emissions. The coefficients are positive and negative before and after PER crosses the threshold, respectively, showing an inverted U-shape. The finding is similar to Wu's [8] research results in terms of the impact of PER on CO_2 emissions of China's iron and steel industry. When PER crosses the threshold, its impact mechanism changes from the green paradox effect to the forced emission reduction effect. Besides, its impact on the carbon emission intensity is significantly positive, indicating that its impact mechanism has always been the green paradox effect.

In the central region, the coefficient of CER on the total carbon emissions is significantly negative, indicating a forced emission reduction effect. Strengthening formal ER intensity helps mitigate CO_2 emissions of the central textile industry. The coefficient of CER on the carbon emission intensity is not significant. The coefficients of MER on the total carbon emissions and carbon emission intensity are both significantly negative, showing that the impact mechanisms are also dominated by the forced emission reduction effect. The coefficients of PER are insignificant.

Similar to the central region, CER and MER both exert a significant negative influence on carbon emissions of the western textile industry, suggesting that they both have the forced emission reduction effect on CO_2 emissions. It implies strengthening CER and MER can help lower the total carbon emissions and carbon emission intensity in the western region. The coefficients of PER are not significant.

In the northeastern region, the coefficients of CER and PER are not significant. Besides, MER has a single threshold effect on the total carbon emission, but it's also insignificant. The coefficient of MER on carbon emission intensity is significantly negative, indicating a forced emission reduction effect. MER tools can significantly reduce the carbon emission intensity of the northeastern textile industry.

CONCLUSIONS

This paper employs the threshold model and panel model to analyse the impacts of heterogeneous ERs on CTI's CO_2 emissions and explore their regional heterogeneity. The research results are as follows:

- At the national level, the study concludes CER has a forced emission reduction effect and a green paradox effect on CTI's total carbon emissions and carbon emission intensity, respectively. Strengthening the government's formal environmental regulation and supervision can significantly reduce CTI's total carbon emissions, but it cannot lower carbon emission intensity. MER shows a forced emission reduction effect on the carbon emission intensity. The use of market-based tools can effectively drive textile enterprises to reduce carbon emission intensity. The coefficients of PER are not significant.
- At the regional level, the result verifies a U-shaped relationship between CER and CO_2 emissions in the eastern textile industry. When the threshold is exceeded, CER's influence changes from a forced emission reduction effect to a green paradox effect. And CER shows a forced emission reduction effect in the central and western regions. The impact of MER on the carbon emission intensity of the eastern textile industry is N-shaped, which means MER can lower carbon emission intensity only within a certain range. And its impacts on the central and western regions are also the forced emission reduction effect. There is an inverted U-shaped relationship between PER and the total carbon emission in the eastern textile industry. After the threshold is crossed, the forced emission reduction effect begins to dominate. While PER has always had a green paradox effect on carbon emission intensity in the eastern region.

Based on the findings above, this paper puts forward the following policy suggestions:

- At the national level, China should continue to strengthen formal government environmental regulation to lower the total carbon emissions of the textile industry and make good use of market-based tools such as carbon tax and carbon emissions trading to reduce the carbon emission intensity of the textile industry.
- At the regional level, in the eastern region, formal government environmental regulation and the use of market-based tools should be kept moderate so as not to bring excessive environmental pressure on textile enterprises. And it's necessary to further improve public environmental awareness and supervision. In the central and western regions, it should further strengthen CER and MER to reduce CO_2 emissions in the textile industry. In the northeastern region, it's essential to utilize effectively market-based tools to reduce the carbon emission intensity of the textile industry.

So the government should fully consider the heterogeneity of ERs' impact on carbon emissions, formulate precise policies and use different ER tools flexibly to help CTI to curb CO_2 emissions and achieve the goal of green development.

The prospects for further research are to explore the heterogeneous impacts of ERs on CTI's sub-sectors and take more effective measures to reduce CO_2 emissions of CTI.

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