Different types of environmental regulations and carbon intensity: empirical analysis of China's garment industry

DOI: 10.35530/IT.075.02.20239

ZHANG JIANLEI
HE LIN
SHEN PANDENG

ABSTRACT – REZUMAT

Different types of environmental regulations and carbon intensity: empirical analysis of China's garment industry

Environmental regulation is an important tool to mitigate carbon emissions. To explore the relationships between different types of environmental regulations and carbon intensity (CI) of China's garment industry, this paper uses multiple econometric models to study the effects of command-and-control environmental regulation (CER), market-incentive environmental regulation (MER) and public-participation environmental regulation (PER) the carbon intensity of China's garment industry and analyses their regional heterogeneity. The results show that at the national level, both CER and MER have a green paradox effect on CI of China's garment industry, while the effect of PER is not significant. At regional level, in the eastern garment industry the influence of CER on CI is dominated by the forced emission reduction effect, while MER pushes up the emission intensity within a certain range. Increasing PER helps to reduce the CI of western and North-eastern garment industry. The potential for implications from the results and policy recommendations are also discussed.

Keywords: *China's garment industry, carbon intensity, environmental regulation, green paradox effect, forced emission reduction effect*

Diferite tipuri de reglementări de mediu și intensitatea emisiilor de carbon: analiză empirică a industriei de îmbrăcăminte din China

Reglementarea mediului este un instrument important pentru atenuarea emisiilor de carbon. Pentru a explora relațiile dintre diferitele tipuri de reglementări de mediu și intensitatea emisiilor de carbon (CI) din industria de îmbrăcăminte din China, această lucrare utilizează mai multe modele econometrice pentru a studia efectele reglementării de mediu de comandă și control (CER), reglementarea de mediu care stimulează piața (MER) și reglementarea de mediu cu participarea publică (PER) privind intensitatea emisiilor de carbon din industria de îmbrăcăminte din China și analizează eterogenitatea lor regională. Rezultatele arată că, la nivel național, atât CER, cât și MER au un efect de paradox verde asupra CI a industriei de îmbrăcăminte din China, în timp ce efectul PER nu este semnificativ. La nivel regional, în industria de îmbrăcăminte din est, influența CER asupra CI este dominată de efectul de reducere a emisiilor forțate, în timp ce MER împinge în sus intensitatea emisiilor într-un anumit interval. Creșterea PER ajută la reducerea CI în industria de îmbrăcăminte din vest și din nord-est. Se discută, de asemenea, potențialul de aplicare a rezultatelor și recomandărilor de politici.

Cuvinte-cheie*: industria de îmbrăcăminte din China, intensitatea emisiilor de carbon, reglementarea mediului, efect de paradox verde, efect de reducere a emisiilor forțate*

INTRODUCTION

Under the strategy of China's "carbon peaking and carbon neutralization", green development is the consensus of all industries of the national economy. As a major source of carbon emissions in China, the textile and garment industry has been under strict regulation. In recent years, the Chinese government has actively promoted energy saving and emission reduction in the textile and garment industry, and has formulated and implemented many laws, regulations and policies to drive the sustainable development of the industry. China's 14th Five-Year Plan for the Development of Textile and Garment Industry has proposed to "reach a new level of green development" and set a goal of 18% reduction in CO_2 emissions per unit of industrial value-added in China's textile and garment industry from 2021 to 2025. The garment sector is an important part of China's textile and garment industry and reducing carbon intensity (CI) of the garment industry is of great practical significance to achieve this green development goal.

As environmental quality and sustainable development have become a global concern, governments have been seeking instruments suitable for achieving the objectives. Three generations of tools within environmental policy: command and control, market-based or flexible instruments, and voluntary agreements were identified. Environmental regulation (ER) has been used to reduce the carbon emissions and carbon intensity, and promote effectively regional low-carbon development. However, extant empirical

evidence on the relationship between environmental regulation and carbon emissions was inconsistent. Some studies showed that moderate environmental regulation could reduce CI and strictly and properly designed environmental regulation could stimulate business innovation, and the "compliance costs" due to environmental regulation could be effectively offset by the compensation effect of innovation, so the enterprises improved their productivity and competitiveness. Zhu and Ruth [1] studied the relationship between environmental regulations and carbon emissions using Tobit model. They found that environmental regulations played an important role in energy saving and emission reduction, and improving environmental standards could effectively reduce carbon emissions. On the contrary, some scholars believed that environmental regulation might not contribute to the reduction of carbon emissions, which was also known as the green paradox hypothesis [2]. Ritter and Schopf [3] concluded that green policies would accelerate the extraction of fossil energy, which would lead to a sharp increase in carbon emissions and was not helpful for the improvement of carbon efficiency. Schou [4] argued that environmental regulation could not mitigate carbon emissions, and as natural resources continued to be consumed and the emissions would automatically decrease. Some studies suggested that green paradox effect and forced emission reduction effect coexisted. Min [5] found that the impact of environmental regulation on carbon emissions showed a clear inverted U-shaped trend. Before and after the turning point, the green paradox effect and the forced emission reduction effect were observed, respectively.

As different types of environmental regulations differ in terms of regulatory efficiency, regulatory costs, penalties, and scope of application, scholars also compared the variability of the impacts of three environmental regulations on carbon emissions. Studies by Wang and Huang [6], Dong and Wang [7] and Almeida et al. [8] using Chinese and EU data confirmed that CER, MER and PER all could reduce total carbon emissions. Guo and Chen [9] observed that in China environmental regulation had a greater impact on carbon emissions in developed regions (i.e., eastern region) than in developing regions (i.e., central and western regions). Wu's [10] study revealed that environmental regulation could effectively curb carbon emissions in eastern and central regions, while it did not work as expected in the western region. Abbas et al. [11] used the data of BRICs to prove that MER played a mediating role in the impact of the renewable energy development on carbon emissions.

Research results on the relationship between environmental regulations and carbon emissions in China's garment industry are scarce. Published literature mainly estimated the total carbon emissions of the textile and garment industry [12] and analysed its influencing factors [13]. However, there was a lack of specialized research on the garment industry, and even less on carbon emissions of the industry. Can environmental regulation reduce carbon intensity of China's garment industry? What is the impact of different types of environmental regulations on the garment industry? Given the development level of China's garment industry varies from region to region, are there regional heterogeneities in the impact of various types of environmental regulations? Answering these questions will provide evidence suggesting specific policy recommendations targeting the sustainable development of China's garment industry.

This paper first measures carbon intensity of China's garment industry during 2005–2019, and analyses its trend nationally and by region. Then following the benchmark model and threshold regression model, this paper explores the linear or non-linear relationship between different environmental regulations and carbon intensity of the garment industry.

Furthermore, it examines the heterogeneous effects of various environmental regulations on carbon intensity across different regions. Finally, the potential for implications from the results and some policy recommendations are discussed. Compared with previous studies, the contribution of this paper is that it examines the impact of ERs on carbon intensity in China's garment industry for the first time. On the other hand, it provides a comprehensive analysis of the relationship between ERs and carbon intensity at national and regional levels.

METHODOLOGY AND DATA SOURCES

Estimation model

Benchmark model

In order to study the impacts of different environmental regulations on carbon intensity of China's garment industry, this paper constructs a benchmark panel model of the relationship between environmental regulations and carbon intensity according to the existing studies [14] as follows:

$$LnY_{it} = C_{it} + \beta LnXER_{it} + \theta LnX_{it} + \varepsilon_{it} \qquad (1)$$

where Y_{it} represents carbon intensity of the garment industry of province i in year t. XER_{it} denotes three kinds of environmental regulations: CER_{it}, MER_{it} and PER_{it}. X_{it} is the control variable and ε_{it} is the residual. β and θ represent the regression coefficients of independent variables and control variables.

Threshold regression model

It has been shown that there may be a nonlinear relationship between environmental regulations and carbon intensity. Most scholars used static panel threshold models to measure the nonlinear relationship between independent and dependent variables. Hansen [15] first proposed the threshold model to analyse the influence of independent variables on dependent variables under different threshold values. In the threshold model, each threshold value represents a point of transition. The relationship between variables varies in different ranges and single-threshold or multi-threshold models can be constructed according to the number of thresholds. To investigate whether different environmental regulations have a

significant threshold effect on carbon intensity of China's garment industry, we construct the panel threshold model as described below following the study of Hansen:

$$LnY_{it} = C_{it} + \beta_1 LnXER_{it} \cdot I(XER_{it} \le \gamma_1) + \\ + \beta_2 LnXER_{it} \cdot I(\gamma_1 < XER_{it} \le \gamma_2) + ... + \\ + \beta_n LnXER_{it} \cdot I(\gamma_{n-1} < XER_{it} \le \gamma_n) + \\ + \beta_{n+1} LnXER_{it} \cdot I(XER_{it} > \gamma_{n+1}) + \theta LnX_{it} + \varepsilon_{it} \quad (2)$$

where *i, t* represent the region and year, respectively. *I*(*) is the indicator function that takes the value of 1 when the condition in parentheses holds and 0 otherwise. γ is the threshold value to be estimated. β and θ denote the influence coefficients of independent variables and control variables in different ranges of threshold variables, respectively. The meanings of other variables are consistent with the benchmark model.

Variables

Dependent variables

Carbon intensity (CI) is the amount of CO_2 emissions per unit of gross output of China's garment industry. In general, CI decreases with the technological progress and economic growth.

Independent variables

Command-and-control environmental regulation (CER) is that the government makes laws and regulations to enforce against companies that destroy the environment. CER is expressed as the ratio of completed investment in industrial pollution control of each province to the gross industrial output of industries above the designated size.

Market-incentive environmental regulation (MER) is based on the "polluter pays" principle. The government does not intervene directly in the production of enterprises, but only guides them to reduce environmental pollution by the appropriate market regulation. This paper measures MER by the proportion of sewage charges in each province to the gross industrial output of industries above designated size.

Public-participation environmental regulation (PER), also known as informal environmental regulation exerts pressure on local governments and polluters through public environmental demands or environmental information disclosure. According to Pargal [16], here the entropy method is adopted to calculate the weighted values of residents' income, population density and education level in each province as a measure of PER.

Control variables

The structure of energy consumption (ES) can partly reflect the composition and structure of regional economies. It's measured by GDP per capita. If the energy consumption is mainly carbon-based, carbon emissions of the region are correspondingly higher. And if it is dominated by clean energy, the emissions are lower.

The level of urbanization (URB) is an important indicator of the degree of urban development and is estimated here by the ratio of the urban population to the total population. Urban expansion also brings increased energy consumption and more carbon emissions.

Foreign Direct Investment (FDI) provides a direct measure of a region's capability to attract capital, which is expressed as the total amount of foreign direct investment. Typically, investments often flow to areas where human resources costs are low. These areas, in comparison, are usually backward and have relatively high carbon emissions.

Data sources

All the data used in the empirical research are derived from the China Statistical Yearbook, China Industrial Statistical Yearbook and China Emission Accounts and Datasets (CEADs). CEADs have not yet published data on carbon emissions by sector for 2020 and beyond, and the statistical yearbook prior to 2005 did not have individual statistics on the garment industry. Due to the data availability the research periods cover from 2005 to 2019.

THE CARBON INTENSITY OF CHINA'S GARMENT INDUSTRY

With the Chinese government's increasing emphasis on environmental protection, some industries, including the garment industry, have been subject to stricter regulations on carbon emissions. As a result, the CI of garment industry in China and all its four regions showed a fluctuating decline from 2005 to 2019, although in a different way across regions (table 1). The energy efficiency and environmental performance of the central garment industry have improved significantly. The CI of central garment industry had been decreasing year by year with a convergence trend, from 1.22 times of the national average in 2005 to 0.35 times in 2019. Central region had seen the significant reduction in CI. It is also worth noting that CI in the western region showed a gradual decreasing trend from 2005 to 2013, but then increased year by year from 2014, with recurrence and fluctuations. This resulted in the highest CI in the country, with 55.5 tons per billion CNY in 2019, which was 4.02 times the national average. From 2005 to 2019, its CI decreased by only 7.9 tons per billion CNY, with a decline of 12%, which was the smallest of the four regions. It showed the western garment industry was facing great pressure to reduce its CI. In addition, in the eastern region CI had also been declining, but at a slower pace. In 2019, CI of eastern garment industry was 1.19 times the national average, indicating the eastern region had to make more efforts to reduce CI and improve carbon emission efficiency.

Table 1

CARBON INTENSITY OF GARMENT INDUSTRY IN CHINA AND BY REGION					
Year	Carbon intensity (ton/billion CNY)				
	China	Eastern	Central	Western	North-eastern
2005	74.4	72.0	90.7	63.4	245.4
2006	68.7	64.0	126.4	49.3	225.3
2007	58.8	56.8	75.6	20.9	210.9
2008	53.7	50.0	73.7	20.7	267.8
2009	44.5	42.1	47.7	15.9	204.5
2010	37.4	36.4	29.5	31.4	132.2
2011	29.7	28.8	21.1	15.2	122.0
2012	24.5	24.5	16.6	14.9	82.5
2013	18.2	19.4	10.6	12.2	46.7
2014	16.9	18.2	7.6	15.3	50.2

THE IMPACTS OF ENVIRONMENTAL REGULATIONS ON CARBON INTENSITY OF CHINA'S GARMENT INDUSTRY

This paper firstly examines the threshold effects of three environmental regulations on CI of China's garment industry. The test results (table 2) show that CER has a significant double threshold effect on CI of eastern garment industry, but the single threshold effect is not significant. The same results are observed for MER's influence on CI of national and eastern garment industry, respectively. The significant single threshold effect of PER on CI exists in the western garment industry, while its double threshold effect is not significant. The others don't pass the threshold effect test (due to the limited space, only the significant test results are listed in table 2). Then the Hausman tests (not presented here for the same reason) show that the fixed effect model should be used for the estimation. The regression results are shown in table 3, which again only lists the impact coefficients of core independent variables.

At national level

The impact coefficient of CER on CI of China's garment industry is significantly positive (0.134), which indicates a green paradox effect. This means that tighter CER causes higher CI in the garment industry, which is contrary to the results Wu's [17] research on China's iron and steel industry. The reason may be that the garment industry is typically labour-intensive, rather than capital-intensive, and it is more sensitive to the changes in production cost. The increase in environmental protection costs due to CER had a crowding-out effect on the investment of technological innovation in clothing enterprises, which was negative for the improvement of carbon efficiency. MER shows a double threshold effect on CI, but its coefficient is significant (0.693) only between the two thresholds. It suggests that within this range MER also has a green paradox effect on CI, and the use of MER tools such as transactional emission permits increases CI of China's garment industry instead of reducing it. It may likewise be due to the crowding-out effect of ER costs on technological innovation inputs. The regression coefficient of PER is positive, but not significant.

At regional level

In the eastern region, CER has a double threshold effect on the CI of the garment industry. The impact coefficients (table 3) are both significantly negative, –0.507 and –2.161 when CER is less than the first threshold and between the two, respectively. It demonstrates that CER's impact on CI is dominated

Table 2

THE THRESHOLD EFFECT TEST RESULTS						
Regions	Dependent variables	Number of thresholds	P-value	Threshold values	Lower	Upper
China	MER	Double	0.000	–3.459	–3.466	–3.433
				–3.339	–3.318	–3.229
Eastern	CER	Double	0.000	1.236	1.234	1.318
				1.261	1.229	1.306
MER	Double	0.000	–3.408	–3.459	–3.361	
				–3.229	–3.318	–3.207
Western	PER	Single	0.000	–3.883	–	–

Table 3

THE REGRESSION RESULTS OF GARMENT INDUSTRY IN CHINA AND BY REGION				
Region	**ER**	**CI**		
China	CER	0.134*		
	MER		–0.052 (MER ≥ –3.459)	
			0.693***(–3.459 < MER ≤ –3.229)	
			–0.167(MER > –3.229)	
	PER			0.273
Eastern	CER	–0.507*(CER ≤ 1.236)		
		–2.161***(1.236 < CER ≤ 1.261)		
		0.014 (CER > 1.261)		
	MER		–0.106 (MER ≤ –3.408)	
			0.653***(–3.408 < MER ≤ –3.229)	
			–0.302 (MER > –3.229)	
	PER			1.125***
Central	CER	0.110		
	MER		–0.173	
	PER			0.671*
Western	CER	0.160		
	MER		–0.160	
	PER			–0.494(PER ≤ –3.883)
				–0.628*(PER > –3.883)
North-eastern	CER	–0.329		
	MER		–0.534***	
	PER			–0.978*

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

by a forced emission reduction effect and increasing formal environment regulation helps reduce CI of eastern garment industry. A double threshold effect is also observed between MER and CI, but the regression coefficient is only significant (0.653) between the two thresholds. This means that within a certain range MER pushes up CI of eastern garment industry. The coefficient of PER is significantly positive (1.125), showing a green paradox effect.

In the central region, the impact coefficient of PER is also significantly positive (0.671), showing a green paradox effect, similar to that in the eastern region. The other coefficients are not significant and will not be discussed here.

In the western region, there is a single threshold effect between PER and CI. The impact coefficient is only significant (–0.628) when PER is greater than the threshold. It indicates that PER can effectively reduce CI only when the intensity of PER exceeds a certain threshold, contrary to the results in the eastern and central regions.

Similar to the western region, PER also has a forced emission reduction effect (–0.978) on the CI of North-eastern garment industry. Therefore, enhancing public participation in environmental protection can help reduce CI in the Western and North-eastern garment industry, but not curb the growth of CI in the Eastern and central. In addition, the coefficient of MER is also significantly negative (–0.534), which means MER can be used as effective tool to supervise and force companies to reduce the CI of North-eastern garment industry.

CONCLUSIONS AND POLICY RECOMMENDATIONS

This paper uses multiple econometric models to study the impacts of three different types of environmental regulations on carbon intensity of China's garment industry and explore their regional heterogeneity. The research results are as follows:

- At national level, CER has a green paradox effect on CI of China's garment industry and increasing formal environment regulation is not beneficial to the reduction of CI of garment industry. The relationship between MER and CI is also dominated by a green paradox effect. The impact coefficient of PER is not significant.
- At regional level, the empirical results indicate a significant heterogeneous effect of environmental regulations on CI in different regions. Specifically, in eastern garment industry CER shows a forced emission reduction effect on CI, whereas MER has a significant positive effect which means MER has increased CI of eastern garment industry within a certain range. A forced emission reduction effect of MER on CI exists in the North-eastern region. The impact of PER on CI is found to be different among

four regions: enhancing public participation in environmental protection can help reduce CI of the western and North-eastern garment industry, but it is not helpful in the eastern and central regions.

Based on the findings above, this paper provides the following policy recommendations to promote the green and low-carbon development of China's garment industry. (1) Environmental policies or measures in China's garment industry should be gradual and not simply pursue excessive regulatory intensity. They should keep CER and MER within reasonable limits to avoid putting too much pressure on garment companies in environmental protection. (2) The eastern region should continue to advance the innovation of CER methods, set stricter environmental standards and strengthen policy implementation. In the Northeast area, a combination of CER and MER should be adopted. Local government should implement a tougher environmental enforcement and accelerate the widespread application of MER. On the other hand, as in the western region, it is necessary to raise public awareness, encourage the public to actively participate in environmental protection and improve the supervision and disclosure requirements for enterprises.

Despite the contributions, this study also has limitations. Due to data availability, the data of China's garment industry from 2005 to 2019 is used as the research sample. More information may be revealed in the future if the data in 2020–2022 is available.

ACKNOWLEDGEMENTS

This work was supported by Zhejiang Province Soft Science Research Program (2024C35095).

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Authors:

ZHANG JIANLEI[1], HE LIN[1], SHEN PANDENG[2]

[1]Jiaxing University, Faculty of Marketing, College of Business,
No.899 Guangqiong Rd, 314001, Jiaxing, China
e-mail: zjl200640256@163.com

[2]Jiaxing Vocational and Technical College, Faculty of Fashion Design, College of Fashion Design,
No. 547 Tongxiang Avenue, 314036, Jiaxing, China
e-mail: 499976120@qq.com

Corresponding author:

HE LIN
e-mail: career2378@163.com