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ENVIRONMENTAL REGULATION, INDUSTRIAL AGGLOMERATION, AND SUSTAINABLE DEVELOPMENT IN THE CHINESE TEXTILE INDUSTRY

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Abstract. Is it possible for the imposition of environmental regulation to develop the textile industry? Is it possible to balance quality and efficiency with energy conservation and emission reduction and achieve the sustainable development of the textile industry? The main objective of this study is to analyze the effects of the environmental regulation on industrial agglomeration and industrial efficiency within the textile sector. The findings reveal that, first, environmental regulation has significantly facilitated the agglomeration of the textile industry to regions with less stringent environmental standards. The restructuring and optimization of domestic value chains have also been promoted. Second, environmental policies in the process of the promotion of the industrial agglomeration are accompanied by a significant improvement in industrial efficiency. This improvement has contributed to the achievement of sustainability goals in the textile domain. Third, the influence of environmental regulations on industrial agglomeration and industrial efficiency improvement of the textile industry is strongly heterogeneous in terms of ownership. This impact is more significant in state-owned industries and private industries. This study holds substantial theoretical significance and practical relevance in promoting environmentally friendly and sustainable progress in the Chinese textile industry.

Keywords: environmental regulation, industrial agglomeration, industrial efficiency, sustainable development.

JEL Classification: L16, L67, H23.

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Introduction

Since China's market-oriented reforms, the country's manufacturing enterprises have made full use of the cost advantages of resource factors, preferential taxation, and other policies to actively integrate into the global value chain dominated by multinational corporations. This has been achieved through industrial transfer and other means and has not only developed the manufacturing industry itself[1] but also the optimal allocation of domestic resources. In addition, the evolution of spatial patterns of industrial agglomeration improves industrial efficiency (Li, 2020). However, in terms of traditional manufacturing industries, such as the textile industry[2], developed countries are taking advantage of technology to gradually transform the textile industry into a technology-intensive industry. Chinese enterprises are using technology to reclaim their share of the international textile market. Meanwhile, competition from developing countries, such as India, Brazil, and Vietnam, is also intensifying, and other developing countries are developing their textile industries in large numbers. These competitors are conducting incoming processing trade and actively seizing the international market share of China's textile industry. After years of progress, the textile industry has achieved a fully integrated industrial chain in China. The industry has facilitated the employment of a large number of people in China and has a strong ability to self-regulate market risks as well as more obvious international competitive advantages (Liu et al., 2009). However, the overall industrial efficiency of the textile industry in China is not high, with the gradual disappearance of the population dividend. As such, problems such as weak innovation capacity and insufficient brand influence are becoming increasingly prominent. Moreover, the efficiency of the industry's environmental impact and energy use has not formed a global competitive advantage. The crude production method involving environmental degradation and high energy consumption has kept the textile industry in an inefficient mode of operation (Gao & He, 2021). According to national statistics, the year 2019 witnessed the textile industry consuming a total of 73.98 million tons of standard coal. The energy consumption was 2.45 times higher than that in 2000. In the same period, emissions of carbon dioxide increased by 1.50 times (Cai et al., 2018). Thus, the textile industry is now faced with the dual predicament of "low industrial efficiency and inefficient use of environmental energy". How, then, can sustainable development in the textile industry be achieved by promoting its development while simultaneously balancing quality and efficiency with energy saving and emission reduction, thereby cracking the "dual" predicament? What is the appropriate solution?

Environmental regulation policies are the major focus and mean for promoting green economic transformation and improving ecological and environmental quality (Liu et al., 2021). The environmental regulatory measure implemented under cleaner production stan-

[1] Based on the most recent data released by the Ministry of Industry and Information Technology, it can be observed that the proportion of global manufacturing value added has witnessed a substantial surge, soaring from a meager figure of under 3% in 1990 to approximately 30% in the year 2021.

[2] According to data released at the end of 2019, from the fourth national economic census, in both the manufacturing and wholesale and retail sectors, the textile and garment industry had a total of 1.21 million legal entities, with assets of RMB 9.37 trillion. In 2018, the business revenue reached RMB 12.7 trillion or more than 14% of China's total GDP. This made the textile industry the second largest industrial sector in China after the electronics and information industry. Therefore, it is important to study traditional industry issues using the textile industry as an example.

dards introduced in 2003 under the lead of the Ministry of Ecology and Environment of China has become the key to addressing the above "dual" challenges. The cleaner production standard required of the textile industry forms an important part of this environmental regulation. Textile enterprises are required to continuously adopt measures, such as improving design, using clean energy and raw materials, and advanced process technologies and equipment to reduce pollution at source. These steps complete the transformation of the textile industry from "end-of-pipe treatment" to "front-end prevention" of pollution. This can improve resource use efficiency and regional industrial efficiency (Han & Hu, 2015; Wen et al., 2021). These steps also help reduce or avoid the generation and emission of contaminants during production, services, and product use, thereby mitigating the hazards to the environment.

Industrial agglomeration pertains to the phenomenon where a particular industry exhibits significant concentration within a well-defined geographic region, with various elements of industrial capital continuously converging within a spatially limited scope (Wang et al., 2023). This also implies that when the textile industry faces the constraints of cleaner production standards, the relative differences in the conditions of regional resource factor supply and product demand faced by the textile industry arise owing to variations in the enforcement levels of local environmental regulations. This affects the decisions of the textile industry regarding site selection and production, causing the evolution in the spatial pattern of industrial agglomeration (Song & Zhao, 2019). Moreover, it provides an opportunity for the textile industry to establish or enhance its relative competitiveness and improve industrial efficiency (Sheng, 2021). Hence, elucidating the correlation between environmental regulation, industrial agglomeration, and industrial efficiency holds great theoretical value and practical significance. This clarification is necessary to address the dual predicament of the textile industry, promote the green and sustainable progress in the Chinese textile industry.

However, there is a certain gap in previous studies regarding the above issues. On the one hand, existing literature mainly focuses on examining the connection between the environmental regulation of "terminal control" and industrial upgrading (Fu & Li, 2010; Huang & Qi, 2022). Assessing the influence of "front-end control" environmental regulation (cleaner production standards) on industrial efficiency poses challenges. On the other hand, the majority of analyses in existing literature are from the perspective of intergenerational equity and finance (Tian & He, 2021; Zhao et al., 2022). There remains a discernible gap concerning the study of the impact of environmental regulation based on the domestic and foreign dual value chains. In addition, as the intermediary mechanism of environmental regulation to promote industrial upgrading, cost and innovation effects have been widely discussed (Han, 2018; Jin & Song, 2020). However, the intermediary role of industrial transfer still lacks empirical verification.

This study examines the impact of cleaner production standards (as an environmental regulatory policy) on decisions such as industrial agglomeration and industrial efficiency in the textile industry. This is achieved using matched data on cities and industrial enterprises at the prefecture level. In comparison with existing literature, this study makes the following contributions: first, regarding research content, this study extends the research on environmental regulation by examining how it influence the industrial agglomeration and industrial efficiency within the textile industry. This is done by taking a "front-end prevention and control" perspective on environmental regulation. It finds that the implementation of cleaner production standards has had a substantial positive impact on both the agglomeration and efficiency of enterprises within the textile industry. Second, regarding research structure, this study integrates environmental regulation, industrial agglomeration, and industrial efficiency into a unified framework to explore the impact of environmental regulation on industrial agglomeration and industrial efficiency of the textile industry. Additionally, the results reveal the internal logic between the two and expand the existing research boundary to a certain extent.

The remaining parts of the paper are structured as follows: Section 1 presents the theoretical mechanism. Section 2 presents the research design, including data, variables, and econometric model setting. Section 3 presents the empirical results and analysis, including the basic regression results and robustness tests, and the last Section presents the research findings and policy recommendations.

1. Theoretical mechanisms

Since joining the World Trade Organization (WTO), driven by both domestic and international demands, the overall textile industry in China has experienced sustainable development and stable growth. The scale of the industry has continued to expand, and a domestic value chain has been formed and increasingly perfected. The industry has helped to address the employment problems of many people in China (Liu et al., 2009). In contrast, the textile industry in China is mainly embedded in global value chains through Original Equipment Manufacturer (OEM) processing for large international companies and brands. Although this approach facilitates access to advanced knowledge and technology (Odei & Stejskal, 2020), the value added in the processing and manufacturing chain is low, and the textile industry is at risk of low-end lock. In addition, the textile production process involves the utilization of slurries, oils, dyes, and chemical additives for product treatment, all of which generate a large amount of wastewater. The operation of looms and other equipment consumes a great deal of energy and emits plenty of carbon dioxide and dust. Thus, the textile industry is now faced with the dual predicament of "low industrial efficiency and inefficient use of environmental energy".

Since China's market-oriented reforms, the criteria for the promotion of local officials have transferred from mainly political performance to economic performance (Yang et al., 2010). Within the framework of China's decentralized governance system, local governments control a large amount of local economic resources. Moreover, having the attribute of "political figures" means that local government officials will adjust their practices in accordance with the performance evaluation standards established by the central authorities and also adjust the weight of those criteria in their utility function (Zhou, 2004; Wang et al., 2017). They aim to gain maximum political promotion, and this ultimately results in significant differences in local economic and social progress (Tao et al., 2021). Consequently, to achieve political promotion, local government officials may be willing to relax environmental standards to draw investments and promote economic development. Such officials are willing to sacrifice the regional ecological environment for short-term economic growth, specifically to meet assessment objectives and thereby demonstrating weaker enforcement of environmental regulations (Zhou, 2007; Yu et al., 2020). In the performance appraisal system of officials, environmental performance criteria reflecting sustainable development constitutes an important factor that influences the promotion of local government officials. These criteria make the performance orientation of government officials less GDP-oriented and inevitably lead local governments to reinforce the development and enforcement of environmental regulatory policies (Heberer & Senz, 2011). As such, does the differentiated level of enforcement of local environmental regulations, which vary according to the preferences of local government officials, contribute to the agglomeration of the textile industry in "environmental regulation depressions?"

For the textile industry, the economic implications associated with environmental regulation compliance constitute a significant factor that merits careful consideration during the decision-making process. An increase in compliance costs leads to a loss of cost advantage, which ultimately leads to a reduction in market share and profits (Wang & Xu, 2015). According to the market failure theory and the pollution haven hypothesis, polluters will not take the initiative to deal with their pollution emissions. However, they are more willing to relocate to regions with laxer environmental regulations. With the continued strengthening of environmental regulation enforcement, the profit margins of the textile industry continue to be compressed. Hence, the incentive for textile industrialists to expand their living space and increase profits by moving outward increases, realizing the agglomeration of the textile industry in areas with weak environmental regulations (Han, 2018).

On the other hand, when environmental regulations are reinforced, the textile industry will face a great deal of uncertainty in its choice of technological innovation to resolve its pollution problems (Yu, 2015). Various technical difficulties will inevitably arise in the process of technological innovation, which may lead to uncertainty in the success of technological development and feature a long R&D cycle. When is launched in the market, even if the development is successful, the new product may not be accepted by consumers because of the product's performance, price, and other factors (Chao et al., 2021). Based on the stakeholder theory, environmental regulation can be seen as the concentrated embodiment of the environmental demands of various stakeholders. To meet the demands of different stakeholders regarding the environment, the textile industry and the associated polluters will further decide what environmental strategies to adopt to meet the relevant environmental regulations. In contrast, the option of transferring the entire textile enterprise or the polluting production chain out of the country involves less pressure and risk for the enterprise because of the inter-regional differences in the implementation of environmental regulations and an active investment promotion focus by local governments. Deciding to move out of the country will result in relatively less cost and uncertainty (He et al., 2013). Hence, the textile industry choosing to outwardly transfer is the most direct coping approach.

Based on the above analysis, this study proposes the following:

Hypothesis 1 (H1): Differentiated levels of environmental regulation constraints cause the textile industry to move to regions with weaker environmental regulation constraints, achieving industrial agglomeration.

According to the resource-based theory, the textile industry can gain competitiveness by integrating and utilizing its existing resources. If the textile industry is in a region with strong environmental regulation constraints, the industry can transfer the low-end processing and manufacturing links that do not possess comparative advantages to regions with weaker environmental regulation constraints. On the one hand, because the low-end processing and manufacturing links of the textile industry are characterized by high pollution, transferring out the highly-polluting production chain allows the industry to avoid environmental regulation penalties and the cost of improving their production chain. This facilitates capital flow to productive services, such as R&D and design. However, high-quality service inputs may stimulate the extension of production from marginal to core manufacturing, which improves industrial efficiency in the textile industry (Grossman & Rossi-Hansberg, 2010).

In regions with stronger environmental regulations, the development of R&D and design in the textile industry enables R&D and production to be linked inter-regionally. This facilitates the breaking of administrative protection and market barriers between domestic regions and the formation of hyper-scale markets. In turn, this allows the industry to more fully exploit the potential of the domestic market and integrate resources from upstream and downstream of the textile industry value chain. This improves industrial efficiency (Beverelli et al., 2019).

Based on the above analysis, this study proposes the following:

Hypothesis 2 (H2): The agglomeration of textile production links caused by environmental regulations in areas with weaker environmental regulations has improved the efficiency of the textile industry in areas with stronger environmental regulations.

Regions with laxer environmental regulation constraints can exploit their comparative advantages, such as raw materials, energy, and labor, to fully incorporate advanced technologies, advanced management methods, business concepts, and high-level talents. This occurs when taking over the processing and manufacturing aspects of the textile industry that has transferred from regions with strong environmental regulation constraints to improve industrial efficiency (Zhang & Huang, 2017).

First, there is the market integration effect. Differentiated environmental regulation causes the processing and manufacturing links of the textile industry to move and cluster in regions with laxer environmental regulations. In accordance with the industrial agglomeration theory, when a cluster forms a certain scale, the textile industry in the cluster promotes its productivity by improving the efficiency of labor matching, sharing intermediate inputs, and learning technology and knowledge. This, in turn, improves industrial efficiency in the textile industry (Duranton & Puga, 2004; Combes et al., 2012).

Second, based on the Porter hypothesis, after taking over the production and processing links of the textile industry in regions with weaker environmental regulations, the local textile industry can fully incorporate advanced production technology and management experience (Porter, 1998; Zhang & Huang, 2017). In addition, the industry can also take the land, labor, and production raw materials price advantages at the places being taken over. This is coupled with investment promotion that grants preferential policies in taxation and other aspects, which reduces financial constraints, whereby the textile industry would be forced to carry out innovation in the production chain. This will improve industrial efficiency in the textile industry (He et al., 2019).

Finally, improving industrial efficiency in production links can push R&D, design, after-sales, and other high value-added links to invest in a large number of service elements to improve resource allocation efficiency and further improve industrial efficiency in the textile industry (Grossman & Krueger, 1995; Navas-Aleman, 2011).

Based on the above analysis, this study proposes the following:

Hypothesis 3 (H3): The agglomeration of textile production links caused by environmental regulations in areas with weaker environmental regulations has promoted the efficiency improvement of the textile industry in areas with weaker environmental regulations.

2. Research design

2.1. Model setting

In the light of the DID technique, this study assesses the impact of the environmental regulation of the Cleaner Production Standard for the Textile Industry (HJ/T 185-2006) as an exogenous impact on the industrial agglomeration and efficiency. The Cleaner Production Standard for the Textile Industry was promulgated by the Ministry of Ecological Environment of China in 2006 and refers directly to the cleanliness of production processes in the textile industry. This standard provides a comprehensive evaluation and ranking of textile enterprises based on their production and emissions. The standard thereby gives the textile enterprises clear criteria for evaluating and assessing clean production techniques, which is conducive to improving regional industrial efficiency and abating environmental pollution.

Although the cleaner production standards for the textile industry promulgated by the state are uniformly normative for enterprises in all regions, local governments have relatively large discretionary power when it comes to implementing environmental regulations. This frequently causes the degree of impact from environmental regulation implementation to vary because of inter-regional differences (Zhang et al., 2018). Therefore, this study constructs experimental and control groups for DID tests. In this study, control and experimental groups were constructed based on the contaminant clearance levels[3] of the cities at the prefecture level (Vig, 2013; Campello & Larrain, 2016). In particular, the mean contaminant clearance levels for the two years prior to 2006 (i.e. 2004 and 2005) were calculated for the sample cities at the prefecture level (see "variable settings" for the calculation method). On this basis, half of the lowest contaminant clearance levels were defined as the experimental group, and half of the highest contaminant clearance levels were defined as the control group. To eliminate the differences between time and region, a DID model with fixed effects of year and city was constructed for empirical testing, and the econometric model is as follows:

$$TS_{i,t} = \beta_0 + \beta_1 \times did_{i,t} + \gamma \times X_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t}; \quad (1)$$

$$did_{i,t} = post \times treat, \quad (2)$$

[3] A positive correlation exists between the level of contaminant clearance and the strength of environmental regulation enforcement in the region.

where the notation i refers to the city at the prefecture level; t is the year; $TS_{i,t}$ represents the level of industrial agglomeration within the textile industry in city i at the prefecture level during year t; and $did_{i,t}$ represents the interaction effect between *post* and *treat*. Next, *post* is an indicator variable, which takes a value of 1 for 2006 and after the implementation of the cleaner production standard for the textile industry; otherwise, it takes a value of 0. Then, *treat* is also an indicator variable, which takes a value of 1 when the city is in the experimental group and 0 when the city is in the control group; $X_{i,t}$ represents other control variables. Finally, δ and λ denote the fixed effects of city and year, respectively. The coefficient of β_1 measures the effect of environmental regulation on the agglomeration of the textile industry. If β_1 is significantly positive, it indicates that environmental regulation has caused a significant agglomeration of the textile industry to regions where environmental regulation is weaker.

To test whether the environmental regulation of cleaner production standards is accompanied by improvement in regional industrial efficiency in influencing the process of industrial agglomeration in the textile industry, a model has been set up as follows:

$$VAR_{i,t} = \beta_0 + \beta_1 \times did_{i,t} + \beta_2 \times did_{i,t} \times TS_{i,t} + \gamma \times X_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t}, \quad (3)$$

where $VAR_{i,t}$ denotes the value-added rate of the textile industry (used to measure the industrial efficiency of the textile industry). When the coefficients of β_1 and β_2 are both significantly positive, it indicates that the environmental regulation of cleaner production standards has the dual effect of industrial agglomeration and improving the industrial efficiency of the textile industry. The other variables are the same as those in Model (1).

The above models can only demonstrate that the textile industry agglomeration (driven by cleaner production standards) can improve industrial efficiency in the textile industry in regions with weaker environmental regulation. However, this does not reflect the situation of the textile industry in regions with a stringent environmental regulation constraints. Therefore, to further test whether the improvement of industrial efficiency in the textile industry exists in regions with stringent environmental regulations, the following model has been constructed:

$$VAR_{i,t} = \beta_0 + \beta_1 \times TS_{i,t} + \gamma \times X_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t}, \quad (4)$$

where, if β_1 is positive, indicating that the agglomeration of textile industries has improved industrial efficiency in the textile industry. The remaining variables bear the same meaning as those in Model (3).

2.2. Variable setting

2.2.1. Explanatory variables

(1) Industrial agglomeration (*TS*)

Research on relative industrial agglomeration has been conducted by scholars such as Zhao and Yin (2011), Chen (2002), and Liu et al. (2011). In this way, the methods of these studies can be used to measure the change in industrial agglomeration. Specifically, this study used the year in which the enterprise was established to identify the new situation of a region's textile industry, representing the entry of the textile industry. Then, the newly increased output will be obtained. Industrial agglomeration will be assessed with the ratio of the newly added value of the industries to the total value of the regions.

(2) Industrial efficiency (*VAR*)

The enhancement of industrial efficiency stands as the essential pathway to achieve sustainable development within the textile industry (Li et al., 2010). This study used the ratio of the added value of the industry to the total production value to measure industrial efficiency. The ratio conveys more comprehensive information (Antràs et al., 2012).

2.2.2. Sample grouping variables

Some scholars have adopted industrial wastewater discharge compliance rates and industrial sulfur dioxide removal rates as proxy variables for the contaminant clearance level (*QCL*). However, relying solely on a single indicator might not provide a comprehensive representation of the environmental regulation intensity within a region. Therefore, this study referred to the method of Fu and Li (2010) and chose the weighted average of four indicators. Specifically, wastewater discharge compliance rate, sulfur dioxide removal rate, soot removal rate, and comprehensive utilization rate of solid waste are used to measure the contaminant clearance level in cities at the prefecture level. The specific steps are as follows:

First, the four abovementioned indicators were normalized through mathematical transformation, and their values were set in the range of 0–1.

$$YS^{\mathrm{b}}{}_{i,j,t} = [YS_{i,j,t} - Min(YS_{i,\,j})]/[Max(YS_{i,j}) - Min(YS_{i,j})], \tag{5}$$

where, $YS_{i,j,t}$ are the original values of indicator j of city i in year t, and $Min(YS_{i,j})$ and $Max(YS_{i,j})$ represent the maximum and minimum values of indicator j (j = 1, 2, ..., m) in all years of city i (i = 1, 2, ..., n), respectively. The superscript b implies that the corresponding variable is normalized. Therefore, $YS^{b}{}_{i,j,t}$ are the normalized values of indicator j of city i in year t.

Second, the weights for each indicator are calculated as follows:

$$W_{i,j,t} = YS_{i,j,t} / \overline{YS}_{j,t}, \tag{6}$$

where the numerator of Equation (6) is the indicator j of city i in year t, and the denominator is the average value of this indicator for all cities at the prefecture level in the same year.

Finally, the contaminant clearance level of cities at the prefecture level is calculated as follows:

$$QCL_{i,t} = \sum\nolimits_{j=1}^{4} W_{i,j,t} \times YS^{b}{}_{i,j,t} / 4. \tag{7}$$

2.2.3. Control variables

In order to guarantee the model's unbiased estimation, this research comprehensively considers as control variables factors that could potentially influence the upgrading and transfer of the textile industry. Referring to Song et al. (2021), this study selects control variables from six dimensions. (1) The economic development level (*pgdp*) is measured using the logarithm of GDP per capita (Huang & Qi, 2022). (2) The tax burden level (*tax*) is measured using the logarithm of the actual tax burden of the region. The change in tax burden is one of the important factors that textile enterprises should consider when making investment decisions (Liu et al., 2019). (3) The infrastructure level (*inf*) is measured using the actual paved road area per capita. The level of infrastructure may affect the supply cost of textile enterprises (Rao et al., 2019). (4) The population agglomeration level (*lm*) is quantified by the number of individuals per square kilometer. Population agglomeration measures the demographic dividend, which directly affects the production behavior of the textile industry (Su & Wei, 2013). (5) The human capital level (*hs*) is quantified by the number of general undergraduate and college students enrolled in a prefecture-level city. (6) Employee compensation level (*pw*) is indicated using the average salary of employees in a prefecture-level city. Employee compensation levels reflect labor costs in the textile industry (Niu & Jiang, 2011).

In addition, the autocorrelation and multicollinearity between variables were also tested. The variance expansion factor (VIF) of the independent variable and each control variable of the equation is 2.17, which is far less than 10. This indicates that the independent variable and control variables in the model are not seriously collinear. The F statistic of the Wooldridge test for autocorrelation in the panel data is 0.894, and the p-value is 0.3457, both of which are greater than 0.1. This indicates that there is no autocorrelation problem.

2.3. Sample selection

The textile industry data at the prefecture level was obtained by summing the textile enterprise data in China's industrial enterprise database to the prefecture level. Further, as the National Bureau of Statistics of China officially released the second revision of the industry classification standards in May 2002, there were inconsistencies in the industry codes of individual enterprises in the database. This can lead to bias in the data statistics. Moreover, the 2010 data in the industrial enterprise database was seriously lacking, so the industrial enterprise samples before 2003 and in 2010 were excluded. Meanwhile, in this study, invalid samples with 0 or negative values for the main variables (such as gross industrial output, fixed assets, and intermediate inputs) were excluded before summing up the data. Raw data for other prefecture-level city variables were obtained from the statistical yearbooks of each prefecture-level city, the China City Statistical Yearbook, and various public information. The descriptive statistics for the main variables in this study are presented in Table 1.

Table 1. Variable descriptions and descriptive statistics

Variable type	Variable symbols	Variable name	N	mean	sd	min	max
Predicted variable	*TS*	Industrial agglomeration	1239	0.089	0.138	0.000	0.787
	VAR	Industrial efficiency	1211	0.945	0.071	0.613	1.000
Sample grouping variables	*QCL*	Contaminant clearance level	1239	3.285	8.987	0.044	66.242

End of Table 1

Variable type	Variable symbols	Variable name	N	mean	sd	min	max
Control variables	*pgdp*	Economic development level	1235	9.593	0.745	4.595	11.809
	tax	Tax burden level	1218	12.455	1.585	6.568	16.477
	inf	Infrastructure level	1232	166.500	1091.06	0.020	20840
	lm	Population agglomeration level	1236	413.866	309.706	10.66	2209.31
	hs	Human capital level	1189	65265.7	119308.9	0.000	796006
	pw	Employee compensation level	1233	19288	8439.411	15.06	118685.3

3. Empirical results and analysis

3.1. The effect of environmental regulations on the agglomeration of the textile industry

This research employs the classical DID model to estimate the net effect of the environmental regulation in the textile industry on the agglomeration of industries in the textile industry. The results of the estimation are detailed in Table 2. As presented in Columns (1) and (2), the environmental regulation has significantly contributed to the transfer of the textile industry from regions with stronger environmental regulation constraints to regions with weaker environmental regulation constraints. This has resulted in the agglomeration of the textile industry in "environmental regulation depressions". In addition, the effect of environmental regulations on the agglomeration of the textile industry is even more significant after the inclusion of a series of control variables. A few previous studies also support this finding, such as Wang and Zhong (2016) and Song and Zhao (2019). Those studies found that reducing the level of environmental regulation causes an inflow of industries with high energy consumption. Our findings support the "pollution haven" hypothesis as well. However, Sanna-Randaccio and Sestini (2012) discovered that an elevation in a country's environmental tax will result in the transfer of some or all of the country's production to nations with less stringent environmental regulations, achieving industrial agglomeration. If the country possesses a relatively large market scale, even if it strengthens the collection and management of environmental tax, the relevant industry will not transfer out.

As presented in Columns (3) to (5), the coefficients of environmental regulations are all positive, further confirming the above results. However, a significant effect was only observed on state-owned and private textile industries, with no significant effect on foreign enterprises. The possible reason for this finding is that a foreign enterprise not only brings advanced management concepts and technological facilities to regional development but also influences the technological innovation capacity of the taking over regions through technological spillover effects and the forward–backward correlation effects between industries. Therefore, under the traditional GDP-based performance appraisal and promotion mechanism, local governments pursue "incomplete implementation" of environmental regulatory policies to

Table 2. The effect of environmental regulation on the agglomeration of the textile industry

Variables	(1)	(2)	(3)	(4)	(5)
	Full samples		State-owned industry	Private industry	Foreign-owned industry
did	0.0131* (1.2000)	0.0221** (2.0112)	0.0160* (1.7432)	0.0119** (0.9317)	0.0110 (0.7105)
lm		−0.000049** (−2.1973)	−0.000055 (−0.3514)	−0.0001** (−2.1730)	0.00001 (0.3433)
pw		−0.000013** (−2.0639)	0.00001 (1.2094)	−0.00002** (−2.2815)	−0.000012* (−1.7341)
hs		0.000014 (0.4989)	−0.00002 (−0.6800)	0.00006* (1.6563)	−0.00007* (−1.9550)
inf		−0.000013* (−0.9242)	−0.00003* (−0.0344)	−0.000016* (−0.7901)	−0.00004* (−0.2551)
pgdp		−0.0244*** (−3.5214)	−0.0031 (−0.4524)	−0.0191** (−2.2265)	−0.0203** (−1.9946)
tax		0.0035* (1.7250)	0.0010 (0.4161)	0.0039 (1.6033)	0.0007 (0.2263)
_cons	0.0849*** (18.6800)	0.3164*** (5.6157)	0.0147 (0.1955)	0.2949*** (4.3072)	0.2858*** (3.2155)
Fixed effects	Control	Control	Control	Control	Control
N	1239	1164	1164	1164	1164
R^2	0.2607	0.1832	0.0448	0.1446	0.1460

Note: ***, **, and * denote a significant regression coefficient at the levels of 1%, 5%, and 10% respectively, with t-values in brackets. Same below.

attract more foreign-invested enterprises to develop the local economy. Examples of this incomplete implementation include nominal implementation, selective implementation, and negative implementation (Sun & Qu, 2019). On this basis, the production technology standards for the entry of foreign-owned textile industries should be further unified and standardized. The aim should be to create a relatively fair production environment and foster a robust and sustainable growth trajectory for the textile industry.

The estimation results in Column (2) were used to analyze the effect of the control variables on the industrial agglomeration of the textile industry. Among these results, only the coefficient of *hs* was insignificant. This could be attributed to the labor-intensive nature of the textile industry, making it insensitive to changes in the level of human capital. All other control variables had significant effects on the agglomeration of textile industries, but only the regression coefficient of tax burden (*tax*), which promoted the agglomeration of textile industries, was significantly positive. This may be because the higher the level of tax burden, the heavier the tax pressure on the textile industry. Under a heavy tax burden, the industry must have sufficient funds to respond to the environmental regulation. This burden has forced the textile industry to move to regions with weaker environmental regulation constraints, realizing the agglomeration of the textile industry in areas with weak environmental regulations. Some possible reasons for the inhibition effect of other control variables on the textile industry transfer are that areas characterized by elevated economic development and wages are more able to attract the inflow of economic factors, such as talent and capital. Another reason is that the benefits of factor aggregation outweigh the costs of environmental regulations (Copeland & Taylor, 2004), which inhibits the transferring out of the textile industry and is not conducive to the agglomeration of the textile industry (Wang & Zhong, 2016). Moreover, regions with higher levels of infrastructure and population agglomeration have lower general labor costs, which reduces the probability of industrial transfer, inhibiting industrial agglomeration (Fenge et al., 2009; Wen & Zhang, 2019).

3.2. The effect of environmental regulation on the industrial efficiency of the textile industry

Model (3) is further estimated in this study by using the DID model to test the effect of the environmental regulation on industrial efficiency. The results of the estimation are detailed in Table 3. As presented in Columns (1) and (2), environmental regulation has significantly improved the regional industrial efficiency of the textile industry in regions with weaker regulation. In addition, such an industrial efficiency effect of environmental regulation becomes more evident after the inclusion of a series of control variables. Yu et al. (2020) found that environmental target constraints would make local governments improve industrial efficiency by strengthening environmental regulations and other behaviors. This finding further supports the conclusion of this study. Gale and John (1999), through the study of heavy pollution industries in Europe, discovered that environmental regulation exerts a more substantial influence on the overall development of the industry in the long term. This finding is also confirmed by our results, as depicted in Figure 2. Some documents expand our research. For example, using data on Korean manufacturing enterprises, Yoo and Heshmati (2019) found that environmental regulations are more beneficial to improving the production efficiency of green industries than high-polluting manufacturing industries.

Table 3. The effect of environmental regulation on industrial efficiency in the textile industry

	(1)	(2)	(3)	(4)	(5)
	Full samples		State-owned industry	Private industry	Foreign-owned industry
did	0.0066* (1.5639)	0.0104** (2.1731)	0.0160* (1.5392)	0.0117* (1.9579)	0.0021 (0.2115)
*did*TS*		0.0060* (0.3224)	0.0427** (2.1423)	0.0262* (1.8420)	0.0016 (0.0345)
_cons	0.9432*** (486.9256)	0.8623*** (21.0136)	0.7760*** (9.9537)	0.9409*** (17.4806)	0.8343*** (9.8011)
Control variables	Control	Control	Control	Control	Control
Fixed effects	Control	Control	Control	Control	Control
N	1211	1139	1132	1139	1118
R^2	0.3974	0.4504	0.3506	0.4110	0.3013

Meanwhile, the coefficient of the interaction term between environmental regulation and the textile industry agglomeration was positive and significant at the 10% level. This finding suggests that the environmental regulation has significantly improved the regional industrial efficiency of the textile industry in regions with weaker environmental regulation. Strict regulations have promoted the agglomeration of the textile industry in areas with laxer environmental regulations. As presented in Columns (3) to (5), the coefficients of environmental regulation and the interaction term between environmental regulation and the textile industry agglomeration were positive, further confirming the above results. However, the significant effect was only seen for state-owned and private textile industries, with no significant effect on foreign enterprises. One possible reason for this finding is that some foreign enterprises have transferred to China to circumvent the environmental regulations in their home countries and thus maintain their current level of technology. Moreover, to attract foreign investment, some local governments (in China) may also weaken the environmental controls on foreign enterprises, thus making it difficult for improving the regional industrial efficiency of environmental regulations to work on foreign enterprises (Jin & Song, 2020).

To comprehensively examine the general effect of the textile industry agglomeration on each region under the environmental regulation of cleaner production standards, Model (4) is estimated, and the results are presented in Table 4. As presented in Columns (1) and (2), the regression coefficients for the agglomeration of the textile industry are significantly positive. Further, the coefficient errors are within acceptable limits, suggesting that the agglomeration of the textile industry triggered by the environmental regulation has significantly improved the regional industrial efficiency of the textile industry. This study further classified the samples into regions with weaker environmental regulations and those with stronger environmental regulations (based on the same criteria as the control and experimental groups in Model (1)). The regressions were conducted accordingly, and the results are presented in Columns (3) and (4). As presented in the table, the regression coefficients of the agglomeration of the textile industry are both significantly positive at the 10% confidence level. However, the coefficients of regions with stronger environmental regulations are smaller than those of regions with weaker environmental regulations. One possible reason for this finding is that, as presented in Table 2, the environmental regulation has led to a transfer of the textile industry from regions with more stringent environmental regulation to those with laxer environmental regulation, leading to the agglomeration of the textile industry in areas with laxer environmental regulations. However, the textile industrial agglomeration is caused by environmental regulations, so those that have transferred are mostly high-polluting enterprises. Moreover, regions with stronger environmental regulations still retain productive service links, such as design, R&D, and after-sales. This places the textile industry in regions with stronger environmental regulations at the middle and high end of the division of labor in the value chain, which leads to relative difficulty in terms of improving regional industrial efficiency (Hu, 2016).

Table 4. The effect of industrial agglomeration on industrial efficiency in the textile industry

	Difference in differences model	Panel fixed effects model		
	(1)	(2)	(3)	(4)
	Full sample	Full sample	Laxer regulation region	More stringent regulation region
did	0.0104** (2.1731)			
TS	0.0225* (1.6616)	0.0219** (2.1110)	0.0223* (1.7313)	0.0159* (0.8080)
Control variables	Control	Control	Control	Control
Fixed effects	Control	Control	Control	Control
N	1139	1139	570	567
R^2	0.4504	0.4481	0.5361	0.4646

3.3. Robustness test

3.3.1. Parallel trend test

Before the implementation of cleaner production standards, the absence of significant differences between the treatment and control groups was an important prerequisite for the application of the DID model. Figure 1 depicts the impact of the implementation of environmental regulation policies on the agglomeration of the textile industry in different years. As depicted, no observable statistical distinction in the degree of transfer of textile enterprises between regions with more stringent environmental regulation and those with laxer environmental regulation before the enforcement of the policy compared to the year before the implementation of the environmental regulation policy. This finding suggests that the estimation results in Table 2 satisfy the parallel trend hypothesis.

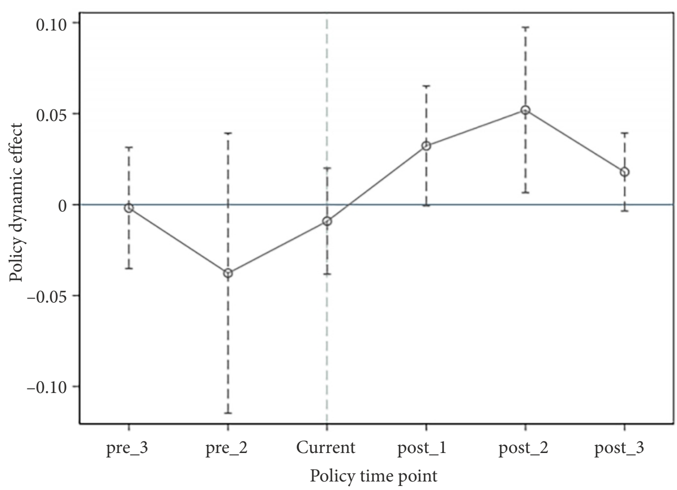

Figure 1. The effect of environmental regulation on industrial agglomeration

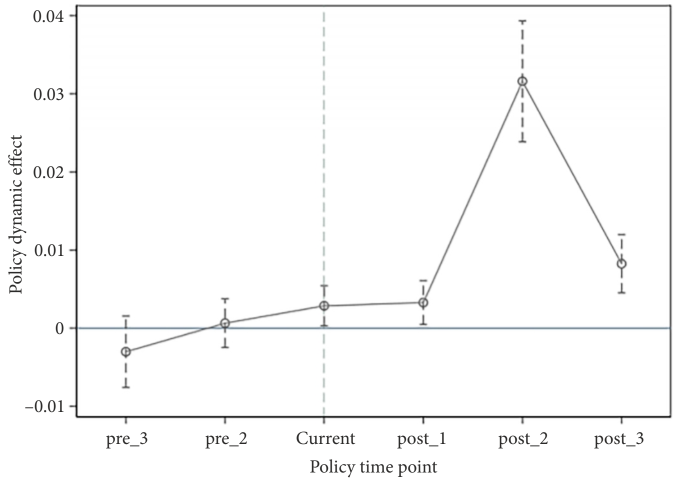

Figure 2. The effect of environmental regulation on industrial efficiency

By following a similar approach, this study replaced the predicted variables with the textile value-added rate (used to measure the industrial efficiency in the textile industry). Then, this study examined whether there was a statistical distinction in the industrial efficiency between the treatment and control groups when the environmental regulatory policy of cleaner production standards was in effect, as illustrated by the estimation results in Figure 2. As depicted, no observable statistical distinction between the industrial efficiency of the treatment and control groups before the environmental regulation policy took effect. This finding indicates that it is reasonable for this study to apply the DID model to test the effect of environmental regulation policies on the industrial efficiency of the textile industry.

3.3.2. Replacement of the control group selection method

To secure the robustness of the empirical results, this study changed the construction method of the control and experimental groups for the relevant tests. Specifically, cities with one-third of the highest contaminant clearance level were selected as the control group, while the experimental group was defined as cities with one-third of the lowest contaminant clearance level. On this basis, regressions were performed on Models (1) and (3), and the results are presented in Columns (1) to (2) of Table 5. As presented, the regression coefficients for environmental regulation policies are significantly positive for both the textile industry agglomeration and the improvement of regional industrial efficiency. This finding aligns with the test results reported above. These results also suggest that the role of environmental regulatory policy, which is designed to promote industrial agglomeration and improve regional industrial efficiency of the textile industry, is still present in the new grouping scenario.

3.3.3. Exclusion of the effect of other policies

To control the potential influence of the paid use and trading system of emission rights implemented since 2007 on the results, this study first excludes the 11 pilot areas, such as Tianjin City, Hubei Province, and Chongqing City. Then, the DID method is adopted to assess the effectiveness of the enforcement of the environmental regulatory policy. The empirical results are presented in Columns (3) to (4) of Table 5. As presented, the estimated results of the regression coefficients of environmental regulation policies are significantly positive at the 10% confidence level. This finding indicates the robustness of the benchmark regression results in this study.

3.3.4. Placebo test

This study constructs a false policy time by delaying the enforcement of the environmental regulatory policy for two years to conduct a placebo test. The regression results of the placebo test are presented in Columns (5) to (6) of Table 5. As presented, none of the regression coefficients of the core explanatory variable is significant, suggesting that the placebo policy did not have any acceleration effect on industrial agglomeration and the improvement of regional industrial efficiency in the textile industry. Therefore, the environmental regulation policy did have an effect on promoting industrial agglomeration and the enforcement of regional industrial efficiency, which is beneficial to the sustainable development of the textile industry.

Table 5. Robustness test

	(1)	(2)	(3)	(4)	(5)	(6)
	Industrial agglomeration	Industrial efficiency	Industrial agglomeration	Industrial efficiency	Industrial agglomeration	Industrial efficiency
did	0.0353* (1.8820)	0.0176*** (3.0628)	0.0405* (1.7929)	0.0102* (1.7726)	0.0151 (0.9278)	0.0053 (0.9307)
Control variables	Control	Control	Control	Control	Control	Control
Fixed effects	Control	Control	Control	Control	Control	Control
N	760	750	681	679	1160	1139
R^2	0.3374	0.5332	0.3282	0.3880	0.3384	0.4485

3.3.5. Endogenous test

Cleaner production standards are designed to evaluate and rank textile industries based on their production and emissions, thus giving those industries clear criteria for the evaluation and assessment of cleaner production. Moreover, the agglomeration or the improvement of regional industrial efficiency of the heavily-polluting links of the textile industry in different regions may lead to changes in the production and emissions situation of the textile industry in each region. This would affect the development of cleaner production standards, and, therefore, there could potentially be an issue of reverse causality between cleaner production standards and the industrial agglomeration and efficiency of the textile industry. In order to enhance the credibility and reliability of the core regression findings, this research uses instrumental variable estimation methods to mitigate possible endogeneity problems in the models.

As relatively few indicators exist at the prefecture level, it is difficult to find an instrumental variable that is directly related to the cleaner production standard as environmental regulation. Therefore, this study referred to the ideas of Cai et al. (2016) regarding the selection of instrumental variables and selected the mean annual precipitation (*IV1*) and mean temperature (*IV2*) of the prefecture-level cities as instrumental variables from the perspective of natural climatic conditions. First, when the levels of contaminants in the environment remain the same, more precipitation and higher temperatures are conducive to reducing the concentration of contaminants in the regional environment, thus reducing the constraints of environmental regulation. Therefore, the selection of mean annual precipitation and mean temperature as instrumental variables satisfies the correlation requirement. Furthermore, the selection of mean annual precipitation and mean temperature as instrumental variables also satisfies the requirement of exogeneity. This is because the mean annual precipitation and mean temperature in a region are natural phenomena that do not have other mechanisms of action in relation to the agglomeration and industrial efficiency of the textile industry, except that these variables may influence the concentration of contaminants.

Table 6 presents the results of the two-stage least squares estimation of the two instrumental variables for the environmental regulation. The estimation results of the first stage indicate that the instrumental variables selected satisfy the correlation and verify the exogeneity hypotheses. Moreover, the estimation results in the second stage of Table 6 indicate that the estimated coefficients of cleaner production standards (as an environmental regulation on the textile industry agglomeration and industry efficiency) both pass the 5%-level significance test. In addition, the symbols remain consistent with the underlying regressions, suggesting that after mitigating the potential endogeneity, the findings of this study remain robust.

Table 6. Results of the instrumental variable method test

Stage 2		
Predicted variable	Industrial agglomeration	Industrial efficiency
did	0.0931** (0.67)	0.0492** (2.22)
Control variables	Control	Control
Fixed effects	Control	Control
Stage 1		
Predicted variable	*did*	*did*
IV1	–0.3262* (–1.76)	–0.3149* (–1.72)
IV2	–0.0142* (–0.64)	–0.0139* (–0.62)
Kleibergen-Paap rk LM Test	17.390 [0.0002]	16.1641 [0.0003]
Kleibergen-Paap rk Wald F Value	14.801	14.717
Sargan-Hansen Test	0.018[0.8931]	1.436[0.2307]

Note: ***, **, and * denote regression coefficients significant at the levels of 1%, 5%, and 10% respectively, with t-values in the parentheses and p-values in square brackets.

Conclusions

This study empirically tests the effect of the environmental regulation on agglomeration and efficiency in the textile industry. Specifically, the DID method is used to conduct a quasi-natural experiment with the implementation of cleaner production standards. The results of the study reveal that, first, environmental regulation has significantly facilitated the transfer of the textile industry to regions with weaker environmental regulations and realized the agglomeration of the textile industry in areas with weak environmental regulations. However, the implementation of the policy involves a prolonged time cost, and the effects produced by the policy are of hysteresis. Second, in the process of promoting the agglomeration of the textile industry, environmental policies are accompanied by significant improvements in regional industrial efficiency. These effects have helped achieve the sustainable development of the textile industry. Moreover, although such improvement in regional industrial efficiency is commonly found, the effects are more significant in regions where the constraints of environmental regulation are weaker. Some scholars have found that environmental regulation can facilitate the product quality of enterprises and the international competitiveness of industries. Fundamentally, their findings were a result of the improvement of the industrial efficiency of the textile industry. Third, the influence of environmental regulations on agglomeration and efficiency improvement of the textile industry is strongly heterogeneous in terms of ownership. This impact is also more significant in state-owned and private industries.

Policy recommendations

In light of the results obtained from the preceding analysis, this study advances several potential policies for consideration. First, steps should be taken to deepen the reform of the responsibility system for environmental protection aims and strengthen the status of environmental performance in the performance assessment of officials. For a long time, local government officials have had a lack of incentive regarding the protection of the environment. Incorporating environmental performance into the performance evaluation process of local officials would exert a strong disciplinary and deterrent effect on the decision-making behavior of local officials, providing them with an incentive to strengthen environmental controls and carry out environmental pollution control. Ultimately, this would contribute to the sustainable development of the textile industry.

Second, although the environmental regulation requires local governments to set asymmetrical management targets for textile enterprises regarding the different levels of pollution within their jurisdictions, enterprises may only aim to comply with cleaner production audits and see cleaner production standards as minimum emission requirements. Therefore, to strengthen the effect of environmental regulation, it is necessary to increase the investigation and accountability of textile enterprises that have not met the standards of cleaner production. It is also necessary to strengthen the financial and policy support of the local government for textile enterprises that have reached the minimum standards of cleaner production. This support will stimulate these enterprises' continuous action in implementing cleaner production and ultra-low emissions to achieve the transition from forced transformation to incentive development. These steps would also continuously promote the Chinese textile industry's ongoing efforts to improve regional industrial efficiency.

Third, as environmental regulations are heterogeneous in terms of time and ownership, for the textile industry agglomeration and industrial efficiency, it is necessary to discard the current "unified" environmental regulation policy. The government should revise the strength of environmental regulations on a cyclical basis, and environmental regulations should be tailored to the situation of different textile industries with different ownership.

This study explores the mechanism through which the textile industry can achieve sustainable development based on "front-end" environmental regulations. It broadens the boundary of existing research and has important significance for achieving the dynamic balance between environmental protection and the textile industry's sustainable development. However, this study has some limitations. Because the Chinese industrial enterprise database is used, the data of this database from recent years could not be obtained (other databases contain insufficient samples of the textile industry). Therefore, it will be necessary to test the recent impact of cleaner production standards on the sustainable development of the textile industry after the data are updated.

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Author contributions

Conceptualization, and methodology, X.J., Z.M., and P.Y.; software, validation, and formal analysis, F.C., J.L.; data curation, writing-original draft preparation, writing- review, and editing, X.J. and Z.M.; supervision, X.J., S.S. and F.C.; funding acquisition, X.J. and Z.M. Each author has thoroughly reviewed and approved the final version of the manuscript for publication. X.J. and Z.M. contributed equally to prepare this manuscript.

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