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Impact of Regional Development Strategy on the Productivity of Polluting Firms:Evidence From China

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This study aims to analyse the heterogeneous impact of the China's Western Development Strategy (WDS) on the productivity of different types of firms. Based on the heterogeneous firm model and simulation, this study utilizes the WDS as a quasi-natural experiment and uses the difference-in-difference-in-differences (DDD) method to study the heterogeneous impact on the productivity of polluting and non-polluting firms. The WDS has increased the productivity of polluting firms in the western region by 8.0–12.6%, compared to the central region and non-polluting industries. This phenomenon is the result of the environmental cost effect and the migration effect, but not the result of the Porter effect. In addition, this study shows that the heterogeneity of productivity improvement in state-owned firms, large-scale firms, and firms not located in the acid rain and sulfur dioxide control zones is more significant. The study suggests that it is necessary to implement industry-differentiated regional policies, implement different regional preferential policies for polluting firms, and to strengthen environmental regulations, so as to achieve a win-win situation between firm efficiency improvement and environmental protection.

Keywords: regional development strategy, productivity of polluting firms, heterogeneity, environmental regulation, migration effect

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1 INTRODUCTION

Since the implementation of the reform and opening-up policy in 1978, China's economy has developed rapidly, but regional differences have also widened. To reduce these differences, Chinese government began implementing a regional development strategy, known as Western Development Strategy (WDS), in 2001. This strategy aims to improve the level of economic development and ecological environment construction in the western region (Lai, 2002). The WDS provided a series of policy support to the western region of China, such as increasing capital investment such as fiscal expenditure, credit support, transfer payment, improving the investment environment such as tax incentives, preferential land and mineral resources, opening wider to the outside world, and developing technology and education. After the implementation of WDS, the economy in the western region has grown rapidly, but at the same time, the environmental pollution problem in the western region has continued to deteriorate (Cui et al., 2016).

In recent years, many articles have begun to identify and analyse the policy results of the WDS from both economic and environmental perspectives. Yang et al. (2018) constructed a provincial-level eco-productivity index and found that since the implementation of the WDS, the eco-productivity of the western region had continued to increase, and the difference on comparison with other regions had reduced. Zhuo and Deng (2019) measured the efficiency of the green economy at the inter-provincial level and found that although the WDS had improved the efficiency of green economy in the western region through the synthetic control method, there were still significant differences compared to other regions. Zhang et al. (2019) used the Propensity Score Matching Difference in Differences (PSM-DID) method to find that the WDS cannot reduce the carbon emission intensity of the western region.

In contrast to the above literature, which focuses on macro-aggregated variables, this study uses firm-level data and considers the WDS as a quasi-natural experiment to study the heterogeneous impact of the strategy on the productivity of polluting and non-polluting firms. More importantly, studying the impact on the productivity of polluting firms can evaluate the effect of the implementation of the environmental protection goals of WDS. This study aims to evaluate the implementation effect of WDS, that is, the impact of WDS on the productivity of different types of firms, to explain why WDS has a greater impact on the productivity of polluting firms in the western region, and how to achieve a win-win situation between firm efficiency improvement and environmental protection. Based on the heterogeneous firm model and simulation, this study utilizes the WDS as a quasi-natural experiment and uses the difference-in-difference-in-differences (DDD) method to study the heterogeneous impact on the productivity of polluting and non-polluting firms.

The marginal contribution of this article may be explained as follows: 1) Incorporating place-based policy and environmental regulations into the heterogeneous firm model. Through simulation, it is verified that the WDS is more conducive to increasing the efficiency of polluting firms in the western region. 2) Based on firm-level data, it is verified that the WDS is more conducive to increasing the productivity of polluting firms in the western region. 3) It is found that this phenomenon is the result of the combined effect of environmental cost advantage and migration effects, but the Porter effect did not have a significant impact on this process. 4) Based on the characteristics of firms or regions such as ownership, firm size, and "acid rain and sulfur dioxide control zones", this article analyses the impact of the WDS on the heterogeneous improvement of productivity of polluting and non-polluting firms.

2 THEORETICAL MODEL

This study expands the heterogeneous firm model and incorporates place-based policies and environmental regulations to analyse the impact of the WDS on polluting and non-polluting firms.

2.1 Consumer Behaviour

Suppose there are only two regions in the entire economy: the western region W and the central region M. All consumers share the utility function given by:

$$U = \alpha\int_{r\in\Omega} q^r dr - \frac{1}{2}\gamma\int_{r\in\Omega}(q^r)^2 dr - \frac{1}{2}\eta\left(\int_{r\in\Omega} q^r dr\right)^2 + q^0, \quad (1)$$

where q^0 represents the consumption of homogeneous goods and q^r denotes the consumption of differentiated good r of a set Ω of differentiated products. The demand parameters α, γ and η are all positive. A higher α and lower η increase demand for differentiated products. γ reflects consumer preference for diversity.

Assuming that consumption of homogeneous goods is always positive, on solving the consumer utility maximisation problem, the inverse demand function of differentiated good r can be obtained as:

$$p^r = \alpha - \gamma q^r - \eta\int_{j\in\Omega} q^j dj, \quad (2)$$

where p^r denotes the price of differentiated good k. Let $\bar{\Omega}$ denote the set of products with positive consumption levels in equilibrium. We can solve for the individual consumer's demand for product r as:

$$q^r = \begin{cases} \frac{1}{\gamma}\left(\bar{h} - p^r\right), & p^r \le \bar{h} \\ 0, & p^r > \bar{h}, \end{cases} \quad (3)$$

where $\bar{h} = \alpha\gamma + \eta|\bar{\Omega}|P/\gamma + \eta|\bar{\Omega}| > 0$ denotes the price threshold when the consumption of commodity r is non-negative. P denotes the mean price of $\bar{\Omega}$. Then, the demand function of the region $v \in \{W, M\}$ for product r is:

$$Q_u^r = \frac{N_v}{\gamma + \eta\left|\bar{\Omega}_v\right|}\left(\alpha + \frac{\eta}{\gamma}\left|\bar{\Omega}_v\right|P_v\right) - \frac{N_v}{\gamma}p^r, \quad (4)$$

where $|\bar{\Omega}_v|$ denotes the mass of varieties consumed in region v. N_v denotes the population of region v. To simplify the analysis, we ignore the impact of population by assuming $N_W = N_M = 1$.

2.2 Producer Behaviour

Labour is the only element in production. The labour market is perfectly competitive; the elasticity of supply is 0, and the wage of unit labour is standardised to 1. The homogeneous good, produced under constant returns to scale using one unit of labour per output, is freely traded across regions. The differentiated goods sector is characterised by increasing returns, monopolistic competition, and iceberg trade costs, which generate emissions of a transboundary pollutant. According to the different pollution emissions per unit of product, firms producing differentiated goods can be further divided into K $(K \ge 2)$ industries. The differentiated goods market is a monopolistic competition, and firms need to pay fixed costs s in advance, while the marginal cost is affected by the firms' characteristics, policy advantages, and environmental regulations. Located in the region u, the marginal cost function of a firm in industry k is:

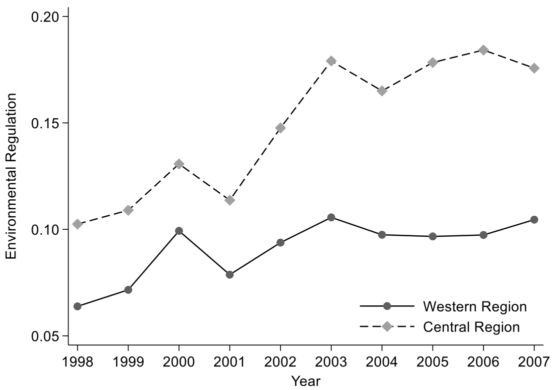

FIGURE 1 | Differences in environmental regulation on both sides of the boundary between central and western China. *Note*: The SO_2 removal rate was used to measure the degree of environmental regulation.

$$mc(u,k,h) = f_u^k \frac{h}{a_u}; k = 1, \cdots K, \tag{5}$$

where h denotes the firm's characteristics, and when not considering policy advantages and environmental regulations ($f_u^k, a_u = 1$), we can index firms by their unit labour requirement h In other words, a differentiated product manufacturer can be represented by a three-dimensional array (u,h,k) Following Melitz and Ottaviano (2008), $1/h$ obeys a Pareto distribution with the parameter σ, and the distribution function of h is $G(h) = (h/h_{\max})^{\sigma}$.

The place-based policy has the same impact on all industries in the region and a_u denotes the policy advantage of firms located in the region u. Benefiting from the WDS, firms in the western region have received support from policies pertaining to finance, government investment, financial credit, and talent. Therefore, the policy advantages may be assumed as follows:

$$a_u = \begin{cases} A > 1 & u = W \\ 1 & u = M. \end{cases} \tag{6}$$

Drawing on the research of Zeng and Zhao (2009), firms hire more labour to comply with the environmental regulations of local governments. To simplify the analysis, we assume $K = 2$, that is, polluting and non-polluting industries, of which only polluting industries face environmental regulations. In addition, due to different regional development conditions, there are differences in environmental regulations between regions (Wang et al., 2019), and there are huge differences in environmental regulations between central and western China (**Figure 1**). Regarding this phenomenon, on the one hand, the level of economic development in the western region is relatively low, the local government's attention is more focused on economic growth, and the tolerance for pollution is relatively higher (Pang et al., 2019). On the other hand, it is located in the upper reaches of the river. Geographical location also increases the free-riding motivation of the western region. Therefore, the environmental regulations for industry k in region u can be set as follows:

$$f_u^k = \begin{cases} 1 & k \text{ is a non} - \text{polluting industry} \\ F_W > 1 & k \textit{ is a polluting industry}, u = \text{W} \\ F_M = \Phi F_W & k \textit{ is a polluting industry}, u = \text{M}. \end{cases} \tag{7}$$

For the firm (u,h,k) from **Equation 4**, its demand in the region v is

$$q_{uv}(h) = \frac{N_v}{\gamma}\left[\bar{h}_v - p_{uv}(h)\right], \tag{8}$$

where $p_{uv}(h)$ denotes the firm (u,h,k) s differentiated good price in the region v. The profit function of this firm is as follows:

$$\pi_{uv}^k(h) = \left[p_{uv}(h) - f_u^k \tau_{uv}\frac{h}{a_u}\right] q_{uv}(h), \tag{9}$$

where $\tau_{uv} = 1$ if $u = v$ and $\tau_{uv} = \tau$ if $u \neq v$.

On solving the profit maximisation problem, we obtain the following optimal price:

$$p_{uv}(h) = \frac{1}{2}\left(\bar{h}_v + f_u^k \tau_{uv}\frac{h}{a_u}\right). \tag{10}$$

In addition, if the firm's profit is negative, it will stop operating; therefore, its equilibrium profits are:

$$\Pi_{uv}^k(h) = \begin{cases} \frac{N_v}{4\gamma}\left(\bar{h}_v - \frac{f_u^k \tau_{uv} h}{a_u}\right)^2, h \in (0, C_{uv}^k] \\ 0, \quad\quad h \in (\text{C}_{uv}^k, \infty), \end{cases} \tag{11}$$

where $C_{uv}^k = a_u \bar{h}_v / f_u^k \tau_{uv}$ denotes the critical production cost. In a market with monopolistic competition, as long as profits can be obtained, firms will continue to enter the market, and the market will reach its equilibrium only when profits become zero.

$$\sum_{v \in \{W,M\}} \int \Pi_{uv}^k(h) dh = s. \tag{12}$$

2.3 Equilibrium Analysis

In equilibrium, the price thresholds in the central and western regions can be solved using the following equations:

$$\begin{aligned} \left(f_W^k\right)^{-\sigma}\left(\bar{h}_W\right)^{2+\sigma} + \left(\tau f_W^k\right)^{-\sigma}\left(\bar{h}_M\right)^{2+\sigma} &= A^{-\sigma} 2\gamma(1+\sigma)(2+\sigma)h_{\max}^{\sigma} \\ \left(f_M^k\right)^{-\sigma}\left(\bar{h}_M\right)^{2+\sigma} + \left(\tau f_M^k\right)^{-\sigma}\left(\bar{h}_W\right)^{2+\sigma} &= 2\gamma(1+\sigma)(2+\sigma)h_{\max}^{\sigma}. \end{aligned} \tag{13}$$

Following Combes (2012), the productivity threshold values of $\bar{\varphi}_u^k$ are:

$$\bar{\varphi}_u^k = \frac{a_u}{f_u^k \bar{h}_u}. \tag{14}$$

The heterogeneity of productivity in industry k between the central and western regions is $\Gamma_k = \bar{\varphi}_W^k / \bar{\varphi}_M^k$ If $\Gamma_k > 1$, implying that the productivity of the western region is significantly higher than that of the central region. $|\Gamma_{\text{pol}} - \Gamma_{\text{nonpol}}|$ measures the heterogeneity of polluting and non-polluting industries between the central and western regions.

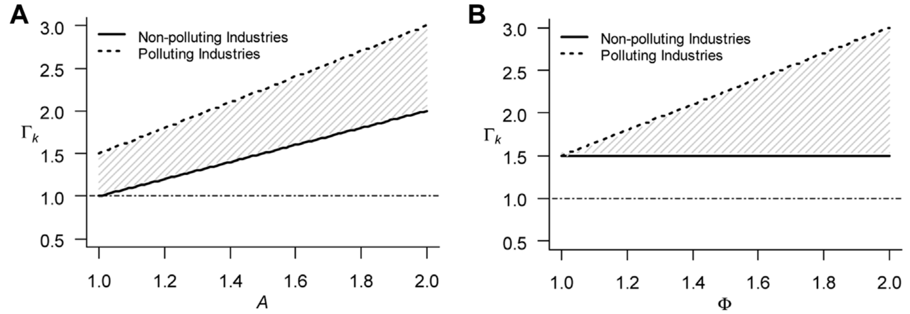

FIGURE 2 | Simulation results of heterogeneity improvements of firm productivity. *Note*: The solid lines (dashed lines) in the figure represent the heterogeneity of the productivity of non-polluting industries (polluting industries) in the western and central regions, and the shadows represent the heterogeneity between polluting and non-polluting industries. In addition, loose environmental regulation parameter $\Phi = 1.5$ in **(A)** and policy advantage parameter $A = 1.5$ in **(B)**.

As **Equation 13** cannot be solved explicitly, this study conducts a comparative static analysis through a numerical simulation. According to Del Gatto et al. (2006), σ approaches 2. The other parameter values are: $F_W = 1, \tau = 1.5, \gamma = 2, h_{\max} = 30$.

Based on the simulation results, it can be seen that with the WDS, the productivity of firms in the western region has effectively improved, when compared with that of the central region. In particular, the productivity of polluting industries has increased more significantly with the strengthening of policy advantage (A increasing), which improved the cost advantage of loose environmental regulation. The heterogeneity of productivity improvement among industries continues to expand (**Figures 2A**). Furthermore, benefiting from the WDS, the tax burden of firms in the western region has dropped significantly, and credit and transfer payments have also eased the financing constraints of these firms. The resulting cost-side improvement will effectively improve firm efficiency, and talent support and infrastructure improvement will further enhance human capital and promote knowledge spillover. At the same time, since the heterogeneity of the industry is not considered, and the western region implements relatively loose environmental regulations, the cost advantage of polluting firms in the western region has been magnified, leading to crowding out of non-polluting industries, which will expand the heterogeneity of productivity improvement among industries. In addition, when the policy advantages are fixed, greater difference in environmental regulations between the central and western regions will increase the productivity of polluting firms in the western region (**Figures 2B**).

Based on the above theoretical model analysis and numerical simulation results, we can put forward the following research hypothesis:

Hypothesis: the WDS has a heterogeneous impact on the productivity of different types of firms; when the environmental regulation in the western region is relatively loose, the WDS is more conducive to the improvement of the productivity of polluting firms in the western region.

3 DATA AND EMPIRICAL STRATEGY

3.1 Variable and Data

To test the conclusions reached in the theoretical section, this study utilises firm-level data for the period 1998–2007, from the annual surveys conducted by the National Bureau of Statistics. Additionally, this study treats the development of the western region as a quasi-natural experiment to identify its heterogeneous impact on different industries. This is to ensure that there are parallel trend assumptions in the strategy and non-strategy regions before strategy implementation (Bertrand et al., 2004). Therefore, this study selected a sample of firms in the cities on both sides of the provincial boundary line dividing the central and western regions in the WDS, including 57 cities in 14 provinces along the boundary line, of which 26 cities are located in the western region and 31 cities are located in the central region. For the cities on both sides of the boundary line, their geographical environment, climatic conditions, and culture are similar, and the heterogeneous influence between different cities can be eliminated as much as possible. The migration cost of firms on both sides of the boundary line is relatively low. In addition, although the WDS was determined in 2000, the strategy implementation began in 2001. Hence, the strategy's implementation year is considered as 2001 for this study.

3.1.1 Firm Data

Referring to the research of Brandt et al. (2012), outliers are cleaned up and the samples are collected in the cities mentioned earlier. Total factor productivity (TFP) is one of the best proxy variables for firm productivity, and the LP method (Levinsohn and Petrin, 2003) is used to calculate TFP. In addition, Yu (2015) pointed out that firm size, whether to export, and ownership would affect the choice of a firm's production technology and thus, affect TFP. Therefore, this study controls for the following variables: firm size (**log(size)**, measured by the logarithm of the firm's total assets), export (**log(ex)**, measured by the logarithmic measure of the export value of firm +1), and whether the firm is a state-owned firm, and whether the firm is foreign-funded (**State-owned** and **Foreign**; measured by a dummy variable; assumed to be 1 if yes and 0otherwise).

With reference to Dou and Han (2019), the samples are divided into polluting and non-polluting firms by calculating the Pollution Density Index (PDI). Simultaneously, to improve robustness, this study also divides the sample according to the Pollution Intensity Index (PII) and the Pollution Comprehensive Index (PCI). The specific calculation method and classification results are presented in the Appendix.

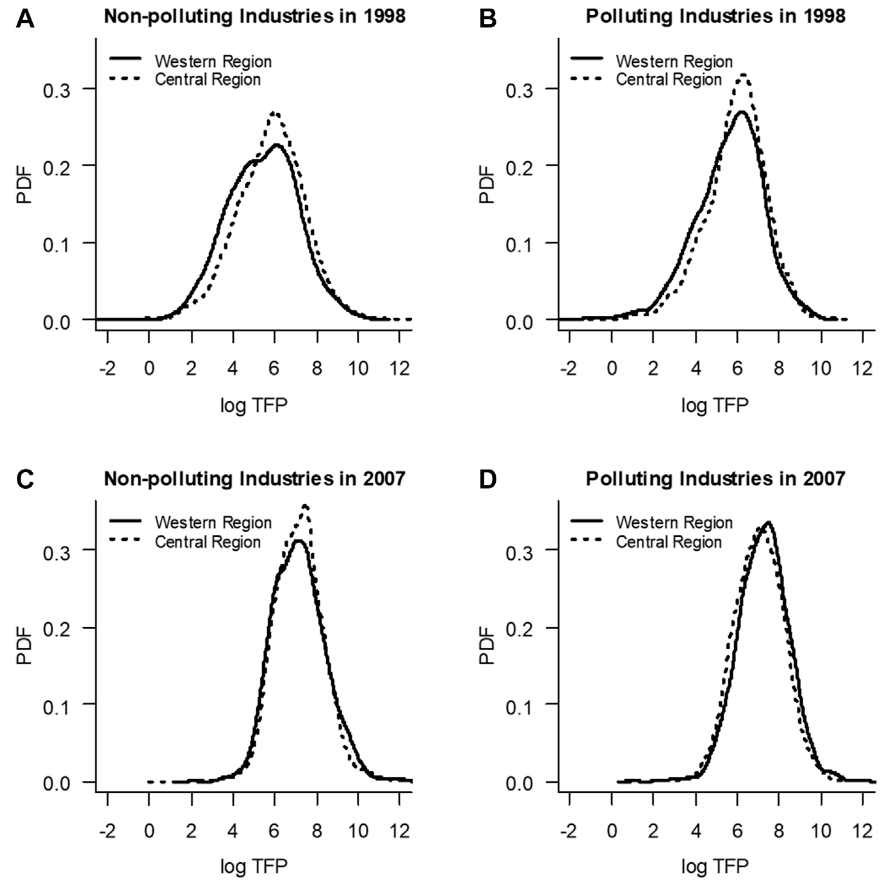

FIGURE 3 | Log TFP distributions before and after the WDS.

This study draws the kernel density map of the non-polluting industry and polluting industry firms' TFP in the central and western regions in 1998 before the implementation of the WDS and after its implementation in 2007 (**Figure 3**). It can be seen that in 1998, for both polluting and non-polluting firms, the TFP distribution in the western region showed a significant left deviation relative to that in the central region (**Figures 3A**, **Figures 3B**). By 2007, compared with 1998, the TFP distribution of all firms in the western region shifted significantly to the right compared to the central region. In 2007, the TFP distribution of polluting firms in the western region shifted significantly to the right compared to the central region (**Figures 3C** and **Figures 3D**).

This shows that with the implementation of the WDS, the distribution of TFP of non-polluting and polluting firms in the central and western regions has undergone structural changes. Compared with the central region, the TFP of firms in the western region has effectively improved but the increase in TFP is heterogeneous, and the strategy is more conducive to the increase in productivity of polluting firms in the western region. Among them, the distribution coefficient of the pollution firms in 2007 was significantly positive at the 1% level, indicating that the overall productivity of the polluting firms in the western region surpassed that of the central region. This also intuitively verifies the results of the numerical simulations.

3.1.2 Environmental Regulation

China's city-level environmental statistics have been published since 2003, which does not coincide with the period considered in this study. However, the EPS China Green Development Database has provided emissions data for firms since 1998. Therefore, referring to Zhou et al. (2017), the emissions data for firms were summed up at the city level and the SO_2 removal rate was used to measure the degree of environmental regulation in the study.

3.2 Specification

This study adopts the difference-in-difference-in-differences (DDD) approach to identify the heterogeneity of the WDS on the productivity improvement of polluting and non-polluting firms. Referring to Cai et al. (2016), the baseline regression model is set as follows:

$$\ln \mathrm{TFP}_{ikut} = \beta \mathrm{Treat}_u \times \mathrm{Post}_{2001} \times \mathrm{Dirty}_k + X_{it}\theta + \delta_i + \eta_{kt} + \lambda_{ut} + \rho_{uk} + \varepsilon_{ikut}, \tag{15}$$

TABLE 1 | Effect of the WDS on improvement of productivity of firms.

The Dependent Variable: Log (TFP)			
	(1)	**(2)**	**(3)**
$Treat*Post_{2001}*PDI$	0.126** (0.0579)	—	— —
$Treat*Post_{2001}*PCI$	— —	0.0820* (0.0464)	— —
$Treat*Post_{2001}*PII$	— —	— —	0.0801* (0.0465)
Log (size)	0.303*** (0.0101)	0.303*** (0.0101)	0.303*** (0.0101)
Log (ex)	0.0145*** (0.00200)	0.0145*** (0.00200)	0.0145*** (0.00200)
State-owned	−0.0750*** (0.0269)	−0.0754*** (0.0269)	−0.0754*** (0.0269)
Foreign	−0.00672 (0.0358)	−0.00685 (0.0358)	−0.00688 (0.0358)
City-year fixed effects	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes
City-industry fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Observations	76,132	76,132	76,132
R-squared	0.861	0.860	0.861

Note: ***p < *0.01*, **p < *0.05*, *p < *0.1. Standard errors clustered at firm level are reported in parentheses.*

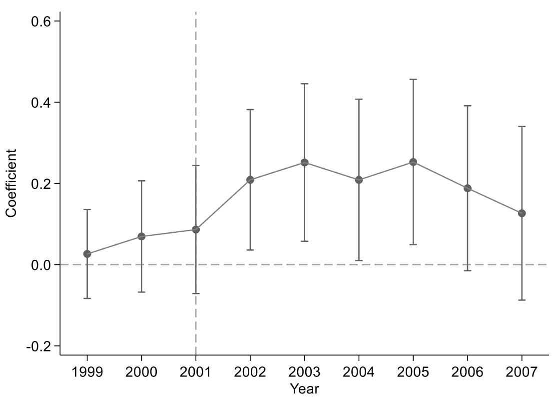

FIGURE 4 | Result of the parallel trend test.

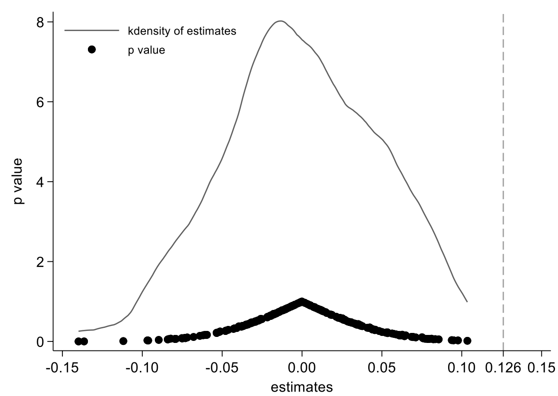

FIGURE 5 | Result of Placebo test.

where TFP_{ikut} represents the total factor productivity of firm i in city u belonging to industry k in year t $Treat_u$ indicates whether city u is located in the strategy zone, that is, $Treat_u = 1$ if city u located in strategy zone and is 0 otherwise; $Post_{2001}$ indicates the post-treatment period, that is, $Post_{2001} = 1\ \forall t \geq 2001$ and is 0 otherwise; $Dirty_j$ indicates whether industry k is a polluting industry, that is, $Dirty_k = 1$ if industry k is a polluting industry identified by PDI, PII, or PCI; δ_i is firm fixed effect; η_{kt} is industry-year fixed effect; λ_{ut} is city-year fixed effect; ρ_{uk} is city-industry fixed effect; X_{it} represents a control variable. $\beta > 0$ indicates that the WDS increases the productivity of polluting firms, which is consistent with the conclusions of the previous theoretical model analysis. Th error term ε_{ikut} is assumed to be normally distributed with zero mean value and at constant variance (Hae-Young & Kim, 2019; Elahi et al., 2021; Ehsan et al., 2022).

4 EMPIRICAL ANALYSIS

4.1 Main Results

The baseline regression results are presented in **Table 1**. The empirical results indicate that irrespective of the method used to identify polluting industries, as the WDS progresses, the polluting firms in the western region increases significantly by 8.0–12.6%, on average, compared with the central regions and non-polluting industries. In other words, the WDS has led to heterogeneity in the improvement of firm productivity; that is, this strategy is more conducive to the improvement of the productivity of polluting firms in the western region.

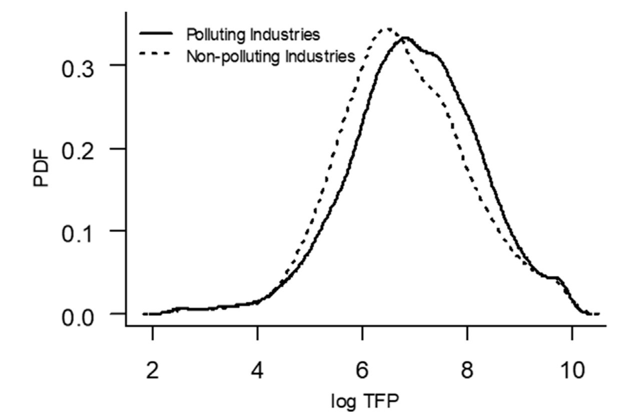

FIGURE 6 | Log TFP distributions in the western region.

4.2 Robustness Checks

4.2.1 Testing for Variation Over Time

The premise of adopting the DDD method is that the data meet the parallel trend assumption, that is, before the implementation of the WDS, the trend of TFP changes in the western and central regions should be consistent. With reference to Liu and Qiu (2016), this study sets the following model:

$$\ln \mathrm{TFP}_{ikut} = \sum_{t=-2}^{6} \alpha_t \mathrm{Treat}_u \times \mathrm{Year}_{t_0+t} \times \mathrm{Dirty}_k + X_{it}\theta + \delta_i + \eta_{kt} + \lambda_{ut} + \rho_{uk} + \varepsilon_{ikut}, \tag{16}$$

where Year_{t_0+t} indicates year dummies of year t after the strategy was implemented, α_t measures the leading and lagging effects of the WDS.

Figure 4 shows the estimated value of α_t at the 95% confidence interval. From the results, the trend of α_t during the period $t \le 0$ was relatively flat and the estimated value was not significant; after the implementation of the strategy, α_t increased significantly. This shows that the parallel trend assumption is satisfied before the strategy is implemented, and the effect of the WDS is seen immediately. In addition, it showed a downward trend after 2005, which indicates that the influence of heterogeneity among industries in the western region has a trend of convergence.

4.2.2 Placebo Test

To rule out the possibility of missing city-industry-time level variables, referring to Chetty et al. (2009), this study conducts a placebo test by randomly selecting 26 out of the 57 cities as virtual strategy cities. Then, a virtual triple difference term, $\mathrm{Treat}_u^{False} * \mathrm{Post}_{2001} * \mathrm{Dirty}_k$, was constructed. Due to the randomness of the selection, this virtual triple difference term did not affect the explained variable, that is, $\beta^{False} = 0$. To avoid the impact of small probability events, this study carried out 200 random selections (La Ferrara et al., 2012). The estimated coefficients based on randomly selected strategy cities are distributed around 0, and most of the p-values are also greater than 0.1 (**Figure 5**). This shows that the baseline regression results did not cause serious biases due to missing variables.

4.3 Mechanism Analysis

The previous section verifies that this strategy is more conducive to increasing the TFP of polluting firms in the western region. Regarding the analysis of the internal mechanism, according to the theoretical model, the looser environmental regulations in the western region have led to the region's polluting firms having a larger environmental compliance cost advantage under the impact of the WDS, thereby increasing productivity. In contrast, the strategy may also cause highly efficient polluting firms to move to the western region, thereby increasing the overall efficiency of polluting firms. In addition, according to Porter's hypothesis (Porter and Linde, 1995), polluting firms may also have innovation compensation effects.

TABLE 2 | Results of cost effect.

The Dependent Variable: Log (TFP)

	Full Sample			Survival Sample		
	(1)	(2)	(3)	(4)	(5)	(6)
ER	–0.0850*** (0.0272)	–0.0840*** (0.0272)	–0.0840*** (0.0272)	–0.0550* (0.0320)	–0.0536* (0.0320)	–0.0537* (0.0320)
$\mathrm{Treat*Post_{2001}*PDI}$	0.143** (0.0642)	— —	— —	0.143** (0.0651)	— —	— —
$\mathrm{Treat*Post_{2001}*PCI}$	— —	0.0866* (0.0519)	— —	— —	0.0902* (0.0527)	— —
$\mathrm{Treat*Post_{2001}*PII}$	— —	— —	0.0895* (0.0518)	— —	— —	0.0927* (0.0527)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
City-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	73,066	73,066	73,066	51,317	51,317	51,317
R-squared	0.856	0.855	0.856	0.874	0.874	0.875

Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. *Standard errors clustered at the firm level are reported in parentheses.*

TABLE 3 | Testing for Porter hypothesis.

The Dependent Variable	Log (TFP)			Log (XCP)		
	(1)	(2)	(3)	(4)	(5)	(6)
XCP	0.0155*** (0.00252)	0.0154*** (0.00252)	0.0154*** (0.00252)	— —	— —	— —
ER	— —	— —	— —	−0.240*** (0.0665)	−0.241*** (0.0667)	−0.241*** (0.0667)
Treat*$Post_{2001}$*PDI	0.143** (0.0659)	— —	— —	−0.0612 (0.179)	— —	— —
Treat*$Post_{2001}$*PCI	— —	0.111** (0.0513)	— —	— —	0.0599 (0.118)	— —
Treat*$Post_{2001}$*PII	— —	— —	0.115** (0.0514)	— —	— —	0.0548 (0.118)
Treat*$Post_{2001}$	— —	— —	— —	−0.0196 (0.172)	−0.0995 (0.103)	−0.0966 (0.103)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
City-year fixed effect	Yes	Yes	Yes	No	No	No
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
City-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	64,106	64,106	64,106	64,106	64,106	64,106
R-squared	0.877	0.877	0.877	0.769	0.769	0.769

Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. *Standard errors clustered at firm level are reported in parentheses.*

4.3.1 Cost Effect

Figure 1 shows that the environmental regulations in the western region are relatively loose. Therefore, if it can be verified regional firms with lower environmental regulations are more efficient, cost advantage can then be considered as an important factor that leads to a more significant increase in the productivity of polluting firms in the western region.

The empirical results show that when the environmental regulation (ER) is reduced by one unit, the firms' TFP will significantly increase by 8.4–8.5% at the full sample level (**Table 2**(1–3)). In the surviving sample (the firms that survived during the period), when the environmental regulation is reduced by one unit, the TFP will significantly increase by 5.4–5.5%. This shows that loose environmental regulations can indeed increase TFP by reducing the cost of environmental compliance for firms, and may increase the attractiveness of polluting firms.

Notably, under the control of environmental regulations, the triple difference term is still significantly negative at the level of at least 10%. This shows that the WDS will magnify the cost advantage of polluting firms in the western region, which will lead to a greater increase in the productivity of polluting firms in that region.

4.3.2 Migration Effect

Based on the previous analysis, polluting firms in the western region have dual advantages in policy and environmental costs, which will inevitably attract firms to migrate to the west. If a large number of highly efficient polluting firms do so, the productivity of polluting firms in the western region will increase. On screening the samples of newly built firms in the western region after 2001, it can be observed that compared to the newly built non-polluting firms, the distribution of newly built polluting firms is significantly rightward (**Figure 6**), and the TFP is significantly increased by 10.6%.

4.3.2 Porter Hypothesis

In addition to cost-side improvements, technological innovation is also a potential way to improve firm productivity (Aloini et al., 2015; Elahi et al., 2021; Elahi et al., 2022). As demonstrated in this study, when compared with non-polluting firms, polluting firms face stricter environmental regulations. According to Porter effect, this may force polluting firms to innovate more. This study adopts the logarithm of the output value of new products (**log(XCP)**) to measure the innovation behaviour of the firm and test it through the following two steps. The results are shown in **Table 3**.

On the one hand, firm innovation significantly increases TFP. On average, a 1% increase in the output value of new products will drive a 1.5–1.6% increase in TFP (**Table 3** (1–3)). On the other hand, the regression analysis of environmental regulation on firm innovation shows that for every unit reduction in environmental regulation, the output value of new products of the firm will increase by 24% (**Table 3** (4–6)). This shows that strict environmental regulations do not force firms to carry out more innovative activities. On the contrary, stricter environmental regulations increase the cost input, thereby reducing innovation input. The triple difference and double difference terms are not significant, which also shows that there is no significant difference in innovation behaviour between the central and western regions, and between polluting and non-polluting firms. In other words, no significant innovation compensation effect has been observed for polluting firms in the western region.

TABLE 4 | Testing for heterogeneous effects.

The Dependent Variable: Log (TFP)	(1)	(2)	(3)	(4)	(5)	(6)
	State-Owned	NON-SO	LARGE	SMALL	CZ	NOT-CZ
Treat*Post$_{2001}$*PDI	0.166** (0.0740)	–0.0971 (0.113)	0.228*** (0.0867)	0.107 (0.0830)	0.0604 (0.0708)	0.311*** (0.0979)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
City-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
City-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,768	50,449	37,778	34,543	45,425	30,618
R-squared	0.889	0.794	0.839	0.868	0.847	0.883

Note*: State-owned indicates state-owned firms sample; NON-SO, indicates non-state-owned firms sample; LARGE, indicates large-scale firm sample; SMALL, indicates small-scale firm sample; CZ, indicates firm sample in "the acid rain and sulfur dioxide control zones"; NOT-CZ, indicates firm sample "not in the acid rain and sulfur dioxide control zones".*

4.4 Heterogeneous Effects

In the baseline regression, the heterogeneity characteristics of firms or regions are controlled only in the form of controlled variables or fixed effects. The following section further clarifies the impact of these heterogeneous characteristics. The results are listed in **Table 4**.

First, in contrast to other types of ownership firms, there is a closer political connection between state-owned polluting firms and the government, and they often have stronger bargaining power in the environmental protection game with local governments (Wu et al., 2017). The subsample regression shows that the productivity of state-owned polluting firms in the western region has increased significantly by 16.6%, which is higher than the full-sample regression result. For the sub-sample of non-state-owned firms, the triple difference term is not significant. This shows that the advantage of the WDS in improving the productivity of polluting firms in the western region is more significant in state-owned firms. The reason for this phenomenon is likely to be that local governments have looser environmental regulations on state-owned polluting firms.

Second, the difference in firm size may also affect the productivity of polluting firms in the western region. This study uses the average of total assets of the firm as the threshold to perform subsample regression. It can be seen that the productivity of polluting firms above the average scale in the western region increased significantly by 22.8%, while there was no significant difference below the scale. This also shows that large-scale firms have greater environmental cost advantages, and therefore their productivity has been greatly improved in the development of the western region. This may be because larger firms are often "big taxpayers" benefiting from local protectionism, and may be given preferential treatment in specific environmental law enforcement.

Finally, as one of China's most important environmental policies, the policy of "the acid rain and sulfur dioxide control zones," implemented in 1998, will also affect the productivity of polluting firms. Tang et al. (2020) verified that polluting firms in the acid rain and sulfur dioxide control zones will face higher environmental regulation costs and their productivity growth will be hindered. The sample in this study included 31 cities belonging to the acid rain and sulfur dioxide control zones, of which 14 cities are located in the western region. By dividing the sample into two subsamples of "the acid rain and sulfur dioxide control zones" and "not in the acid rain and sulfur dioxide control zones", it can be seen that in the former, the productivity of polluting firms in the west does not have a significant advantage, while in the latter, the productivity of polluting firms in the west has significantly increased by 31.1%, much higher than the regression result of the full sample. In other words, the lower environmental compliance costs of polluting firms not in the acid rain and sulfur dioxide control zones led to more significant heterogeneity in productivity improvement among industries.

5 CONCLUSION

As one of the government's regional policies, the effectiveness of regional strategies has always been the focus of debate in academic circles. This study considers the WDS as the starting point and focuses on the analysis of the heterogeneity and mechanism of TFP promotion of polluting and non-polluting firms based on theoretical simulation and empirical research.

The research results of this study indicated that the WDS, without considering industry heterogeneity, has resulted in a significant increase of 8.0–12.6% in the productivity of polluting firms in the western region when compared with the central region and non-polluting firms. In other words, the WDS is more conducive to polluting firms to improve efficiency. The enlarged cost advantages brought about by the looser environmental regulations in the western region and the preference of highly efficient polluting firms to relocate to the western region have contributed to this phenomenon. In addition, the results further point out that in the western region, the productivity of polluting firms that are state-owned, large in scale, and not located in the acid rain and sulfur dioxide control zones, has increased even more.

Therefore, in the future, the government must ensure the effective implementation of regional development strategies, consider the heterogeneous effects of such strategies on different industries, and combine such strategies with industrial environmental policy. It is necessary to change the traditional "one size fits all" approach and systematically consider the heterogeneity between industries and regions. Only then can we achieve a win-win situation between the improvement of firm efficiency and the green development of the economy.

There are also some limitations in this study. Due to data limitations, it is impossible to study the long-term effects of the WSD. In the future, with the continuous disclosure of micro-data, it is possible to further examine the long-term heterogeneity impact on firm productivity after 10–20 years.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

JD: Conceptualization, Writing-Reviewing and Editing, Validation, Resources. ZT: Methodology, Writing-Original. YJ: Data Processing.

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REFERENCES

Aloini, D., Pellegrini, L., Lazzarotti, V., and Manzini, R. (2015). Technological Strategy, Open Innovation and Innovation Performance: Evidences on the Basis of a Structural-Equation-Model Approach. *Meas. Bus. Excell.* 19 (3), 22–41. doi:10.1108/mbe-04-2015-0018

Bertrand, M., Duflo, E., and Mullainathan, S. (2004). How Much Should We Trust Differences-In-Differences Estimates? *Q. J. Econ.* 119, 249–275. doi:10.1162/003355304772839588

Brandt, L., Van Biesebroeck, J., and Zhang, Y. (2012). Creative Accounting or Creative Destruction? Firm-Level Productivity Growth in Chinese Manufacturing. *J. Dev. Econ.* 97, 339–351. doi:10.1016/j.jdeveco.2011.02.002

Cai, X., Lu, Y., Wu, M., and Yu, L. (2016). Does Environmental Regulation Drive Away Inbound Foreign Direct Investment? Evidence from a Quasi-Natural Experiment in China. *J. Dev. Econ.* 123, 73–85. doi:10.1016/j.jdeveco.2016.08.003

Chen, Z., Kahn, M. E., Liu, Y., and Wang, Z. (2018). The Consequences of Spatially Differentiated Water Pollution Regulation in China. *J. Environ. Econ. Manag.* 88, 468–485. doi:10.1016/j.jeem.2018.01.010

Chetty, R., Looney, A., and Kroft, K. (2009). Salience and Taxation: Theory and Evidence. *Am. Econ. Rev.* 99, 1145–1177. doi:10.1257/aer.99.4.1145

Combes, P., Duranton, G., Gobillon, L., Puga, D., and Roux, S. (2012). The Productivity Advantages of Large Cities: Distinguishing Agglomeration from Firm Selection. *Econometrica* 80, 2543–2594.

Cui, Y., Lin, J., Song, C., Liu, M., Yan, Y., Xu, Y., et al. (2016). Rapid Growth in Nitrogen Dioxide Pollution over Western China, 2005-2013. *Atmos. Chem. Phys.* 16, 6207–6221. doi:10.5194/acp-16-6207-2016

Del Gatto, M., Mion, G., and Gianmarco, I. P., O. (2006). Trade Integration, Firm Selection and the Costs of Non-europe. *SSRN Electronic Journal*, *CEPR Discussion Papers* 5730. doi:10.2139/ssrn.926528

Dou, J., and Han, X. (2019). How Does the Industry Mobility Affect Pollution Industry Transfer in China: Empirical Test on Pollution Haven Hypothesis and Porter Hypothesis. *J. Clean. Prod.* 217, 105–115. doi:10.1016/j.jclepro.2019.01.147

Ehsan, E., Zhang, Z., Khalid, Z., and Xu, H., (2021). Application of an Artificial Neural Network to Optimise Energy Inputs: An Energy- and Cost-Saving Strategy for Commercial Poultry Farms. *Energy* 244:123169. doi:10.1016/j.energy.2022.123169

Elahi, E., Khalid, Z., Tauni, M. Z., Zhang, H., and Lirong, X. (2021). Extreme Weather Events Risk to Crop-Production and the Adaptation of Innovative Management Strategies to Mitigate the Risk: A Retrospective Survey of Rural Punjab, Pakistan. *Technovation* 2021 (4), 102255. doi:10.1016/j.technovation.2021.102255

Elahi, E., Khalid, Z., and Zhang, Z. (2022). Understanding Farmers' Intention and Willingness to Install Renewable Energy Technology: A Solution to Reduce the Environmental Emissions of Agriculture. *Appl. Energy* 309, 118459. doi:10.1016/j.apenergy.2021.118459

Elahi, E., Zhang, H., Lirong, X., Khalid, Z., and Xu, H. (2021). Understanding Cognitive and Socio-Psychological Factors Determining Farmers' Intentions to Use Improved Grassland: Implications of Land Use Policy for Sustainable Pasture Production. *Land Use Policy* 102, 105250. doi:10.1016/j.landusepol.2020.105250

Ferrara, E. L., Chong, A., and Duryea, S. (2012). Soap Operas and Fertility: Evidence from Brazil. *Am. Econ. J. Appl. Econ.* 4, 1–31. doi:10.1257/app.4.4.1

Kim, H. Y. (2019). Statistical Notes for Clinical Researchers: Simple Linear Regression 3 - Residual Analysis. *Restor. Dent. Endod.* 44 (1), e11. doi:10.5395/rde.2019.44.e11

Lai, H. H. (2002). China's Western Development Program. *Mod. China* 28, 432–466. doi:10.1177/009770040202800402

Levinsohn, J., and Petrin, A. (2003). Estimating Production Functions Using Inputs to Control for Unobservables. *Rev. Econ. Stud.* 70, 317–341. doi:10.1111/1467-937x.00246

Liu, Q., and Qiu, L. D. (2016). Intermediate Input Imports and Innovations: Evidence from Chinese Firms' Patent Filings. *J. Int. Econ.* 103, 166–183. doi:10.1016/j.jinteco.2016.09.009

Melitz, M. J., and Ottaviano, G. I. P. (2008). Erratum: Market Size, Trade, and Productivity. *Rev. Econ. Stud.* 75, 985. doi:10.1111/j.1467-937x.2007.00463.x

Pang, R., Zheng, D., Shi, M., and Zhang, X. (2019). Pollute First, Control Later? Exploring the Economic Threshold of Effective Environmental Regulation in China's Context. *J. Environ. Manag.* 248, 109275. doi:10.1016/j.jenvman.2019.109275

Porter, M. E., and Linde, C. v. d. (1995). Toward a New Conception of the Environment-Competitiveness Relationship. *J. Econ. Perspect.* 9, 97–118. doi:10.1257/jep.9.4.97

Tang, H.-l., Liu, J.-m., and Wu, J.-g. (2020). The Impact of Command-And-Control Environmental Regulation on Enterprise Total Factor Productivity: A Quasi-Natural Experiment Based on China's "Two Control Zone" Policy. *J. Clean. Prod.* 254, 120011. doi:10.1016/j.jclepro.2020.120011

Wang, X., Zhang, C., and Zhang, Z. (2019). Pollution Haven or Porter? the Impact of Environmental Regulation on Location Choices of Pollution-Intensive Firms in China. *J. Environ. Manag.* 248, 109248. doi:10.1016/j.jenvman.2019.07.019

Wu, H., Guo, H., Zhang, B., and Bu, M. (2017). Westward Movement of New Polluting Firms in China: Pollution Reduction Mandates and Location Choice. *J. Comp. Econ.* 45, 119–138. doi:10.1016/j.jce.2016.01.001

Yang, F., Yang, M., Xue, B., and Luo, Q. (2018). The Effects of China's Western Development Strategy Implementation on Local Ecological Economic Performance. *J. Clean. Prod.* 202, 925–933. doi:10.1016/j.jclepro.2018.08.203

Yu, M. (2015). Processing Trade, Tariff Reductions and Firm Productivity: Evidence from Chinese Firms. *Econ. J.* 125, 943–988. doi:10.1111/ecoj.12127

Zeng, D.-Z., and Zhao, L. (2009). Pollution Havens and Industrial Agglomeration. *J. Environ. Econ. Manag.* 58, 141–153. doi:10.1016/j.jeem.2008.09.003

Zhang, C., Zhou, B., and Wang, Q. (2019). Effect of China's Western Development Strategy on Carbon Intensity. *J. Clean. Prod.* 215, 1170–1179. doi:10.1016/j.jclepro.2019.01.136

Zhou, Y., Zhu, S., and He, C. (2017). How Do Environmental Regulations Affect Industrial Dynamics? Evidence from China's Pollution-Intensive Industries. *Habitat Int.* 60, 10–18. doi:10.1016/j.habitatint.2016.12.002

Zhuo, C., and Deng, F. (2019). How Does China's Western Development Strategy Affect Regional Green Economic Efficiency? *Science of the Total Environment* 707, 135939. doi:10.1016/j.scitotenv.2019.135939

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