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The Impact and Spillover Effects of Environmental Regulation on GTFP

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Abstract. Have environmental regulations introduced by local governments in China promoted regional green development? This paper identifies the impact and spillover effect of environmental regulations on Green Total Factor Productivity by using provincial panel data over the period 2005-2018. We found that the intensity of ERs is positively correlated with regional GTFP growth and also benefits its neighbours. I have also identified green innovation and FDI transfer as two mechanisms of action leading to this phenomenon. Finally, the effects of environmental regulation also vary according to geographical location, the degree of dependence on polluting industries and the level of nationalisation.

1 Introduction

Over the past decade, China's energy intensity has fallen by a cumulative 26.2%, equivalent to using 1.4 billion tonnes of standard coal less and emitting 2.94 billion tonnes of carbon dioxide less. However, the staggering macro emission reduction figures do not mean that China has made sufficient efforts in environmental management. If we turn to the regional level, China's current model of environmental governance is still dominated by 'tail-end governance', meaning that local environmental protection efforts will only increase if the central government imposes strict emission reduction targets on them (Chen et al., 2022[1]). The disinterest of local officers in environmental protection may not stem from excessive environmental regulation, as most studies of China suggest that the country may still be in a phase of under-governance compared to over-governance (Wang and Shi, 2018[2]).

In this paper, I look at the effects of environmental policy implementation over the period 2005-2018. In order to consider the impact of environmental regulation (ER) more comprehensively, I choose the green total factor productivity (GTFP) as the explanatory variable and construct an exogenous proxy variable for local environmental policy in order to identify the response of GTFP to a different level of ER chosen by local government. The regression results show that stricter levels of environmental regulation can contribute to China's overall growth and that each one-standard-deviation increase in the level of environmental regulation leads to a 4.97% increase in the standard deviation of GTFP.

However, it is still worth exploring the spatial spillover effects of environmental regulation. In China, the incentive for government departments to fulfil their governance responsibilities perfectly comes from the opportunity for promotion, which makes them inevitably competitive with officials from other provinces. If there are indeed spillover effects of environmental regulation, then they will make decisions taking into account not only local performance indicators, but also the responses of other provinces, and implement specific competitive or cooperative strategies. To this under-studied problem, I construct a geographically distance-weighted indicator to represent the impact of local environmental policies, which is called nearby environment regulation (NER). This paper also confirms the existence of positive spillovers from environmental regulation and reveals two ways in which it may affect GTFP - by shifting polluting industries outwards and by driving up the level of innovation in other regions.

Finally, there may be some heterogeneity in the degree of impact of environmental policies due to significant differences in individual characteristics across Chinese provinces. I divided the sample into three subgroups based on geography, level of pollution and level of nationalisation, and represented them by dummy variables. By constructing an interaction term between this dummy variable and environmental regulations (both ER and NER), I obtain the following conclusions. Provinces and municipalities with high reliance on polluting industries are more sensitive to local environmental regulation, but do not show heterogeneity in the impact of nearby environmental regulation. In addition to this, both the eastern region and higher levels of enterprise privatisation strengthen the effect of NER, but weaken the effect of ER.

This paper also provides some policy insights - even if environmental indicators are included in the promotion assessment system for officials, there is a strong incentive for officials to provide inadequate environmental regulation because nearby provinces can become free-riders who benefit from local environmental regulation at

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no cost. Thus, although China introduces a series of restrictions at the national level and incorporates environmental indicators into the officials' appraisal system, the problem of incompatible incentives may still be a potential concern for local environmental protection.

The contributions of this paper are as follows. Firstly, this paper focuses on the rarely studied spillover effects of environmental regulation and expands on the mechanisms of action and heterogeneity of both local and nearby environmental regulation. Moreover, I choose a relatively exogenous proxy variable of environmental regulation to overcome the possible endogeneity problems of previous literature.

The remainder of the essay is structured as follows. Theoretical hypotheses and a review of the literature are presented in Section 2, and the measurement of the main indicators is covered in Section 3. The results and discussions of the empirical analysis are introduced in Section 4. The study findings and political ramifications are presented in Section 5.

2 Relationship between ER And GTFP in China

Given that environmental indicators have been included in the promotion system for officials since 2005, measuring local governance performance alongside economic indicators, we need an indicator that encompasses at least both economic and environmental impacts to evaluate the effectiveness of environmental policies. An ideal indicator would be green total factor productivity. It covers several elements those local officials consider when making decisions: preferred economic benefits (including employment, capital, and energy) and averted environmental losses (emissions of the three major pollutants). Therefore, the GTFP was chosen as a performance indicator to assess the combined impact of local environmental regulation in this paper.

There is so far no consensus in the academic community regarding the direction and mechanism of its effect on green productivity. The main views are currently divided into three schools of thought, which consider the relationship as a positive impact, a negative impact and uncertainty respectively.

Most researchers suggest that stricter environmental regulations will be beneficial to the improvement of TFP and the increase of GTFP (Li and Shen, 2012[3]). Some scholars also argue that the "cost effect" of ER, which increases the cost of environmental compliance for firms, reduces energy efficiency and firm performance, and is detrimental to GTFP (Lei and Yu, 2013[4]). Others believe that the relationship between ER and GTFP, technological innovation and technical efficiency is "inverted U-shaped" (Li and Tao, 2012[5]). Li et al. (2013[6]) find that environmental regulation can promote green total factor productivity only when it lies between the threshold values of 1.999 and 3.645. Huang, QH. et al. (2018[7]) found through PVAR model those environmental regulations can boost green productivity in the short run, but have a negative impact on environmental conditions in the long run. Accordingly, we argue, based on the idea of the environmental Kuznets curve, that there may be an optimal level of regulation that promotes GTFP.

Hypothesis1 The effect of ER on GTFP shows an inverted U-shaped relationship of promotion followed by inhibition.

However, little attention has been paid to the spatial effects of environmental policies. Xu and Pan (2020[8]) found positive spatial spillover effects of environmental regulations developed in other provinces on industrial green productivity. Zhang and Qiao (2022[9]) find a negative spatial spillover effect of all three environmental regulations on manufacturing GTFP through a spatial error model. As the existing studies have focused on manufacturing industries and are insufficient in number, this paper proposes hypothesis2 to test whether ER does have a spillover effect.

Hypothesis2 Environmental regulations in nearby provinces have a significant impact on the province.

There are many different views on the transmission channel of ER to GTFP, mainly focusing on technological innovation and FDI. Among scholars, represented by Porter, it is argued that environmental regulation will promote innovation (Hamamoto, 2006[10]; Jing and Zhang, 2014[11]). However, other scholars have emphasised the 'cost effect' (Wagner, 2007[12]). Thus, the role of R&D activities between ER and GTFP is unclear. On the other hand, environmental regulations may lead to the withdrawal of highly polluting foreign firms from the local market and reduce FDI (Fu and Li, 2010[13]). It has also been argued that the relocation of industries as a result of environmental regulation can degrade the environment in the destination province (Shen and Jin, 2019[14]). Some scholars have also studied new mediators, arguing that environmental regulations can lead to changes in factor allocation between highly polluting and clean industries (Yuan and Bu, 2022[15]) or to an upgrading of regional industrial structures (Li and Wu, 2022[16]), thus causing changes in GTFP. Based on the existing literature, the mechanisms of green innovation and FDI are still unclear and this paper will focus on verifying the moderating role of these two variables.

Hypothesis3 Green innovation and FDI may be the transmission mechanism of ER's and NER's influence on GTFP.

3 Data and variables

3.1 Data

The sample in this paper is drawn from 30 provincial-level administrative regions in China (except for Tibet, Taiwan, Hong Kong and Macau), including Beijing, Shanghai, Tianjin and Chongqing four prefecture-level cities which have a small geographical area but play an important role in the economy. I constructed a panel dataset using data from 2005-2018, containing 420 observed variables, all from provincial statistical yearbooks disclosed by each province and the China Energy Statistical Yearbook.

3.2 Variables

3.2.1 Green total factor productivity (GTFP)

As mentioned earlier, the impact of environmental policy is multi-layered, so discussing only a single aspect of ER on the economy, employment, pollution emissions, and so forth may lack realistic implications. What we really need to discuss is whether the introduction of environmental regulation is a 'dilemma' or a 'win-win' for overall local development, which covers various factors such as employment, economic growth and environmental protection. Therefore, the explanatory variable chosen for this paper is GTFP.

In this paper, each province is treated as a decision-making unit (DMU) to construct the production frontier, which is estimated using data envelopment analysis (DEA) and then based on which the productivity index is calculated. First, assuming that each decision unit uses N inputs and the input vector is $x = (x_1, \dots x_N)$. The outputs are divided into desired and undesirable outputs, with the desired output vector $= (y_1, \dots y_M)$ and the undesirable output vector $b = (b_1, \dots b_P)$. The selection of each input and output variable is shown in the table below.

Table 1. Input and output variables in DEA model

Category	Variable	Data and description
Input indicators	Labor input	Average number of workers employed
	Capital investment	Fixed asset stock value
	Energy input	Total energy consumption
Output indicators	Desirable output	GDP after deflating
	Undesirable output	SO2 emissions Industrial dust emissions Wastewater discharge

According to Färe et al. (1994[17]), we can get the output set restricted to these restrictions (assuming constant earnings to scale):

$$P^t(x^t) = \left\{ (y^t, b^t): \sum_{j=1}^{J} \lambda_j^t y_{jm}^t \geq y_{jm}^t,\ m = 1, \dots, M; \sum_{j=1}^{J} \lambda_j^t b_{jp}^t = b_{jp}^t,\ p = 1, \dots, P; \sum_{j=1}^{J} \lambda_j^t x_{jn}^t \geq x_{jn}^t,\ n = 1, \dots, N;\ \lambda_j^t \geq 0, j = 1, \dots, J \right\} \quad (1)$$

where λ_j^t indicates the weight of each cross-section. It thus provides weights which facilitate the construction of the linear segments of the piecewise linear boundary of the technology. Next, we need to determine the solution's objective function and use it to measure the efficiency of each DMU. According to the idea of Chung (1997[18]), the optimal output multiplier can be solved by a directional distance function (DDF), which encourages both the expansion of desired output toward the production frontier and the contraction of pollution emissions towards the pollution minimisation frontier in the basic form $\vec{D}_0^t(x^t, y^t, b^t; g)$, indicating that when the maximum multiple that can be expanded along the direction vector g, the output (y, b) , or the distance between the output and the optimal output point along the direction vector g. In this paper, the direction vector is set to $g = (y, -b)$, which denotes the increase or decrease in desired and undesired outputs. The DDF can therefore be defined as:

$$\vec{D}_0^t(x^t, y^t, b^t; g) = sup\{\beta: (y, b) + \beta(y, -b) \in P(x)\} \quad (2)$$

It denotes the maximum expansion multiple of each output group towards the optimal output group along the $(y, -b)$ direction. Combined DDF with the possible output set, the directional distance function for a specific province in period t can be obtained by solving the following linear program:

$$\vec{D}_0^t(x^t, y^t, b^t; y^t, -b^t) = max\beta \quad (3)$$

$$s.t.\ \sum_{j=1}^{J} \lambda_j^t y_{jm}^t \geq (1+\beta) y_{jm}^t,\ m = 1, \dots, M;$$

$$\sum_{j=1}^{J} \lambda_j^t b_{jp}^t = (1-\beta) b_{jp}^t,\ p = 1, \dots, P;$$

$$\sum_{j=1}^{J} \lambda_j^t x_{jn}^t \leq x_{jn}^t,\ n = 1, \dots, N;\ \lambda_j^t \geq 0, j = 1, \dots, J$$

Finally, with the solution of DDF, an ML productivity index can be constructed. Based on Chung et al. (1997[18]), the productivity change between periods t and (t+1) can be defined as the output-based Malmquist-Luenberger productivity index:

$$ML_t^{t+1} = \left[\frac{1 + \vec{D}_0^t(x^t, y^t, b^t; y^t, -b^t)}{1 + \vec{D}_0^{t+1}(x^t, y^t, b^t; y^t, -b^t)} \right]^{\frac{1}{2}} \times \left[\frac{1 + \vec{D}_0^t(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1})}{1 + \vec{D}_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1})} \right]^{\frac{1}{2}} \quad (4)$$

The ML index can be further decomposed into technical efficiency change (EC) and technical progress change (TC), which is $ML_t^{t+1} = EC \times TC$:

$$EC_t^{t+1} = \frac{1 + \vec{D}_0^t(x^t, y^t, b^t; y^t, -b^t)}{1 + \vec{D}_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1})} \quad (5)$$

$$TC_t^{t+1} = \left[\frac{1 + \vec{D}_0^t(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1})}{1 + \vec{D}_0^t(x^t, y^t, b^t; y^t, -b^t)} \right]^{\frac{1}{2}} \times \left[\frac{1 + \vec{D}_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1})}{1 + \vec{D}_0^{t+1}(x^t, y^t, b^t; y^t, -b^t)} \right]^{\frac{1}{2}} \quad (6)$$

Where EC means the pure productivity gains resulting from the approximation of output to optimal efficiency output, and TC means the change in industrial output caused by pure technical progress. Finally, according to Fu et al. (2018[19]), using 2004 as the base period and setting GTFP to 1 for each province, we then get the GTFP by cumulatively multiplying the ML index.

3.2.2 Environmental regulation (ER)

Environmental laws are complex and frequently challenging to quantify. Most existing papers have relied on ex-post factors like pollutant treatment rates (Fu and Li, 2010[20]) and actual expenditures on pollution treatment to gauge how strict environmental regulations are (Shen, 2012[21]; Lanoie et al., 2008[22]). This indicator of higher-level decision making is superior to ex-post indicators in estimating the impact of environmental regulation on firms' production decisions, with the exception of Chen et al. (2018[23]), who use environmental texts in government work reports. This is because local officials' behaviour is less likely to be influenced by changes in firms' production activities in response to shifting regulatory stringency.

Government work reports are among the most significant official documents created by governments at all levels in the Chinese political system to summarize the social and economic accomplishments of their jurisdictions over the previous year and to set work plans and specific targets for the upcoming year. The work reports' contents typically reflect the province's priorities.

The public frequently uses the percentage of text devoted to certain policies in provincial governments' annual work reports to gauge how much effort local authorities are truly putting forth to meet their objectives for the current year. All of the work reports from 2005 to 2018 can be found among the 30 provinces in the sample, as the majority of them publish government work reports online for simple download and public scrutiny. The yearly government work report for each province will be made public the following year; for instance, the report for 2015 will be made public in early 2016. Governments typically spend more time summarizing past outcomes than developing plans for the objectives for the following year, hence the years referenced in this paper are those in the title of the government's work report. As a result, the work report for the current year, which will be released the next year, will more accurately depict the degree of regulation in the current year.

I use Zhao Chen's (2018[23]) analysis of the work report text to identify all of the sentences that mention the environment (huanjing), energy use (nenghao), pollution (wuran), emission reduction (jianpai), or environmental protection (huanbao) as being connected to the environment. The ratio of the total number of words in the environment-related sentences to the total number of words in the work report for that year is how I determine each province's environment-related text proportion for each year. The percentage of sentences in the entire report that are related to the environment is what this statistic ultimately means, with a greater percentage denoting stricter environmental control.

3.2.3 Nearby environmental regulation (NER)

In order to assess the spillover effects of environmental regulation in other cities, the more common approach is to use a spatial distance or economic distance matrix for weighting. The NER is relatively exogenous as it is difficult for each province to control the environmental policies of other provinces, which can avoid the possible endogenous problem. In general, the spillover effects of industry transfer between provinces and pollution are not strongly related to the economic dependence of both parties, but are closely related to the distance between provinces. For this reason, the paper uses the inverse of the squared linear distance between provinces as a weight to construct an index of the intensity of 'neighbouring regulation' for each province.

$$NER_i = \sum_{k \neq i}^{30} ER_{ik} / D_{ik}^2 \quad (7)$$

Meanwhile, the environmental regulations of the remaining 29 provinces do not have the same impact on a given province - for example, it is difficult to argue that Hainan, the southernmost province in China, is affected by the environmental regulations of Heilongjiang, the northernmost province, even if the NER weighted by the inverse of the distance is already a small value. Therefore, I also take the weight of provinces beyond 1000km and 500km as 0 respectively, and construct the $NER1000$ and $NER500$ indices to measure the strength of environmental regulations in the strict sense of “nearby” provinces to test the robustness of regression.

3.2.4 Other variables

Consider first the Innovation (Inno), which is one of the mediators in this paper. In studies related to environmental regulation and technological innovation, the number of patents indicator is widely used to measure technological innovation output. However, many scholars have chosen the absolute number of green patents to represent the level of innovation, ignoring the differences in the innovation environment across provinces. Some scholars have also used indicators such as R&D investment or the number of all patents, failing to consider that they are not closely related to environmental regulation. Therefore, this paper uses the ratio of the share of green new patent applications to the total number of patent applications as a proxy variable for the level of innovation. The reason for choosing the number of patent applications rather than the number of acquisitions is that Chinese patent applications have an examination and approval process, and the number of patent acquisitions in the current year may not reflect the effect of environmental regulation in the current year.

Next consider FDI, which is the other mediator. As FDI data is published in China's statistical yearbooks at all levels, the variables chosen are relatively consistent across the literature. To eliminate the effect of economic size, I use the ratio of FDI to GDP for each province to measure the local investment of foreign capital.

The main control variables in this paper are decentralization degree, nationalization degree, trade dependency, unemployment rate, industrial structure and human capital resource. As for the decentralization degree

(DC), I choose the expenditure indicator based on Lv BY. (2021[24]) which can better reflect the real budgetary freedom of regional governments. It is calculated as provincial fiscal expenditure/ Overall fiscal expenditure, where fiscal expenditure is all measured as a per capita indicator. The degree of nationalization (State) is measured by the value of state assets/value of fixed assets in the province. The unemployment rate is the registered unemployment rate (Unemp). The industrial structure is expressed using the share of secondary industry to GDP (Sec). To eliminate endogeneity problems caused by contemporaneous correlation between the control variables and the dependent variable, all control variables are lagged.

4 Empirical results

4.1 Basic results

The table below shows the estimated results of the baseline regression. In columns (1) and (2), where no fixed effects are included, the regression coefficient of ER is positive and significant at the 5% level, indicating that local environmental regulation significantly promotes local green development. In the last three columns, I report the results after including time and city fixed effects, and introduce NER and ERD denoting nearby environmental regulation and the quadratic terms for ER respectively. Where NER is positively significant at the 5% level, representing a positive spillover effect of environmental regulation from nearby provinces. The quadratic term for local ER is insignificant, rejecting hypothesis1 and indicating that the relationship between ER and GTFP is linear. Column (4) therefore demonstrates the main results in this paper, indicating that one standard deviation increase in the frequency of environment-related words in government work reports leads to a 4.97% increase in the standard deviation of GTFP relative to the base period, and a one standard deviation increase in the environmental regulation index in nearby provinces leads to a 9.91% increase in the standard deviation of GTFP relative to the base period.

Table 2. Basic regression results

	(1)	(2)	(3)	(4)	(5)
ER	0.483** (2.10)	0.445** (1.99)	0.378** (1.99)	0.392** (2.07)	0.675* (1.82)
NER		0.086 (1.19)		0.155** (2.13)	0.154** (2.11)
ERD					-1.470 (-0.89)
FE	YES	YES	YES	YES	YES

The significant effect of ER on GTFP implies that local governments in China have indeed implemented a series of effective environmental regulations in line with central environmental protection objectives. However, the data in this paper do not show an inverted U-shaped curve, which may not imply that optimal environmental regulation does not exist, because it is also possible that China has not yet reached the inflextion point of the inverted U-shaped relationship. The result of NER, on the other hand, shows that a region can benefit from an increase in environmental regulation in nearby regions, even when controlling for the same local environmental regulation.

4.2 Mediating effect analysis

The previous regressions demonstrate the effectiveness of local and surrounding area ER on GTFP enhancement, but mechanism tests are still needed to understand in what ways environmental policies affect GTFP. Therefore, the following table reports the results of the moderating effect tests on green patent application rates, and FDI levels. As shown in the first two columns, both ER and NER are significantly positive before the inclusion of the two moderators, ensuring that the premise of a moderating effect holds. According to the results in column (3), environmental regulations in local and nearby provinces promote local innovation at the 10% and 5% levels respectively. Column (4) shows that local environmental regulations lead to a decrease in FDI, while environmental regulations in other provinces has the opposite effect. After adding moderators in column (5), the regression coefficients of green innovation and FDI are 0.098 and -0.103, which both have significant effect on GTFP. The coefficients of ER and NER on GTFP change to 0.337 and 0.163 respectively, but the significance does not disappear, representing a partial moderating effect of green innovation and FDI.

Table 3. Mediating effect analysis

	(1) GTFP	(2) GTFP	(3) Inno	(4) FDI	(5) GTFP
ER	0.381** (2.02)	0.371** (1.92)	0.344* (1.75)	-0.325* (-1.87)	0.337* (1.78)
NER	0.164** (2.25)	0.156** (2.15)	0.124** (1.81)	0.090** (2.27)	0.163** (2.23)
Inno		0.098** (2.03)			0.098** (2.04)
FDI	-0.103* (-1.80)				-0.103* (-1.82)
FE	YES	YES	YES	YES	YES

By using mediating effects tests, I have identified two pathways through which ERs act on GTFP, corresponding to two important hypotheses in the environmental field - the 'Porter effect' and the 'pollution refuge' hypothesis. Consistent with the Porter hypothesis, environmental regulation in China causes an increase in the number of green patent applications, as has been confirmed by many scholars. The new finding is that ERs in other provinces also exert pressure on local firms to undertake green R&D, thereby increasing GTFP. Thus, the spillover effects of environmental regulation can work for GTFP through the pathway of increased innovation R&D.

There is also the conventional wisdom that China has become a 'pollution refuge' for developed countries and a 'net importer' of pollution due to its previously lax environmental regulations. This phenomenon is mainly reflected in the inverse relationship between FDI and ER, which is consistent with the above regression results. This paper verifies through empirical evidence from China that stricter environmental regulations lead foreign firms to exit the local market. However, the new finding that higher ER levels in other provinces lead to an increase in local FDI suggests that emission limitation policies may lead to cross-regional shifts in polluting industries. This phenomenon has been ignored by many past studies, but would significantly lead to an increase in undesired output and a decrease in GTFP.

4.3 Heterogeneity test

The table below examines possible heterogeneity by including interaction terms. As mentioned earlier, I construct three sets of dummy variables based on the mean of emission levels, regions and nationalisation levels, and place their interaction terms with the environmental regulation variable ER and NER in the model regression. Therefore, this section focuses on the magnitude and significance of the coefficients of the interaction terms in each column. The regression results in column (1) show that the coefficient on the interaction term of ER is significantly positive at the 1% level for high emission areas, while that of NER has no significant effect on GTFP. The negative coefficient on the interaction term in columns (2) indicates that GTFP in eastern regions is instead relatively insensitive to changes in ER, but that NER has the opposite effect. Column (3) shows the effect of the level of nationalisation, indicating that local environmental regulation is more effective in areas with a higher proportion of state assets, but that the spillover effects of environmental regulation are more pronounced in places with higher levels of privatisation.

Table 4. Heterogeneity test

	(1)	(2)	(3)
ER*D_EMI	1.970*** (3.40)		
NER*D_EMI	0.239 (0.89)		
ER*D_REGION		-1.171*** (-3.37)	
NER*D_REGION		0.361*** (3.27)	
ER*D_STATE			0.867** (2.56)
NER*D_STATE			-0.327*** (-2.79)
FE	YES	YES	YES

Using heterogeneity analysis, I find that three characteristics - higher emissions, location in the mid-west and higher share of state assets - can significantly increase the effectiveness of the ER, while the latter two may diminish the effectiveness of the NER. Emission levels in this paper are measured in terms of combined emissions of pollutants per unit of GDP, rather than absolute values of emissions. As a result, provinces with low emissions have a larger base of emission reductions and more room for efficiency gains. With stringent emission reduction mandates in place, they are able to reduce unintended outputs by drawing on the technology or experience of low-emitting regions, thereby contributing to increased GTFP.

There are also plausible explanations for heterogeneity at the regional level. In China, the eastern provinces generally have a higher level of economic and transaction conditions. The cost of imposing environmental regulations on the east may therefore be high, as local governments could have used the expenditure to support businesses with more development potential or to make more economically efficient investments. As a result, environmental regulation in the eastern provinces is less effective in raising GTFP than in the middle and west. With regard to NER, due to the high density of universities and research institutions in the East, the positive externalities of innovation activities are more pronounced and local areas are more likely to benefit from the increased level of science and technology brought about by environmental regulation in other regions without having to bear the high cost of abatement. Therefore, the effect of NER is more significant in the east.

In terms of nationalisation, in many regions of China, the pillar industries are state-owned assets. The mission of these enterprises is not only to make a profit, but also to fulfil administrative policies. Therefore, enterprises with a high share of state-owned assets will also have a better effect on environmental regulation. However, as most state-owned enterprises are not profit-driven, they have weaker incentives for R&D than private enterprises and are less likely to exploit the positive spillover effects of science and technology, and the effects of NER are relatively less pronounced in areas with high levels of nationalisation.

4.4 Robustness test

Finally, by replacing the explanatory variables ER and NER, I conducted robustness tests. Columns (1) and (2) replace the original NER with a range of values for provinces within 1000km and 5000km respectively. Column (3) replaces ER with another widely used proxy variable for environmental regulation, namely weighted emissions of three major pollutants (ER3P), and regresses the values of NER (NER3P) by calculating them in the same way. The results show that the regression coefficients of the replaced independent variables are still positively significant and the same as the main regression results. Therefore, the regression results in this paper are robust.

Table 5. Robustness test

	(1)	(2)	(3)
NER1000	0.153** (2.20)		
NER1000		0.147** (2.22)	
ER3P			0.048* (1.82)
NER3P			0.141** (1.99)
FE	YES	YES	YES

5 Conclusion

Based on the empirical analysis, this paper concludes that stronger environmental regulation can significantly increase regional GTFP, implying that it is a beneficial initiative to promote regional green development. At the same time, by constructing a distance-weighted index to measure environmental regulation in other regions, I find that the positive effect of environmental regulation can also spread to other provinces.

The paper also explores the mechanisms at work behind environmental regulation. Locally, tighter environmental policies may force firms to develop new green technologies in response to new standards and emission limits, thereby increasing regional productivity levels. At the same time, tighter environmental policies may make it difficult for highly polluting firms to survive and can thus reduce undesired output emissions. For other regions, local technological innovation resulting from stronger local environmental policies will contribute to productivity gains in other regions through knowledge spillovers. However, firms that move out of the local area due to pollution constraints may also relocate elsewhere, increasing pollution emissions instead.

Even if, overall, both ER and NER are able to raise the level of GTFP, their effects will still be somewhat heterogeneous. The positive effect of ER is more pronounced in regions with lower emissions per unit of GDP, while regions with high levels of privatisation in the east enhance the spillover effect of NER but reduce the direct effect of ER. A few possible explanations are that provinces with higher current levels of emissions per unit of GDP have greater potential to reduce emissions and therefore the effect of environmental regulation is more pronounced. In contrast, in the east and in more privatised regions there may be more scientific research activity and stronger positive spillover effects of environmental policy as well as higher pollution reduction cost.

This finding may lead to some potential problems. For example, there may be governmental free-riding when environmental regulations in other provinces can boost GTFP in the local province. Those officials may be inclined to enjoy the spillover effects of environmental regulations in nearby provinces at no cost, while providing inadequate environmental regulations in their own province. Of course, this may also lead to cooperative complicity between local governments, as it is in the interests of both parties to have stronger environmental regulations in place. However, it is still undeniable that, according to the results of this paper, for Chinese provinces, increasing the intensity of local environmental regulations is currently very beneficial for regional development in general, for both local and nearby province.

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