Asymmetric Environmental Regulation: Mechanism and a Yardstick Phenomenon

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Abstract: *In discussing the policy effects of environmental regulation, we should focus not only on whether environmental regulation helps improve the environmental and economic performance of firms, but also on how such improvement is materialized, i.e. whether the obsolete mode of production is reversed. After matching the database of China's industrial enterprises with that of pollution emissions from these industrial enterprises, this paper identifies the asymmetric scope of clean production standards to test the effect of environmental regulation on the total factor productivity (TFP) of the industrial enterprises. Our empirical research finds that the implementation of clean production standards may induce TFP improvement. However, such improvement only occurs for polluters who cannot or who barely meet clean production standards and does little to improve the production standards of polluters with low pollution emission, reflecting the yardstick phenomenon of the asymmetric environmental regulation policy effect: While polluters are forced to improve, clean enterprises that pollute less are more likely to take no action. Further research finds that such TFP improvement is materialized primarily by means of overall firm optimization; the compensation effect is insignificant and does not reverse the backward mode of production. Polluters cope with the implementation of clean production standards by purchasing more equipment and expanding capacity, which adds to the tension between the expansion of capacity and the abatement of pollution emission.*

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1. Introduction

China's rapid economic growth and industrial development have been accompanied by hefty energy consumption along with a hefty amount of pollution emission. Faced with severe environmental challenges, China has initiated a climate ambition of "carbon peak by 2030 and carbon neutrality by 2060". Compared with developed countries, China is expected to have achieved only a moderate level of economic development by the time it reaches carbon peak, and it is expected to take a shorter time than other countries to transition from carbon peak to carbon neutrality. This climate ambition requires a high level of coordination between high-quality economic development and environmental protection.

In the mid- and long-term, reducing the emission of pollutants requires not only strengthening the supervision over pollution abatement and recovery and environmental protection for heavy polluters, but

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also optimizing pollution abatement potentials and leveraging the effect of asymmetric environmental regulation for all enterprises, irrespective of their current level of pollution emission, so that polluters clean up and clean enterprises become even cleaner.

Most existing studies focus on the effects of environmental regulation on environmental performance (Shen and Zhou, 2020; Han et al., 2020) and economic performance (Wang and Liu, 2014; Chen and Chen, 2018; Wang et al., 2018; He et al., 2020), and test the mechanisms and heterogeneity of such effects based on the Porter Hypothesis (Li and Sheng, 2018; Sheng and Zhang, 2019; Ren et al., 2019). However, those studies only regard environmental regulation as an exogenous policy shock for homogeneous enterprises and do not identify the asymmetrical scope of the environmental regulation or the differentiated policy effects of such asymmetry for various types of enterprise.

Environmental regulation should be compatible with the characteristics of the regulated entity. External policy shock is asymmetric for firms, as is the scope of environmental regulation. Such asymmetry is the basis for implementation of the targeted environmental policy. Existing studies have extensively examined the homogeneous policy effects of the same environmental regulation on firms of various ownership types and sizes. But in reality, the scope of environmental regulation is asymmetric and designed to address different types of environmental problems with heterogeneous policy effects. Instead of a one-size-fits-all standard, asymmetric environmental regulation (Tombe and Winter, 2015) sets different standards for enterprises with different levels of pollution emission. Such asymmetric environmental regulation has differentiated policy effects for polluting and clean enterprises.

In coping with asymmetric environmental regulation, profit-seeking enterprises seek to minimize their cost and maximize their economic performance while meeting the minimum environmental standards. Clean enterprises focus on innovation to slash environmental cost and stay competitive. In contrast, polluters are forced to improve their capacity to lower the intensity of their pollution emission to meet pollution emission standards, which tends to result in those enterprises having better economic performance due to economies of scale. However, their existing capacity for intensive pollution emission challenges further environmental improvement.

The transformation of the economic development pattern lies at the heart of long-term mechanisms for environmental protection simultaneous with high-quality economic development. In evaluating the policy effects of environmental regulation, we should therefore focus on the improvement of environmental and economic performance resulting from such regulation and whether such improvement is achieved by abandoning obsolete modes of production and development. To answer this question, it is necessary to discuss the asymmetric scope of environmental regulation and differences and intrinsic mechanisms of the policy effects of such asymmetry.

With the implementation in 2003 of clean production standards in China’s three sectors as a quasi-natural experiment, this paper identifies the asymmetric scope of environmental regulation and examines how the implementation of clean production standards has influenced the total factor productivity (TFP) of industrial enterprises. As a primary driver for achieving the climate ambition, clean production aims to reduce emissions nationwide and is consistent with the vision for carbon neutrality.

In terms of regulatory scope, clean production standards are divided into various hierarchies and are highly asymmetric. In terms of policy intention, clean production standards are designed for various types of enterprise based on their challenges and possibilities. Presumably, profit-seeking enterprises will seek to meet only minimum clean production standards. Obviously, the regulatory scope of clean production standards is asymmetric, which supports our test of the TFP effect of environmental regulation for industrial enterprises using the difference-in-differences (DID) approach.

Our empirical research finds that environmental regulation is not at odds with economic performance. Instead, the implementation of clean production standards has made industrial enterprises more productive. Yet such an effect is subject to a significant yardstick phenomenon: While polluters are forced to clean up, clean enterprises are more likely to take no action. In other words, such an improvement effect exists for emissions-intensive enterprises that cannot meet the clean production standards or those that meet only the minimum standards, but does little for clean enterprises with low pollution emission intensity.

Further research uncovers that TFP improvement is achieved primarily through firm optimization with an insignificant innovation compensation effect. That is to say, environmental regulation did not cause the backward mode of production to change. In coping with environmental regulation, polluters purchased more equipment and expanded capacity, which worsened the tension between capacity expansion and pollution emissions and created pressures on environmental quality.

This paper makes the following contributions: First, by identifying the asymmetric regulatory scope of clean production standards and by testing the TFP effects of the implementation of clean production standards for industrial enterprises, how environmental regulation contributes to economic performance is revealed at a deeper level. Such revelation will enrich research in this field. Environmental policy implementation should be asymmetrically targeted at all enterprises, so that polluters clean up and clean enterprises become even cleaner.

Second, the yardstick phenomenon for the TFP improvement effect of clean production standards is explained. Previous studies have focused more on polluters' emission abatement, but have yet to pay attention to how compliant and clean enterprises improve their environmental performance. The latter also plays a pivotal role in China's efforts to develop long-term environmental protection mechanisms and coordinate high-quality economic development with ecological civilization. Enterprises subject to environmental regulation are classified as clean, compliant and non-compliant, based on the scope of the clean production standards, in order to analyze the yardstick phenomenon of policy effects stemming from the asymmetric scope of environmental regulation. Clean, compliant and non-compliant enterprises respond differently to the implementation of clean production standards. In this paper, the intrinsic mechanism of environmental regulation's effect is discussed in detail.

Third, this paper discusses how environmental performance is influenced by the implementation of clean production standards. Given the insignificant innovation compensation effect, enterprises meet clean production standards by diluting the intensity of their pollution emission by adding more capacity without phasing out existing obsolete production methods. Such capacity expansions may lead to even more emissions to the environment. From another perspective, this explains why, even though they are complying with pollution emission standards, individual enterprises may not contribute very much to environmental improvement.

2. Literature Review

Over the years, China has enacted stringent systems and legislation regarding environmental protection and imposed environmental responsibilities on polluters (Zhang, 2019). While improving environmental performance and quality, such environmental regulation also affects the production process and economic performance of enterprises (Lin, 2012). As the backbone of economic activity and as major polluters, enterprises bear primary responsibility for environmental management, which makes the case for investigating the response of enterprises to environmental regulation (Han et al., 2020). Unraveling the policy effects of environmental regulation helps improve environmental policymaking.

2.1 Environmental Regulation and TFP of Enterprises

The effects of environmental regulation on the TFP of enterprises are important topics of discussion in the field of China's environmental economics (Ren et al., 2019). Existing studies have been carried out primarily from two perspectives: One type of research attempts to depict and measure the intensity of environmental regulation and test the TFP effects of the environmental regulation on enterprises, which is denoted by such variables as the regulatory intensity (ratio between the cost of pollution control equipment and the total cost of the enterprise's sector) (Lanoie et al., 2008), composite pollution index for a province or city (Wang and Liu, 2014; Li and Chen, 2019), pollution discharge fees (Xu and Xie, 2016), and environmental policy stringency (EPS) (Martínez-Zarzoso et al., 2019). However, those indicators depict the effects of the environmental regulation rather than the environmental regulation itself (Xu and Qi, 2017).

The other type of research tests the productivity variations of enterprises subject to environmental regulation and those exempt from environmental regulation, which is seen as an external policy shock (Berman and Bui, 2001), or the TFP effects of environmental regulation measured before and after an environmental policy took effect. Such environmental policies include, for instance, environmental legislation (enactment of *Environmental Protection Regulations* and *Environmental Pollution Prevention and Treatment Regulations* by various provinces) (Li and Sheng, 2018), the "Three Rivers, Three Lakes" basin management (Wang et al., 2018), pollution right trading (Ren et al., 2019), conferment of the "civilized city" award (Shi et al., 2019), designation of acid rain and SO_2 control zones (Sheng and Zhang, 2019; Tang et al., 2020), the 11th Five-Year Plan (Zhang and Du, 2020), and upstream and downstream differences of water quality monitoring points (He et al., 2020).

Policy effects of environmental regulation are highly heterogeneous. Some studies discussed the heterogeneous effects of environmental regulation on enterprises of different ownership types, and considered that state-owned enterprises (SOEs) were subject to fewer regulatory pressures compared with private enterprises. As a result, environmental regulation has a greater impact on the economic performance of private enterprises (Ren et al., 2019).

Some studies attempted to analyze differences in environmental regulation requirements for threshold-based targets in comparison to absolute emissions limits for enterprises of various sizes using the threshold model, and found that such environmental regulation had a smaller restrictive effect for small businesses than it did for large ones (Long and Wan, 2017; Coria and Kyriakopoulo, 2018).

Still other studies observed the heterogeneous effects of environmental regulation on enterprises that emitted different levels of pollution. Among them, Wang and Liu (2014) estimated the effects of urban environmental regulation intensity (composite index of environmental regulation) on the TFP of the enterprise or divided samples into polluting sectors and non-polluting sectors above or below median sectoral coal consumption as the proxy of pollution intensity (Zhang and Sheng, 2019; Sheng and Zhang, 2019).

Studies on listed companies reclassified polluting enterprises as heavy polluters based on relevant criteria (e.g. *Catalogue of Sectoral Classification for Environmental Inspection of Listed Companies*) (Han et al., 2017) to discuss the heterogeneous effects of environmental regulation on heavily and non-heavily polluting enterprises. Those studies have yet to further identify the asymmetric regulatory scope of the environmental regulation and its differentiated effects on enterprises emitting different levels of pollution within the same sector.

2.2 Asymmetric Environmental Regulation and Its Policy Effects

Environmental legislation stipulates the principle of common but differentiated responsibilities for heterogeneous regulated entities (Wang, 2015). This principle determines the asymmetrical scope of environmental regulation. That is to say, enterprises emitting different levels of pollution should assume different levels of responsibility for emission abatement. They are supposed to act differently to meet specific environmental requirements. Enterprises tend to internalize the cost of pollution abatement to comply with environmental regulation; given the asymmetrical regulatory scope, they invest differently in emission abatement per unit of output, with potentially uneven levels of marginal return.

Technological sophistication allows enterprises to comply with environmental regulation at a smaller cost and with a greatly improved economic performance (Albrizio et al., 2017). Such asymmetry is considered in the policy specification of the environmental regulation to accommodate the possible effects of the environmental regulation on the enterprise's economic performance and its adaptability to environmental regulation. In this manner, differentiated regulatory requirements or compliance standards can be adopted to encourage all enterprises emitting different levels of pollution to improve, so that polluters clean up and clean enterprises become even cleaner.

Clean production standards are a set of productivity parameters for specific sectors designated by regulatory authorities based on the ranking of enterprises according to their clean production levels (Potters et al., 2004). Compared with "one-size-fits-all" environmental regulation, hierarchical compliance standards provide asymmetric regulatory incentives for enterprises based on their existing resource utilization, emissions, product performance and environmental management, among other indicators. Polluters can identify their current pollution emission level and compare themselves with enterprises having advanced levels of pollution control at home and abroad, which may motivate them to meet the highest standards and upgrade to cleaner production.

In discussing the policy effects of asymmetric environmental regulation, we should not only regard environmental regulation as a homogeneous external policy shock, we should also identify the asymmetric scope of the environmental regulation. Some studies have uncovered the existence of a yardstick competition between regulated entities. For instance, Fredrickson and Millime (2002) found the responses of states in the US to the stringency of environmental regulation in neighboring states to be asymmetric. Specifically, if one state has less stringent environmental regulation (denoted by emissions reduction cost) than its neighboring state, it will respond positively to an increase in the stringency of environmental regulation in the neighboring state, and vice versa. Based on China's data, such a yardstick competition phenomenon may also be found, i.e. only the provinces subject to less stringent environmental regulation will take active action (Zhang et al., 2010; Yu et al., 2020). Further research uncovered the "picking-the-low-hanging-fruits" phenomenon for the emissions abatement effect, i.e. environmental regulation is more asymmetric for heavily-polluting enterprises (Ju et al., 2020). Yet this finding based on the intensity of the environmental regulation still falls into the category of heterogeneity analysis without identifying the asymmetric scope of environmental regulation.

2.3 How Environmental Regulation Contributes to Economic Performance

Environmental problems arise from economic and social development, and the crude pattern of development is the root cause of China's environmental problems (Cai et al., 2008). In discussing the policy effects of environmental regulation, we should focus not only on the improvements of environmental and economic performance stemming from environmental regulation, but also the nature of such improvements, i.e. whether enterprises abandon the obsolete modes of production and development and embrace more sustainable ways. To answer this question, we need to discuss the asymmetric scope of environmental regulation, the heterogeneous policy effects arising from such asymmetry, as well as the underlying mechanisms.

Based on the Porter Hypothesis, many studies have discussed whether environmental regulation may induce TFP improvement through the innovation compensation effect. According to the Porter Hypothesis, pollution is a symptom of inefficient production, and enterprises should derive their competitive strength from improvement in efficiency. Relevant studies found the stringency of the environmental regulation to be significantly positively correlated with the probability of environmental R&D spending, which may spur enterprises to invest more in R&D or patent output (Li, Xiao, 2020; Tao et al., 2021; Liu et al., 2021) with positive effects on the growth of productivity (Hamamoto, 2006; Rubashkina et al., 2015; Martinez-Zarzoso et al., 2019).

The narrow Porter Hypothesis considers that some specific types of environmental regulation (such as market incentive environmental regulation) may induce the innovation of environmental technologies that increase output. While the weak Porter Hypothesis considers that environmental regulation may prompt enterprises to adopt new environmental technologies, the strong Porter Hypothesis considers that the vast majority of real-world enterprises cannot realize or maintain production choices to maximize profits (Espínola-Arredondo and Muñoz-García, 2016).

Environmental regulation may help all enterprises broaden their horizon and seek previously neglected opportunities by complying with environmental standards, which may also increase output (Jeff and Palmer, 1997). That is to say, if an environmental regulation induces the innovation of environmental technologies (i.e. the assumption of the narrow Porter Hypothesis), or if enterprises import or apply new environmental protection technologies (i.e. the assumption of the weak Porter Hypothesis), the innovation compensation effect of such environmental regulation may induce enterprises to increase TFP, abandon backward modes of production and development, and improve environmental and economic performance in a sustainable way.

However, if enterprises cope with environmental regulation only by internalizing the cost of emissions abatement or by purchasing or applying new environmental protection technologies, while such exogenous measures may temporarily satisfy environmental requirements (i.e. the assumption of the strong Porter Hypothesis), if the root case is left unresolved, despite improvement in environmental and economic performance, those enterprises will lose their competitive edge as environmental standards continue to rise (Liu and Zhang, 2019) and they fail to seize market opportunities and develop themselves sustainably.

3. Model Creation and Variable Specification

3.1 Model Specification

Clean production is a critical environmental strategy for sustainable development with the dual goals to boost productivity and mitigate environmental risk (Borges et al., 2022). Clean production standards are prioritized based on the current status of enterprise production and pollution discharge to designate clean production evaluation standards for enterprises in relevant sectors. In 2003, China's national environmental protection authority (former State Environmental Protection Administration) implemented clean production standards for the petroleum refinery sector (HJ/T 125-2003), the coking sector (HJ/T 126-2003), and the leather sector (pig leather) (HJ/T 127-2003). These three sectors were faced with more stringent environmental regulation (Long and Wan, 2017) and need to improve production and emissions abatement following the new standards.

Referencing Long and Wan (2017), this paper identifies enterprises of the three sectors (four-digit industry codes are 2511, 2520, and 1910, respectively) for which clean production standards came into effect in 2003 as the experiment group and other sectors as the control group to create a difference-in-differences (DID) model. Existing studies on testing clean production standards have generally followed two approaches for classifying the treatment group and the control group: First, whether the province of an enterprise had enacted clean production policies; second, whether clean production standards had been enacted for the sector in which the enterprise operates. This paper follows the second approach because many provinces had already issued relevant clean production standards before enacting *Measures for Cleaner Production Review (Inspection and Acceptance)*, which makes it hard to determine the dummy variable of time for policy implementation and affects the exogeneity of clean production review policies, as well as the causality of empirical test, if the first approach is followed.

Model (1) is adopted to test the firm TFP effects of environmental regulation:

$$TFP_{i,t}=\beta_0+\beta_1 CP\_Treatpost_{i,t}+\beta_2 CP\_Treat_i+\beta_3 CP\_post_t+\varphi Controls_{i,t}+f_i+\rho P_j\times\tau_t+\varepsilon_{i,t} \qquad (1)$$

The explained variable is current-period firm total factor productivity (TFP). $CP\_Treatpost_{i,t}$ is an indicator variable and denotes the interaction term between the grouping variable and the dummy variable of time. Accordingly, β_1 is the coefficient of primary concern. CP_Treat_i denotes whether the four-digit sector in which enterprise i operates has implemented clean production standards in year t, and if so, the value is 1; otherwise, it is 0. If the year is 2003 or afterwards, the value of CP_post_t is 1; otherwise, it is 0. Given the absence of such data as industrial value-added and intermediate input in the database of China's industrial enterprise in 2004, the year 2005 is regarded as the year following policy implementation. $\rho P_j \times \tau_t$ is the high-order fixed effect of province×year to control for the impact of shocks of region and year that do not change with enterprises; f_i is the fixed effect of enterprises to control for enterprises that do not change with the impact of shocks from temporal change; $\varepsilon_{i,t}$ is stochastic disturbance term.

3.2 Variables and Measurement

Total Factor Productivity (*TFP*). Referencing Levinsohn and Petrin's (2003) approach for estimating firm TFP, we define output as industrial value-added, intermediate input as total industrial intermediate input (in 1,000 yuan), and the labor force input as the annual average headcount of total employees, of which the data disclosed for 2003 are the total headcount of the enterprise at the end of current year. Referencing Olley and Pakes (1996), firm TFP is re-calculated in the robustness test (marked as *TFP_OP*), and firm investment is the difference between an enterprise's fixed assets in the current year and the previous year. Other input and output indicators are the same as above.

Control variables include the natural logarithm (ln*asset*) of an enterprise's total assets, the natural logarithm of fixed assets (ln*k*), the natural logarithm of enterprise age (ln*age*), the natural logarithm of enterprise labor force (ln*l*), the share of state capital in paid-in capital (*state*), the share of foreign capital and capital from Hong Kong, Macao and Taiwan in paid-in capital (*foreign*), the dummy variable of whether the enterprise has received any government subsidy (*subsidy*), the dummy variable of whether the enterprise is an exporter (*export*), the regional GDP of the city (*GDP_city*, in trillion yuan), and the industry concentration of the four-digit sector in which the enterprise operates (*HHI*). $HHI=\sum_{i\in I_t}(sale_{i,t}/total\_sale_{I,t})^2$, where $sale_{i,t}$ is the sales volume of enterprise i in year t, and $total\_sale_{I,t}$ is the gross sales volume of sector I in year t. Greater value of this indicator suggests a higher industry concentration to control for the impact of market competition.

For a more convenient examination of asymmetric environmental regulation's effects on different enterprises, it is advisable to classify enterprises by their emissions intensity. Clean production standards are divided into three hierarchies based on the current industry technology, equipment and managerial practice: Grade 1 standards denote the internationally advanced level of clean production, Grade 2 standards denote the domestically advanced level of clean production, and Grade 3 standards are the basic level of domestic clean production. Various sectors have specified their respective complex composite evaluation index using the theoretical analysis method or expert scoring method. Referencing the principle of indicator benchmark value designation in the *General principles of stipulating the assessment indicator frame of cleaner production*,[1] air pollutant (SO_2) and water pollutant (chemical oxygen demand, COD) of great concern in the existing research are selected to measure the differences of emissions intensity between enterprises in various sectors.

Based on the four-digit codes in the emissions database of industrial enterprises, the distribution function of SO_2 emissions per unit of output for enterprises in each sector is obtained. Enterprises without SO_2 emissions are assigned the value of 0, and those with emissions are categorized by the five-digit codes and assigned the values of 1/2/3/4/5, which denote the ascending order of SO_2 emissions per

[1] *General principles of stipulating the assessment indicator frame of cleaner production for industries* sets out the following principles for designating the benchmark indicator values: "Benchmark values for Grade 1, 2 and 3 standards should be reasonably determined based on the current status of clean production in the sector. In determining Grade 1 benchmark values, the principle is that, referencing internationally advanced clean production indicators, 5% of domestic enterprises meet such benchmark values; in determining Grade 2 benchmark values, the principle is that 20% of domestic enterprises meet such benchmark values; in determining Grade 3 benchmark values, the principle is that 50% of domestic enterprises meet such benchmark values."

unit of output. Furthermore, the distribution function of COD emissions per unit of output is obtained for enterprises in each sector. Enterprises without COD emissions are assigned the value of 0, and those with emissions are categorized by five-digit codes and assigned the values of 1/2/3/4/5, which denote an ascending order of COD emissions per unit of output.

Lastly, the emissions intensity of enterprises (PH) is non-dimensionalized[2] following equation of $PH=COD\_Y/1+SO_2\_Y/0.95$. In addition, enterprises are ranked in an ascending order of emissions intensity (PH values) and divided into clean enterprises (top 20%), compliant enterprises (between 20% and 50%) and non-compliant enterprises (in the lower 50% range). Relative to clean enterprises, both compliant and non-compliant enterprises are polluting enterprises.

3.3 Sample Selection and Data Source

We adopted a relatively short sample period of 2000-2006 considering that an overstretched estimation panel would include other policy effects in using the DID model. After pilot programs were carried out for the three sectors: petroleum refinery (HJ/T 125-2003), coking (HJ/T 126-2003) and leather making (pig leather) (HJ/T 127-2003), from the end of 2006 to early 2007, China's national environmental protection authority implemented clean production standards for 17 other sectors. Meanwhile, the 11th Five-Year Plan since 2006 called for the reduction of major pollutants as binding targets for China's economic and social development, which to some extent interferes with the assessment of the DID effect. Moreover, no more industrial value-added and intermediate input indicators are released from the database of industrial enterprises after 2007, which means that firm TFP cannot be precisely estimated. Hence, our research period ends with 2006.

Other research samples are China's industrial enterprises with corporate financial data, corporate attributes and other information from the database of China's industrial enterprises, as well as such indicators as energy consumption, pollutant generation and polluting equipment input from the emissions database of China's industrial enterprises. The first step of work is to match the two databases and perform a pre-treatment referencing the existing research literature (Yang, 2015). Second, the sector codes of 1998-2002 are re-matched according to the *Classification of National Economic Sectors (GB/T4754-2002)*. Lastly, the following samples are excluded: Samples with missing or smaller-than-zero total industrial output, net worth of fixed assets, industrial sales value and paid-in capital; samples with employees fewer than eight; samples with sales turnover below five million yuan; samples with total assets smaller than current assets or net fixed assets, or cumulative depreciation smaller than current-period depreciation. Finally, we end up with one-year samples of 116,533 enterprises.

4. Benchmark Regression

4.1 Descriptive Statistics

See Table 1 for the descriptive statistics of major variables.

Compared with firm TFP and other characteristic indicators, the standard deviation of emissions intensity is significantly higher. Among the samples, state-owned assets account for an average of 0.187, foreign investments make up for 6.3%, and some 18.7% of enterprises had received government subsidies.

4.2 Environmental Regulation and Firm TFP

The Porter Hypothesis and relevant theoretical analyses all consider environmental regulation as conducive to firm efficiency. However, empirical studies based on data of Chinese enterprises have

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[2] From the *Measures for the Administration of Pollutant Discharge Fees*, it can be learned that COD pollution equivalent (kg) is 1, and SO_2's pollution equivalent (kg) is 0.95.

Table 1: Descriptive Statistics

Variable	Variable symbol	Sample size	Mean	Standard deviation	Min.	Median	Max.
Firm TFP	TFP_t	116,553	7.211	1.222	-2.908	7.134	14.491
Emissions intensity (SO_2)	*SO2_Y*	116,549	2.057	5.117	0.000	0.268	31.526
Emissions intensity (COD)	*COD_Y*	116,549	0.998	3.528	0.000	0.039	24.514
Total assets	*Lnasset*	116,553	10.789	1.528	7.924	10.647	15.313
Fixed assets	*Lnk*	116,553	9.708	1.787	0.000	9.636	18.283
Labor force	*Lnl*	116,553	5.705	1.176	2.197	5.631	11.993
Enterprise age	*Lnage*	116,553	2.375	0.970	0.000	2.303	7.602
Share of state assets	*State*	116,553	0.187	0.365	0.000	0.000	1.000
Share of foreign investment	*Foreign*	116,553	0.063	0.220	0.000	0.000	1.000
Government subsidy	*Subsidy*	116,553	0.187	0.390	0.000	0.000	1.000
Whether the enterprise is an exporter	*Export*	116,553	0.306	0.461	0.000	0.000	1.000
Regional GDP	*GDP_city*	116,553	864.662	829.592	17.931	578.440	6073.828
Industry concentration	*HHI*	116,553	0.057	0.084	0.002	0.027	1.000

reached no consensus given that the empirical results are influenced by sample selection, sample period, variable selection, or estimation. As shown in the regression results of Column (1), Table 2, the implementation of clean production standards may sharply promote firm TFP, which is generally consistent with relevant research. Based on differences in firm size, Long and Wan (2017) empirically tested the positive effect of the implementation of clean production standards on firm profitability. Using the DID approach, Liu and Zhang (2019) found that the implementation of clean production standards significantly increased firm TFP using the treatment group of provinces that had implemented the clean production standards. Yet such treatment hardly controls for the fixed effect of region in which enterprises operate. Having controlled for the fixed effects of enterprise, year and region, this paper finds that such a positive effect still exists, i.e. the implementation of clean production standards may induce firm TFP.

Compared with end-of-pipe pollution treatment outside the production process, the efficient use of energy and other resources is conducive to firm TFP (Han and Hu, 2015). Implementation of clean production standards may contribute to firm TFP improvement by forcing enterprises to optimize resource allocation and update technology. It may even induce the innovation of technologies, including environmental protection technologies.

4.3 Common Trend Test

An important precondition for unbiased estimation using the DID approach is that the common trend hypothesis holds true, i.e. assuming that in the absence of clean production standards, TFP differences between treatment-group and control-group enterprises will not change significantly with the progression of time. Although the enactment and implementation of clean production standards are exogenous for individual sectors or enterprises, it cannot be precluded that some enterprises had already adjusted their output and investment decisions before 2003 under the expectation of potentially more stringent environmental regulation going forward. To exclude the reverse causality of time sequence that may

Table 2: Environmental Regulation and TFP of Industrial Enterprises

	Total samples	Common trend test	<20%	20%-50%	>50%
Variables	TFP_t (1)	TFP_t (2)	TFP_t (3)	TFP_t (4)	TFP_t (5)
CP_Treatpost	0.360*** (6.17)		0.172 (0.98)	0.221*** (2.73)	0.532*** (5.80)
CP_Treat(-2)		-0.009 (-0.17)			
CP_Treat(-1)		0.070 (1.40)			
CP_Treat(0)		0.473*** (6.42)			
CP_Treat(+1)		0.386*** (4.80)			
CP_Treat(2+)		0.269*** (3.25)			
CP_Treat	0.023 (0.29)		0.383*** (11.83)	0.434*** (21.85)	0.408*** (22.13)
Lnasset	0.427*** (37.23)	0.427*** (37.23)	-0.157*** (-8.99)	-0.164*** (-16.86)	-0.161*** (-16.00)
Lnk	-0.157*** (-24.84)	-0.156*** (-24.82)	0.201*** (7.15)	0.244*** (12.12)	0.277*** (14.18)
Lnl	0.273*** (23.55)	0.273*** (23.57)	0.027 (1.64)	0.013 (1.35)	0.014* (1.66)
Lnage	0.016*** (2.93)	0.016*** (2.95)	0.032 (0.76)	-0.093*** (-3.57)	-0.068*** (-3.37)
State	-0.061*** (-4.43)	-0.061*** (-4.44)	0.021 (0.28)	0.064 (1.59)	-0.020 (-0.48)
Foreign	0.028 (1.15)	0.028 (1.15)	-0.001 (-0.04)	0.011 (0.76)	0.007 (0.55)
Subsidy	0.002 (0.24)	0.002 (0.27)	0.077** (2.24)	0.051** (2.01)	0.038** (2.01)
Export	0.061*** (4.75)	0.061*** (4.75)	-0.000 (-0.64)	-0.000 (-1.41)	-0.000 (-0.18)
GDP_city	-0.000** (-2.03)	-0.000** (-2.02)	-0.194 (-0.89)	-0.042 (-0.53)	-0.037 (-0.46)
HHI	-0.075 (-1.61)	-0.075 (-1.61)	3.614*** (12.16)	2.791*** (14.13)	2.623*** (14.58)
Constant	2.538*** (22.67)	2.534*** (22.64)	0.383*** (11.83)	0.434*** (21.85)	0.408*** (22.13)
Fixed effect of enterprise / year / region	Y	Y	Y	Y	Y
N	116,553	116,553	18,205	44,353	53,995
Adj R^2	0.805	0.805	0.835	0.814	0.809

Notes: Numbers in parentheses are *t* values; *** p<0.01, ** p<0.05, * p<0.1.

exist in the above test, it is necessary to perform a dynamic test of the firm TFP effect of environmental regulation. As such, our estimation model is specified as follows:

$$TFP_{i,t}=\delta_0+\sum_{T\in\{-2,-1,0,1,2\}}\delta_T CP\_Treatpost_{iT}+\varphi Controls_{i,t}+f_i+\rho P_j\times\tau_t+\varepsilon_{i,t} \quad (2)$$

Results in Column (2) of Table 2 reveal that the regression coefficients of *CP_Treat(-2)* and *CP_Treat(-1)* are both insignificant, i.e. in the first two years after the clean production standards took effect (2001 and 2002), there was no tangible difference in the firm TFP effect of environmental regulation, and the real difference did not emerge until after 2003 and lasted till at least 2006.

4.4 A Yardstick Phenomenon

The regulatory scope of clean production standards is significantly asymmetric, allowing enterprises with different levels of emissions to adopt certain hierarchies of standards on a voluntary basis. Existing studies have noticed the huge energy efficiency differences of enterprises within various sectors (Chen and Chen, 2019). Similarly, environmental regulation's effects could be highly heterogeneous for enterprises of the same sector. Columns (3)-(5) of Table 2 test the TFP effects of environmental regulation for the three categories of enterprises (clean, compliant and non-compliant enterprises).

As can be seen from the regression results of Columns (3)-(5) of Table 2, the policy effect of asymmetric environmental regulation is significantly different for various enterprises: The estimated coefficient is insignificant for clean enterprises (top 20% by PH) and positive for compliant enterprises (20% to 50% by PH) and non-compliant enterprises (bottom 50% by PH) and passes significance test at the 1% level. That is to say, the implementation of clean production standards did not significantly boost TFP for clean enterprises, and compared with compliant enterprises, TFP improvement for non-compliant enterprises is more sensitive. It is fair to say that the implementation of clean production standards may induce TFP improvement for industrial enterprises, but such an improvement effect primarily exists for emissions-intensive, non-compliant and minimally compliant enterprises. The effect is insignificant for clean enterprises with a low emissions intensity.

In a nutshell, the policy effect of clean production standards is subject to a significant yardstick phenomenon: While polluters are forced to improve, clean enterprises are more likely to sit still. For non-compliant enterprises, the enforcement of clean production standards compels them to improve and avoid the risk of closure, and is thus conducive to their TFP improvement. Yet compliant enterprises are under no pressure to improve. In this sense, clean production standards have a limited effect on their TFP. Clean enterprises, on the other hand, have a low intensity of emissions and meet at least Grade 2 standards, and there is little motivation for them to improve either. Borderline enterprises ranked just above top 50% in terms of emissions intensity, i.e. those that meet Grade 3 clean production standards as per the *Calculation Method for Comprehensive Assessment Index of Cleaner Production*, are likely to adopt a swathe of overall optimizations to stay above the borderline but focus more on economic rather than environmental performance. Those enterprises lack a strong will to further reduce their emissions compared with heavily polluting enterprises below the borderline.

4.5 Robustness Test

Table 3 performs a further robustness test of this paper's benchmark regression.

First, the control group is replaced to perform a Propensity Score Match (PSM) - Difference-In-Differences (DID) test. Implemented many years ago, the clean production standards are more likely to have resulted from government forward-looking planning rather than business lobbying, and may therefore be regarded as an exogenous shock for enterprises. This paper's specification may largely avoid endogeneity arising from reverse causality. Since the clean production standards are unlikely to be implemented in random sectors, sector samples subject to early implementation are supposed to be different from other samples in certain ways. Thus, the PSM approach is followed to select a control group having similar characteristics with enterprises subject to the clean production standards, which may ease the selection bias from the intrinsic differences of enterprises.

In forecasting the propensity scores for the implementation of clean production standards, the control variables of Model (1) are selected as explanatory variables, and enterprise samples subject to the clean production standards are the treatment group. For each sample from the treatment group, another sample similar in ways other than the implementation of clean production standards is selected to form a control group. In the selection process, the logit model is firstly employed to forecast the probability for the sample to enter the treatment group (i.e. propensity score), and the nearest neighbor matching approach is adopted to select samples with the nearest propensity scores with treatment-group enterprises

Table 3: Robustness Test

	PSM-DID	Replacement of explained variable	Replacement of explained variable	Extension of data range	Control for other policies
Variables	TFP_t	TFP_OP_t	LP	$TFP\_OP_t 2013$	TFP_t
	(1)	(2)	(3)	(4)	(5)
CP_Treatpost	0.573***	0.165***	16.104***	0.310***	0.499***
	(5.19)	(3.95)	(3.88)	(4.66)	(8.33)
CP_Treat	-0.075	0.049	-18.440**	-0.112	-0.008
	(-0.33)	(1.01)	(-2.01)	(-1.52)	(-0.09)
Lnasset	0.336***	0.157***	19.548***	0.162***	0.421***
	(5.28)	(19.03)	(24.54)	(23.77)	(34.71)
Lnk	-0.046	-0.263***	-0.423*	-0.254***	-0.157***
	(-1.01)	(-44.04)	(-1.77)	(-73.37)	(-23.86)
Lnl	0.329***	0.038***	-24.401***	0.042***	0.273***
	(4.16)	(4.81)	(-18.80)	(6.36)	(22.81)
Lnage	0.062	0.008*	2.560***	0.021***	0.016***
	(1.27)	(1.74)	(9.67)	(4.05)	(2.78)
State	0.027	-0.050***	0.615	-0.068***	-0.055***
	(0.25)	(-4.47)	(0.66)	(-5.04)	(-3.83)
Foreign	0.089	-0.002	3.438**	0.022	0.027
	(0.32)	(-0.13)	(1.99)	(1.47)	(1.11)
Subsidy	-0.068	0.004	0.455	-0.023***	0.005
	(-1.08)	(0.64)	(1.02)	(-3.89)	(0.65)
Export	0.129	0.027***	3.452***	0.027***	0.055***
	(1.15)	(3.24)	(4.54)	(3.32)	(4.19)
GDP_city	0.000**	-0.000***	0.001	-0.000***	-0.000
	(2.48)	(-2.59)	(1.39)	(-7.87)	(-1.36)
HHI	0.310	-0.047	-7.409***	-0.069*	-0.076
	(0.43)	(-1.25)	(-3.16)	(-1.65)	(-1.61)
Constant	1.955***	1.117***	-44.369***	0.610***	2.606***
	(2.90)	(15.72)	(-6.20)	(8.91)	(22.40)
Fixed effect of firm/year/region	Y	Y	Y	Y	Y
N	1,498	112,176	161,014	164,980	108,946
Adj R^2	0.752	0.637	0.885	0.590	0.805

Note: Numbers in parentheses are *t* values; *** p<0.01, ** p<0.05, * p<0.1.

into the control group as new regression samples. Column (1) of Table 3 reports the regression results of PSM-DID, and the coefficient of *CP_Treatpost* passes the significance test at the 1% level. That is to say, sample selection has not affected the significance of regression results, i.e. the clean production standards have a significantly positive effect on firm TFP.

In addition, Column (2) of Table 3 replaces the method for calculating the explained variable and recalculates enterprise TFP (*TFP_OP*) using the OP approach, where enterprise investment is the difference between current-year and previous-year fixed asset investments, and other input and output indicators are the same with the LP approach.

Column (3) replaces the explained variable with the enterprise's current-year labor productivity (*LP*) and adopts per capita sales revenue (10,000/person) as its proxy variable.

Column (4) extends data results to 2013, and calculated by the income approach, output roughly equals the sum of labor compensation, net production tax, fixed assets depreciation and operating surplus, based on which enterprise value-added is re-estimated and TFP_OP_t2013 as the explained variable is calculated.

Column (5) excludes the impact of other relevant policies. Some laws and regulations or industry emissions standards may also influence enterprise production process and efficiency. Referencing Li et al. (2016) and Zhang and Lyu (2018), we remove sectors subject to the *Emissions Standard for Water Pollutants* or the *Emissions Standard for Industrial Pollutants*[3], and perform a regression for other samples to further address the estimation bias. Judging by the regression results of Columns (2)-(5), all estimated coefficients have passed the significance test at the 1% level, which indicates that this paper's main conclusions are still valid.

5. Further Analysis

5.1 Mechanism of Effects

The implementation of clean production standards has differentiated effects for clean and polluting enterprises, which respond differently to environmental regulation. The Porter Hypothesis assumes that environmental regulation will achieve an innovation compensation effect, inspire the innovation of environmental protection technologies, or force enterprises into technology upgrade to improve or invent products. In this manner, environmental regulation leads to improvements in both economic and environmental performance. Yet it takes time for environmental regulation to induce enterprises to innovate, develop technology, and boost productivity (Albrizio et al., 2017; Jin and Shen, 2018). To comply with environmental regulation, enterprises tend to expand less emissions-intensive capacity by adopting more up-to-date pollution abatement technology or overall optimization without phasing out obsolete capacity.

Table 4 tests whether the differentiated TFP effects of environmental regulation on clean, compliant and non-compliant enterprises are from overall optimization or innovation compensation.

Panel A of Table 4 tests whether enterprises are able to increase their TFP by adjusting capital allocation efficiency. Referencing Ren et al. (2019) and Zhang et al. (2019), corporate capital allocation efficiency is denoted by corporate investment efficiency. Regression results of Column (1) suggest that implementation of clean production standards may boost TFP by raising corporate capital allocation efficiency. However, regression results of Column (2) suggest that environmental regulation has no significant impact on clean enterprises. Columns (3) and (4) suggest that environmental regulation has a

[3] For the implementation of the *Environmental Protection Law of the People's Republic of China* and the *Water Pollution Prevention and Treatment Law of the People's Republic of China*, the former State Administration of Environmental Protection (SEPA) enacted or revised the Emissions Standard for Water Pollutants and the *Emissions Standard for Industrial Pollutants* for the following sectors, including the MSG industry (1461), brewery industry (1522), coal industry (06), electroplating industry (3460), sugar industry (1340), pulp and paper-making industry (2210), inorganic base manufacturing industry (2612), and synthetic leather and artificial leather industry (3050).

Table 4: Mechanism Analysis

Panel A: Capital allocation efficiency				
	Total samples	<20%	20%-50%	>50%
Variables	TFP_t	TFP_t	TFP_t	TFP_t
	(1)	(2)	(3)	(4)
*CP_Treatpost*Absehat*	0.017***	0.073	0.028*	0.029*
	(3.60)	(1.10)	(1.67)	(1.85)
Control variable	Y	Y	Y	Y
Fixed effect of firm/year/region	Y	Y	Y	Y
N	54,251	8,598	17,465	28,216
Adj R^2	0.836	0.858	0.850	0.837
Panel B: Patent application				
	Total samples	<20%	20%-50%	>50%
Variables	TFP_t	TFP_t	TFP_t	TFP_t
	(5)	(6)	(7)	(8)
*CP_Treatpost*Lnpatent*	-0.049	0.249	-0.589	-0.142
	(-0.25)	(0.98)	(-1.22)	(-0.41)
Control variable	Y	Y	Y	Y
Fixed effect of firm/year/region	Y	Y	Y	Y
N	116,553	18,205	44,353	53,995
Adj R^2	0.805	0.835	0.814	0.809

Note: Numbers in parentheses are *t* values; *** p<0.01, ** p<0.05, * p<0.1.

significant impact on polluters.

In fact, the Porter Hypothesis is concerned with corporate competitive advantage and does not regard environmental regulation as damaging to firm output and efficiency. If environmental regulation raises compliance cost, enterprises will seek a superior production frontier by optimizing capital allocation and investment portfolio. They may seek to optimize the allocation of productive capital, emissions reduction capital and technology investment (Barbera and McConnell, 1986), as well as the portfolio of productive investments in various sectors (Leiter et al., 2011).

More straightforwardly, capital conserved from polluting products may also be used for short-term projects with a higher investment net present value to seek a better return (Wang et al., 2018). Accordingly, the manifestation is an improvement of investment efficiency overall corporate optimization. Pollution means unnecessary or insufficient use of resources (Porter and van der Linde, 1995), and most enterprises that fail to meet environmental regulation standards are below the production possibilities frontier and cannot attain or maintain the choices of production that maximize profitability. Even if environmental regulation requires that enterprises set aside a portion of their resources and investment for pollution abatement, it is still likely to push enterprises towards efficiency frontier and not only help enterprises improve efficiency, but also generate non-market benefits such as environmental friendliness and resource conservation (Xepapadeas and Zeeuw, 1999).

Panel B of Table 4 tests whether enterprises with different levels of pollution may achieve TFP improvement through the innovation compensation effect. Referencing Li and Yu (2015), corporate innovation output is measured by the total number of patent applications, and regression results suggest that the implementation of clean production standards did not lead to any significant increase in the innovation output. In fact, the weak Porter Hypothesis considers that environmental regulation will encourage enterprises to apply the latest environmental technology (Jaffe and Palmer, 1997).

Environmental regulation will incentivize enterprises to innovate their production process by purchasing new equipment, i.e. the dynamic integration between physical capital accumulation and technology progress is achieved by investment rather than R&D innovation (Long and Wan, 2017; Zhang and Lu, 2018). Similarly, Liu and Zhang (2019) found that clean production policies only induced an improvement of human capital without raising per capita R&D spending.

5.2 Driving Factors

Environmental regulation's policy effects for clean and polluting enterprises can be explained by the differences of overall optimization strategies and measures adopted by those enterprises in their production and business operation processes. First, since clean production standards aim to optimize multiple pollution and energy consumption indicators, the implementation of such standards will inevitably influence how enterprises behave. For instance, enterprises may meet clean production standards and increase efficiency by purchasing up-to-date production lines. A possible motivation for enterprises to improve production equipment is the mitigation of financing constraint after meeting the requirements of environmental regulation (Su and Lian, 2018). For a company with different polluting departments, it may deploy cleaner production equipment for one department to offset increasing pollution from another (Cui and Moschini, 2020) in order for its overall emissions intensity to meet environmental regulation. Such corporate behaviors at the microscopic level eventually increase corporate output and reduce emissions intensity.

Panel A of Table 5 tests the effects of clean production standards on the improvement of production equipment by enterprises. Regression results in Column (1) suggest that measured by the average treatment effect, enterprises added fixed assets for production and operation (e.g. production lines that meet emission standards) instead of closing old equipment to reduce pollution and reach emissions standards per unit of output. Put simply, polluters meet clean production standards by expanding output capacity.

Panel B of Table 5 tests the possible motivations for capacity expansion. Referencing Lu and Chen (2017), corporate financing constraint is measured by the absolute value of SA indicator. According to the regression results of Panel B, clean production may increase capital allocation efficiency and output capacity by easing corporate financing constraint, but this effect did not appear for clean enterprises. By meeting clean production standards, polluters may receive financing support from banking and other financial institutions, which is otherwise restricted.

Panel C of Table 5 tests the result of firm behavior, i.e. an increase in total output value. Similarly, this effect is insignificant for clean enterprise samples. Han et al. (2020) found that the Energy Efficiency Initiative for a Thousand Enterprises (2006) had reduced emissions by curbing production, but the clean production standards primarily stipulate the emissions of wastewater and other pollutants per unit of feedstock, i.e. pollution intensity rather than aggregate demand. As such, enterprises will adjust their production and operation plans to increase output as a way to reduce overall emissions intensity.

In a nutshell, polluters may purchase "new fixed assets for production and operation", i.e. equipment renewal, to meet clean production standards. The motivation for them to do so is to overcome financing constraint and increase gross output value via overall optimization and firm TFP improvement.

5.3 Environmental Performance

Clean production standards set emissions or energy consumption standards per unit of feedstock input. Although clean production standards may improve firm TFP and economic performance, it may not substantially improve corporate environmental performance and environmental quality. On the contrary, the increase in corporate output value may cause aggregate emissions to rise.

Panel A of Table 6 tests whether the implementation of clean production standards will influence the end-of-pipe emissions mitigation. Our regression results indicate that the implementation of clean

Table 5: Driving Factors

Panel A: New fixed assets for production and operation				
	Total samples	<20%	20%-50%	>50%
Variables	*Lnfa_product_new*	*Lnfa_product_new*	*Lnfa_product_new*	*Lnfa_product_new*
	(1)	(2)	(3)	(4)
CP_Treatpost	0.768**	-0.704	0.731*	1.100*
	(2.56)	(-0.70)	(1.68)	(1.83)
Control variable	Y	Y	Y	Y
Fixed effect of firm/year/region	Y	Y	Y	Y
N	67,168	10,072	25,689	31,407
Adj R^2	0.505	0.476	0.513	0.517
Panel B: Financing constraint				
	Total samples	<20%	20%-50%	>50%
Variables	*SA*	*SA*	*SA*	*SA*
	(5)	(6)	(7)	(8)
CP_Treatpost	-0.020**	0.042	-0.041*	-0.021**
	(-2.51)	(1.35)	(-1.66)	(-2.34)
Control variable	Y	Y	Y	Y
Fixed effect of firm/year/region	Y	Y	Y	Y
N	116,553	18,205	44,353	53,995
Adj R^2	0.888	0.841	0.872	0.927
Panel C: Total output value				
	Total samples	<20%	20%-50%	>50%
Variables	*Lnoutput*	*Lnoutput*	*Lnoutput*	*Lnoutput*
	(9)	(10)	(11)	(12)
CP_Treatpost	0.360***	0.172	0.221***	0.532***
	(6.17)	(0.98)	(2.73)	(5.80)
Control variable	Y	Y	Y	Y
Fixed effect of firm/year/region	Y	Y	Y	Y
N	116,553	18,205	44,353	53,995
Adj R^2	0.868	0.887	0.873	0.873

Note: Numbers in parentheses are *t* values; *** p<0.01, ** p<0.05, * p<0.1.

production standards has spurred enterprises to deploy more pollution treatment facilities, which is also the case for non-compliant and passes the significance test at the 10% level. However, the implementation of clean production standards did not spur clean and compliant enterprises to invest more in pollution abatement facilities. That is to say, the implementation of clean production standards did not promote the environmental performance of clean and compliant enterprises in any significant way.

Panel B of Table 6 tests the possible environmental performance that may result from the implementation of clean production standards. By the average proportion of enterprises subject to the shock of clean production standards in a city, we divide cities into those subject to significant policy shocks and those subject to smaller policy shocks. As can be found from the regression results of Panel B, cities subject to significant policy shocks have seen sharp increases in their SO_2, COD and industrial soot emissions. That is to say, the more enterprises subject to clean production standards in a city, the more the city will experience significant increases in emissions. In fact, this phenomenon has experienced no amelioration. In August 2020, the Sixth Central Environmental Protection Inspection found an increasing

Table 6: Implementation of Clean Production Standards and Environmental Performance

Panel A: Waste gas treatment facilities

	Total samples	<20%	20%-50%	>50%
Variables	*Lnfacility* (1)	*Lnfacility* (2)	*Lnfacility* (3)	*Lnfacility* (4)
CP_Treatpost	0.117** (2.08)	0.287 (1.41)	-0.006 (-0.06)	0.151* (1.67)
Total samples	Y	Y	Y	Y
Fixed effect of firm/year/region	Y	Y	Y	Y
N	116,553	10,554	44,353	53,995
Adj R^2	0.782	0.787	0.804	0.803

Panel B: Macroscopic test

	Cities subject to greater policy shocks			Cities subject to smaller policy shocks		
Variables	*LnSO2* (5)	*LnCOD* (6)	*Lnpower* (7)	*LnSO2* (8)	*LnCOD* (9)	Lnpower (10)
CP_Treatpost	0.130*** (2.71)	0.141* (1.88)	0.172** (2.18)	0.060 (0.35)	-0.025 (-0.40)	0.160 (0.90)
Control variable	Y	Y	Y	Y	Y	Y
Fixed effect of firm/year/region	Y	Y	Y	Y	Y	Y
N	13,649	13,649	13,578	55,229	55,354	55,348
Adj R^2	0.112	0.027	0.100	0.045	0.018	0.064

Note: Numbers in parentheses are *t* values; *** p<0.01, ** p<0.05, * p<0.1.

installed capacity of coal-fired power generation in 12 provinces (municipalities) and a greater density of the energy industry in key regions subject to air pollution prevention and treatment.[4]

6. Discussion and Conclusions

Economic development does not have to be at odds with environmental protection. Over the years, China has made relentless efforts to protect the environment at the same time as initiating economic restructuring and development. Yet the crude pattern of development and the backward industrial structure have led to environmental problems (Cai et al., 2008). While protecting the environment with the most stringent systems and vigorous rule of law, we should make sure that environmental regulation motivates enterprises to pursue a more sustainable mode of production and steer the economy towards higher quality development.

With the implementation of clean production standards as a quasi-natural experiment, this paper employs the difference-in-differences (DID) approach to test the effect of environmental regulation on the TFP of industrial enterprises with the following findings: (i) On the whole, the implementation of clean production standards has significantly increased the TFP for industrial enterprises, but such an effect only exists for the heavy polluter and has little effect on clean enterprises. Only enterprises that fall short of clean production standards are concerned with environmental performance, i.e. the policy effect of environmental regulation is subject to a significant yardstick phenomenon due to its asymmetric regulatory scope: While polluters are forced to clean up, non-polluters are likely to sit still. (ii) Further research finds the TFP improvement effect to be primarily achieved by means of overall

[4] Source: *Environmental supervision - the National Energy Administration has yet to give due priority to environmental protection*, January 29, 2021, https://baijiahao.baidu.com/s?id=1690231814734495133&wfr=spider&for=pc.

firm optimization, and the innovation compensation effect to be insignificant and failing to reverse the backward mode of production. By purchasing equipment and expanding capacity to cope with clean production policies, polluters have exacerbated the tension between capacity expansion and emissions abatement, creating pressures on environmental quality.

The following policy implications can be derived from this paper: (i) The policy effect of environmental regulation is subject to a yardstick phenomenon due to its asymmetrical regulatory scope. In planning and designing the scope of environmental regulation, therefore, the principle of common but differentiated responsibilities should be followed. In addition to targeted policy enforcement, the yardstick should also be raised from time to time for all enterprises to improve their environmental performance irrespective of the current level of their emissions intensity. Despite the asymmetric target-based management for enterprises with different emissions intensities, clean production standards are often regarded by polluters as minimum emission requirements. While holding heavy polluters accountable, regulators should also enhance financial and policy incentives for clean and minimally compliant enterprises to become even cleaner and further cut their emissions.

(ii) The most stringent rule of law should be enforced to protect the environment, paying attention to how environmental regulation influences environmental and economic performance at the enterprise level. Whether environmental regulation may induce the innovation compensation effect should also be closely followed. Long-term mechanisms for environmental protection must galvanize corporate action to clean up and upgrade. After replacing production lines to meet clean production standards, some enterprises still retain a great deal of industrial capacity at polluting and low-value processes following the traditional technology pathway for energy conservation and emissions abatement. Under the *Green Industrial Development Plan*, priority should be given to promoting green industrial development innovations, management and business modes, and developing and rolling out critical green processes, technologies and equipment. Industrial green upgrade and low-carbon development also call for incentives for enterprises to apply innovative green technologies to reach the production frontier across the board and shift from the expansive and polluting mode of industrial development to more efficient and cleaner development.

(iii) Total reduction of pollution emission is the basis for better environmental quality. Rising total pollution emission is pushing the limited environmental capacity to the edge, posing grave challenges to economic development and environmental quality. Globally, the policy failure of environmental regulation lies in the leakage of emissions - such as carbon leakage in the carbon market. Despite China’s great achievements in reducing carbon emissions, patchy emissions reduction data often contradict public perception and environmental quality monitoring data. Polluters meet emissions standards by optimizing the technology path, which may not be an optimal solution for sustainable development. In other words, even if polluters meet emissions standards, their expansion in capacity will intensify the contradiction between economic development and environmental protection and threaten environmental quality. For this reason, it takes relentless efforts to curb aggregate emissions and improve environmental quality.

Green development and the “Beautiful China” vision require the joint effort of environmental and economic regulations (Mi et al., 2018). The 14th Five-Year Plan called for promoting energy and resource efficiency and reducing the aggregate emissions of major pollutants. Both carbon peak and carbon neutrality ambitions require enterprises to make real improvements to their mode of production. This requires asymmetrical environmental regulation to nudge all enterprises to improve their environmental performance irrespective of their current level of emission intensity, so that polluters clean up and clean enterprises become even cleaner. Environmental standards should be raised from time to time based on the compliance status. Long-term mechanisms for environmental protection should be established and improved to balance economic development with environmental protection at a higher level.

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