Does emission-abatement policy reduce emissions?
Evidence from the Indian manufacturing sector

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Abstract

Do emission standards really reduce emissions? Some previous works have suggested that emission standards may actually increase total emissions if the standard stimulates production, even though tightened standards directly reduce emissions. The aim of this paper is to review the effect of emission standards using a monopolistic competition model with firm-heterogeneity a là Melitz that incorporates emission-abatement activity. We also empirically test our theoretical result using industry-level data from the manufacturing sector in India. Our theoretical analysis predicts that a strengthening of emission standards can increase emission amounts, an effect different from conventional ones such as scale-, technique-, and composition-effect, due to the intra-industry reallocation, even if the standards decrease the aggregate output. We also empirically determine that: (1) India experienced such a paradoxical situation from 2005−2012; and (2) investment for emission-abatement activity induced by the tighter emission standards increases emissions at the industrial level in Indian manufacturing. These analytical results imply that the government should not overly trust the effectiveness of emission standards.

Key words: difference in difference; emission-abatement activity; emission standard; firm heterogeneity; Indian manufacturing; intra-industry reallocation

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Data availability statement

The data that support the findings of this study are available from Kobe University under certain restrictions; these data were used under license for the current study and are not publicly available.

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1. Introduction

Environmental preservation is one of the most serious issues in terms of sustainable development. The growing economy requires massive manufacturing production, and hence, CO_2 emissions also increase. According to the BP Statistical Review of World Energy, world CO_2 emissions increased 42.33% during 2000–2018. Global cooperation is needed to break the deadlock in current conditions. The Kyoto Protocol was adopted in 1997 to impose regulations on emissions by developed countries. Due to rapidly increasing emission levels, commitments were also required of developing countries, as discussed in Pittel and Rübbelke (2008). A total of 196 countries, including developing countries, then negotiated the Paris Climate Agreement in 2015, under which they committed to taking steps to limit the increase in global average temperature. To meet the agreement, each country has pledged to impose regulations on emissions from the manufacturing sector. Have, however, the efforts of each country borne fruit, resulting in a reduction in CO_2 emissions?

A huge number of theoretical works have analyzed the effects of environmental policies. Especially recently, research using a monopolistic competition model with firm heterogeneity a la Melitz (2003) have also been presented. The importance of firm heterogeneity in this discussion is that environmental policies could affect emission levels through intra-industry reallocation. In the literature, Konishi and Tarui (2015) and Anòulies (2017) studied emission trading with different allocation schemes of emission allowances using the production function in Copeland and Taylor (1994). Meanwhile, Yokoo (2009) examined the impact of the pollution tax. In addition, Cao et al. (2016) and Forslid et al. (2018) analyzed the case where heterogeneous firms invest in abatement technology in a closed and open economy, respectively.[1]

[1] In addition to Yokoo (2009) and Forslid et al. (2018), Baldwin and Ravetti (2014), Kreickemeier and Richter

A tightening of emission standards is also an important means of emission control, but to the best of our knowledge, there have been no analyses of it within the firm-heterogeneity framework.[2] Both developed and developing countries have actually imposed emission standards, as the Paris Climate Agreement, including the environment protection goals, was adopted by all United Nations Member States except the U.S. in 2015.[3] India, one of the largest contributors of emissions, also adopted the Agreement. However, India has experienced a significant increase in emissions along with rapid economic growth (GDP and CO_2 emissions grew 469.98% and 157.72%, respectively, between 2000 and 2018).[4]

Figure 1 shows the expansion of CO_2 emissions in the Indian manufacturing industry (2005–2013). In an effort to deal with the growth of CO_2 emissions from manufacturers, in 2008, before adopting the Paris Agreement, the Indian government set up a ministry of climate change and released a National Action Plan for Climate Change (NAPCC). The Perform, Achieve, and Trade (PAT) scheme was established under the NAPCC.[5] PAT was the first attempt at CO_2 emission regulation in India, and some studies such as Bhandari and Shrimali (2018) considered the enforcement of restrictions. Under the scheme, each plant was assigned a specific energy

(2014), and Cui (2017) examine the effect of trade liberalization on pollution emissions within the framework of firm-heterogeneity. Cherniwchan et al. (2017) is an important recent survey of trade and the environment.

[2] Helfand (1991) compared the effects of various types of emission standards. Spulber (1985) and Ishikawa and Kiyono (2006) examined the potential for an equivalence relationship between emission taxes, emission permits (quotas), and emission standards, and showed that the standards might increase the total amount of emissions. However, they do not take into account intra-industry resource allocation in their analyses.

[3] The US agreed to the agreement in 2015 and signed on to it in 2016, but withdrew from it in 2017.

[4] India experienced rapid economic growth beginning in the 2000s. Its GDP growth rate from 2014–2018 exceeded that of China, and the nominal Indian GDP reached 2716.75 billion US dollars in 2018. At the same time, India emitted 2,481 million ton of CO_2 and is the third largest contributor of CO_2 emission in the world after China and the US. See *World Economic Outlook* (International Monetary Fund; IMF) and *World Bank national accounts data* (The World Bank).

[5] The PAT's structure flows from the Energy Conservation Act of 2001, which stipulates energy efficiency measures for 15 energy-intensive sectors.

consumption target to be met over a period of 3 years; plants unable to meet their target would be penalized. The government decided which plants would be regulated, and focused on industries involving Iron and Steel; Non-Ferrous Metals; Pulp, Paper and Print; and Wood and Wood Products.[6] This situation provided an opportunity to analyze the impact of higher emission standards on actual emissions by comparing the impact on the industries regulated under PAT and other industries.[7] Although PAT was first implemented from 2012–2015, the regulated industries were selected and the restrictions announced in 2008, so we treat that year as the turning point for India's emission policy in our analysis.[8] Regarding air quality in India, the air quality index (AQI) level reached as high as 858 in certain parts of New Delhi in November 2019, according to the website AirVisual, which monitors air pollution around the world. The AQI level was more than three times the "hazardous" level.[9] Given these conditions, reducing emissions including CO2 was an urgent task in India, hence we consider the case of PAT.

Figure 1 Overall CO_2 emissions in India due to various fuel uses within manufacturing

The aim of this paper is to theoretically explore the impact of emission standards, and to empirically test the theoretical prediction employing industry-level data from the Indian manufacturing sector. To this end, we

[6] Thermal power stations are also regulated, but they belong to the service sector. Hence, we do not include them in our analysis.

[7] We call the emission abatement standards 'emission standards' in this paper. These standards correspond to the PAT Mechanism for Energy Efficiency in India, which is regulation for manufacturing emissions.

[8] A total of 478 plants, covering almost 54% of the total energy consumption in India as per 2007-08 national energy consumption, were regulated during the first implementation period of PAT from 2012–2015 (Bureau of Energy Efficiency, 2011).

[9] According to the World Air Quality Report 2019, 21 of the world's 30 cities with the worst air pollution are in India. Although Greenstone and Hanna (2014) show the air pollution regulations are associated with substantial improvement in air condition in India, the situation remains severe.

develop a monopolistic competition model with firm-heterogeneity that incorporates the emission-abatement activity function depending on firm-specific productivity in addition to emission standards. The advantage of this study compared to existing the literature is as follows: theoretically, our firm-heterogeneity model can reveal the mechanism by which emission standards affect emission amounts through a change in intra-industry resource allocation. In the discussion of emission-abatement policy, this advantage is very important, because even if tighter emission standards directly reduce emissions (due to reduced production), the total emission amount might increase owing to a reshuffling of resource allocation. Our theoretical analysis suggests that an emission-abatement policy can either reduce or increase emissions in a country depending on the situation. Empirically, we reveal that a tightening of the abatement policy increases emissions discharged from the manufacturing sector in India. While most previous studies of India in this field focus on energy intensity (see Goldar, 2011; Goldar, 2013; and Soni et al., 2017), our study is the first to empirically examine the relationship between emission standards and CO_2 emission amount from Indian manufacturing, and to find that the tightening of such standards paradoxically increases emissions.

The remainder of this paper is organized as follows. Section 2 explains the data and variables. Section 3 develops the theoretical model and explores how emission-abatement policy affects the economy and total emissions. Section 4 presents the empirical identification and estimation results. Section 5 concludes our analysis.

2. Overview: Snapshot of emissions and abatement activity in India

Before analyzing the effect of emission standards, we present preliminary findings on current trends in emissions and emission-abatement activities in Indian manufacturing using the Annual Survey of Industries (ASI) data. The ASI, conducted by India's Central Statistical Office (CSO), provides a fairly comprehensive picture of manufacturing activities in India. It covers the manufacturers registered in the Factories Act, firms that produce 68.3% of GDP in the Indian manufacturing sector (see National Commission for Enterprises in the Unorganized Sector, 2010).[10] The ASI data contains basic information about the economic activity of firms, such as the value of products and inputs, number of laborers, labor costs, and more. In particular, the uniqueness of ASI includes detailed information about fixed assets for pollution control. This unique data about India therefore allows us to empirically examine the relationship between CO_2 emission and fixed assets for pollution control.

As noted in the Introduction, many countries including India are strengthening their efforts to prevent climate change and to reduce CO_2 emissions; hence, the manufacturing industries of each country are required to comply with regulations. To meet emission standards, each manufacturer engages in an emission-abatement activity, and such activity requires an investment in facilities, solar power generation, low-emission boiler, etc. Therefore, the volume of such fixed assets in facilities should reflect the strength of emission standards. Although most developing countries do not hold surveys regarding the acquisition of fixed assets for the emission-abatement activity, ASI provides unique information about fixed assets for pollution control equipment.

Figure 2 shows a time series of the log of fixed assets for pollution control equipment at the industry level

[10] Under the Factories Act in 1948 in India, any enterprise that has more than 10 workers and uses power (or 20 or more workers if it does not use power) must register as a "factory".

for 2005‒2012. We here classify the Indian manufacturing sector into 13 industries: Petroleum Refining; Manufacture of Solid Fuel; Iron and Steel; Non-Ferrous Metals; Chemicals; Pulp, Paper and Print; Food Processing, Beverages and Tobacco; Non-metallic Minerals; Transport; Machinery; Wood and Wood Products; Textiles and Leather; and Non-specified Industry. Most industries gradually increased their investment in pollution control facilities. In particular, the investment in some industries such as Wood and Wood Products and Non-specified industry increased suddenly in 2008.

Figure 2 Time series of fixed assets for pollution control equipment

ASI also provides the operating status of each plant, so that it is possible to identify the plants that shut down. From this data, we find that there is a difference in the fixed assets for pollution control between open and shuttered plants. Figure 3 suggests that the distribution of the log of the fixed asset of the shutdown plant is to the left of that of the existing plant. This result seems logical, because a closed plant lacks revenue and therefore does not afford opportunities for investment in pollution control assets.

Figure 3 Distribution of fixed assets for pollution control equipment: existing and shuttered plants

Next, we estimate the emission level of firms from ASI. The Council on Energy, Environment and Water (CEEW) estimates CO_2 emissions at the industry level for 2005‒2012 using data from the ASI (Gupta et al., 2017). They follow the Intergovernmental Panel on Climate Change (IPCC) guidelines, which is the global standard for estimating the CO_2 emission. Figure 4 illustrates industry-level CO_2 emissions in Indian manufacturing from 2005‒2012. The figure shows an upward trend in CO_2 emission in each industry, and in total emissions for all manufacturing, except for Machinery, and Wood and wood products. In particular, emissions from manufacturing Iron and Steel products doubled, from 105 million to 212 million tons during the sample period.

Figure 4 Time series of $\mathbf{CO_2}$ ***emission estimates for the manufacturing sector***

These observations of the Indian manufacturing sector, contrary to expectations, show that CO_2 emissions seem to increase at the industry level despite an increase in fixed assets for pollution control equipment. Now the question becomes, does investment in fixed assets for emission-abatement activities prevent the expansion of CO_2 emission or contribute to the expansion?

Given the observations outlined above, we can hypothesize a scenario to explain such a seemingly paradoxical phenomenon. Certainly, the tighter emission standards could decrease the emissions of individual plants due to investment in fixed assets for pollution control, but it might nevertheless increase the total emissions of an industry or country. The tighter emission standard, which is fairly charged to any plant, leads to unproductive or unprofitable plants exiting the market due to the increased costs of emission-abatement activity. Resources from those shuttered plants, such as labor and assets, would then move to an existing plant. If this reallocation of resources drastically increases the production of an existent plant, the plant’s emissions might increase even if the exit of the unproductive plant reduces emissions. In short, the effect of tighter emission standards depends on the opposite effects of shutdown and existent plants on emissions, and the paradoxical effect of emission standards might be due to intra-industry reallocation. To determine whether our hypothesis is correct, Section 3 considers the effect of emission-abatement policy theoretically with a focus on the role of intra-industry reallocation. In Section 4, we then empirically verify whether the paradoxical case occurs using the unique industrial data in India.

3. The Model

This section presents a theoretical framework that serves as the basis for the empirical analysis to determine the effectiveness of emission-abatement policy in Section 4. To explore the effect of emission-abatement policy focusing on its channel through a change in intra-industry resources, we construct a model with firm-heterogeneity that incorporates emission-abatement activity.[11]

3.1 Utility and demand

The preferences of a representative consumer are given by a standard constant elasticity of substitution (CES) utility function over a continuum of goods, $U = \left(\int_{v \in V} q(v)^{\rho} dv\right)^{1/\rho}$ $(0 < \rho < 1)$, where $q(v)$ denotes the consumption demand of the differentiated goods indexed by v, and the measure of the set V represents the mass of available goods. We consider the set of varieties consumed as the aggregate good $Y \equiv U$, as in Melitz (2003). The price index of the industry is shown as $P = \left(\int_{v \in V} p(v)^{1-\sigma} dv\right)^{\frac{1}{1-\sigma}}$ with the elasticity of the substitution $\sigma \equiv 1/(1-\rho) > 1$. These preferences generate the consumption demand:

$$q(v) = \left(\frac{P}{p(v)}\right)^{\sigma} Y. \tag{1}$$

3.2 Emission-abatement activity

[11] Our closed-economy model can be easily expanded to a multi-country model with trade without alteration of the results. Regardless of this expansion of the model, the basic property of Eq. (12) remains unchanged. For example, a counterpart of Eq. (12) under the $n+1$ symmetric-country setting with iceberg trade cost, τ, differs from Eq. (12) in the body text only in that exogenous variables related to open economy, τ and n, are added.

We now model the emission-abatement activity. Monopolistically competitive firms produce differentiated goods while engaging in emission-abatement activities to meet a common emission standard, z. Because of a stiff penalty, they follow the standard. Labor is the only input for goods production and emission-abatement activity, and it is inelastically supplied at its aggregate level, L. Suppose that one unit of goods production yields one unit of emission, and each firm can reduce A units of emission through its abatement activity. The actual amount of emissions discharged from a firm is then shown as $E = q - A$. Therefore, the emission-abatement rate is derived as $1 - \varepsilon = A/q$, where $\varepsilon \equiv E/q$ suggests emissions per unit of output. As all firms face a common emission standard, the emission-abatement rate of every firm is equal to z, i.e., $1 - \varepsilon = A/q = z$. Thereby, we have $A = zq$, which is the emission standard equation essentially similar to that in Greaker and Rosendahl (2008). Here we set $A = \varphi a$. It is plausible that the level of abatement activity, A, is considered as an increasing function of labor input for abatement activity, a, and the firm-specific labor productivity, φ. Substituting this function into $A = zq$, we obtain the abatement activity function as follows:

$$a = \frac{q}{\varphi} z. \tag{2}$$

Note that Greaker and Rosendahl (2008) discussed the abatement activity resulting from emission standards, but that, in contrast to their analysis, the abatement activity level, a, in our model depends on the firm-specific productivity, φ, in addition to emission standards, z, as shown in Eq. (2).[12]

[12] The PAT Mechanism is the emission standard on energy consumed per unit of production. Considering $1 - \varepsilon = A/q = z$ in our model, a standard on the emission-abatement rate, z, corresponds negatively and one-to-one with the emissions per unit of output, ε. Hence, we regard an increase in z as an introduction of a tighter PAT. Moreover, in Eq. (2), each firm's emission-abatement activity—in other words, the energy-saving activity complying with PAT—is measured by labor units.

3.3 Production and price setting

Each firm is endowed with productivity, φ. The production function of each firm is shown as $q(\varphi) = \varphi l(\varphi)$, where l denotes the labor input for production. We designate labor as a numeraire, and the wage level is normalized to one. The profit function is given as $\pi(\varphi) = p(\varphi)q(\varphi) - \big(l(\varphi) + a(\varphi)\big) - f$, where f is the fixed cost measured in labor units, and is common to all firms. Suppose that each firm requires fixed labor f for emission-abatement activity to meet the regulation level of z and, for simplicity, we specify $f = z$. Maximizing the profit subject to the production function and Eqs. (1) and (2) yields the following pricing rule:

$$p(\varphi) = \frac{1+z}{\rho\varphi}. \quad (3)$$

The profit function can then be rewritten as $\pi(\varphi) = \sigma^{-1} r(\varphi) - z$, where $r \equiv pq$ is the revenue. Relative price, demand, and revenue are derived from Eqs. (1) and (3) as follows:

$$\frac{p(\varphi_1)}{p(\varphi_2)} = \frac{\varphi_2}{\varphi_1},\ \frac{q(\varphi_1)}{q(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma},\ \frac{r(\varphi_1)}{r(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma-1}. \quad (4)$$

3.4 Firm entry and exit

We adopt the usual settings of firm entry and exit in the existing literature of firm-heterogeneity. Prior to entry, all firms are identical. They have to make an initial investment (fixed entry cost), f_e, which is sunk and measured in units of labor. They draw their productivity, φ, from a common distribution, $g(\varphi)$, that has a continuous cumulative distribution, $G(\varphi)$. We assume the Pareto distribution of the form, $G(\varphi) = 1 - \varphi^{-k}$ and $g(\varphi) = k\varphi^{-1-k}$, where $k > \sigma - 1$ is the shape parameter of the distribution, and the lower bound of productivity is normalized to one. If $\varphi \geq \varphi^*$, the distribution of the productivity of the producing firm is shown as $\mu(\varphi) = g(\varphi)/[1 - G(\varphi^*)] = (k/\varphi)(\varphi^*/\varphi)^k$; otherwise, $\mu(\varphi) = 0$, where φ^* is the cutoff productivity, i.e., the lowest productivity of the successful entrant, and $1 - G(\varphi^*)$ is the ex-ante probability of a successful draw. The cutoff productivity, φ^*, ensures the zero-profit condition shown as below:

$$\pi(\varphi^*) = 0 \leftrightarrow r(\varphi^*) = \sigma z. \tag{5}$$

The average productivity of the operating firms, $\tilde{\varphi}$, is defined as

$$\tilde{\varphi} \equiv \left(\int_{\varphi^*}^{\infty} \varphi^{\sigma-1}\mu(\varphi)d\varphi\right)^{\frac{1}{\sigma-1}} = \left(\frac{k}{1+k-\sigma}\right)^{\frac{1}{\sigma-1}} \varphi^*. \tag{6}$$

From Eqs. (4)-(6), we obtain the following:[13]

$$r(\tilde{\varphi}) = \frac{k}{1+k-\sigma}\sigma z. \tag{7}$$

Using Eqs. (4), (6), and (7), we derive the average profit as follows:

$$\pi(\tilde{\varphi}) \equiv \Pi/M = \frac{\sigma-1}{1+k-\sigma} z, \tag{8}$$

where M is the number of firms and Π is the aggregate profit of all firms.

If the firm does produce, it faces δ probability of a bad shock in every period. The firm hit by this shock decides to exit immediately.[14] Then, the value function of each firm is given by $F(\varphi) = max[0, \sum_{T=0}^{\infty}(1 - \delta)^T \pi(\varphi)] = max(0, \pi(\varphi)/\delta)$. We assume that there is no time discounting. Let $F(\tilde{\varphi}) = \sum_{T=0}^{\infty}(1 - \delta)^T \pi(\tilde{\varphi}) = \pi(\tilde{\varphi})/\delta$ represent the present value of the average profit, where $\pi(\tilde{\varphi})$ is the per-unit average profit of all operating firms. The average value function before entry, $\left(1 - G(\varphi^*)\right)F(\tilde{\varphi})$, is equal to the fixed entry cost, f_e, therefore the free entry condition is derived as

$$\pi(\tilde{\varphi}) = \delta f_e \varphi^{*k}. \tag{9}$$

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[13] See Appendix A, for the derivations of our model.

[14] We consider only the steady-state equilibrium, in which the levels of the aggregate variables remain constant over time. Then, productivity does not change over time, and the optimal profit also remains constant. Therefore, the profit of the entry firm has to be zero or positive in every period until the firm is hit with a bad shock.

Using Eqs. (8) and (9), we derive the cutoff productivity as follows:

$$\varphi^* = \left(\frac{\sigma-1}{1+k-\sigma}\frac{1}{\delta f_e}z\right)^{\frac{1}{k}}. \tag{10}$$

Eq. (10) indicates an important property of our analysis, specifically, a tightening of the emission-abatement policy (a rise in z) raises the cutoff productivity. This implies a possibility that such policy makes impacts on the level of emissions through a change in the intra-industry resource allocation.

Proposition 1: A variation in the level of emission standard changes the cutoff productivity level. In other words, emission-abatement policy affects emission levels through a change in intra-industry reallocation.

3.5 Comparative statics

Our analysis faces a parameter constraint, $z \geq \frac{1+k-\sigma}{\sigma-1}\delta f_e \equiv \underline{z} > 0$, which is derived from Eq. (10) and $\varphi^* \geq 1$, where $\underline{z}$ suggests the lower limit of the range of emission standard, z. Therefore, we conduct the following analysis within the range of $0 < \underline{z} \leq z < 1$ ($\because$ $0 < z < 1$). Solving the model algebraically, we obtain the solutions of all variables (see Appendix A). Using these solutions, total emissions can be derived as follows:

$$E \equiv \int_{\varphi^*}^{\infty}\left(q(\varphi) - A(\varphi)\right)M\mu(\varphi)d\varphi = (1-z)\Omega, \tag{11}$$

where

$$\Omega \equiv \left[r(\tilde{\varphi})\frac{1+k-\sigma}{k-\sigma}\frac{\rho}{1+z}\left(\frac{\sigma-1}{1+k-\sigma}\frac{1}{\delta f_e}\right)^{1/k}z^{1/k}\right]\frac{L}{r(\tilde{\varphi})}$$

$$= \left[\frac{1+k-\sigma}{k-\sigma}\frac{\rho}{1+z}\left(\frac{\sigma-1}{1+k-\sigma}\frac{1}{\delta f_e}\right)^{1/k}z^{1/k}\right]L > 0.$$

In the first line of the definition of Ω, the square bracket denotes the measure of average demand (output) per firm, and $L/r(\tilde{\varphi})$ is the measure related to the number of firms. Differentiating Eq. (11), we obtain the effect of the emission-abatement policy as follows:

$$\frac{\partial E}{\partial z} = E\left(\underbrace{\frac{-1}{1-z}}_{\substack{direct\ effect \\ (-)}} + \underbrace{\frac{-1}{1+z}}_{\substack{cost-raising\ effect \\ (-)}} + \underbrace{\frac{1}{kz}}_{\substack{reshuffling\ effect \\ (+)}} \right)$$

$$= \frac{\Omega}{(1+z)kz}\Theta(z) \gtreqless 0, \tag{12}$$

where $\Theta(z) = -z^2 - 2kz + 1$. We make sure of the results of the comparative statics. The first term in the parenthesis of the first line of Eq. (12) suggests that the effect of a tightening of emission-abatement policy (a rise in the emission standard level, z) directly decreases emission amount, E. We call this channel of the policy impact the *direct effect*. Second, a tightening of regulation encourages firms to hire more labor for abatement activities. Consequently, all operating firms raise prices to address increased labor costs. Therefore, E decreases as a result of a reduction in output. This effect corresponds to the second term, and we call it the *cost-raising effect*. Finally, the third term shows the effect through intra-industry resource reshuffling. The tighter emission standard induces an increase in fixed cost. Lower productivity firms will be unable to pay this cost, and will exit from the market, thus raising cutoff productivity. Therefore, the number of firms engaging in abatement activity decreases, and E increases. We call this channel the *reshuffling effect*. The magnitude relation between these three effects determines the sign of Eq. (12), but it is uncertain. If the *reshuffling effect* is weaker than the sum of other two effects, such policy reduces emissions as widely expected. Otherwise, a strengthening of abatement policy unexpectedly increases emissions. More specifically, a tightening of emission-abatement policy might paradoxically increase emissions despite a decrease in aggregate output due to the *cost-raising effect*, and this curious result originates in the *reshuffling effect*, which is a distinctive effect of the model incorporating firm-heterogeneity.

We discuss the sign of Eq. (12) further. The second line of Eq. (12) suggests that $\partial E/\partial z$ depends on the sign of $\Theta(z)$. The $\Theta(z)$-function is a hump-shaped curve, as illustrated in Figures 5a and 5b.

Figure 5a ***$\Theta(z)$-function under lax regulations in the beginning:*** $\underline{z} \le -k + \sqrt{1+k^2}$

Figure 5b ***$\Theta(z)$-function under strict regulations in the beginning:*** $-k + \sqrt{1+k^2} < \underline{z}$

As describes below in Appendix B, we divide our consideration about the sign of $\Theta(z)$ into two different cases: $\underline{z} \le -k + \sqrt{1+k^2}$ and $-k + \sqrt{1+k^2} < \underline{z}$, where $-k + \sqrt{1+k^2}$ is a threshold value of the emission standards; that is, if $z = -k + \sqrt{1+k^2}$, then $\Theta(z) = 0$, and hence $\partial E/\partial z = 0$. The former case ($\underline{z} \le -k + \sqrt{1+k^2}$) is the situation in which the threshold value of z (i.e., $z = -k + \sqrt{1+k^2}$) falls within the range of the parameter constraint; $\underline{z} \le z < 1$ (see Figure 5a). In this case, the lower bound of the emission standard level, $\underline{z}$, is relatively low, i.e., regulations are lax. To be more specific, this corresponds to the case in which the level of the fixed entry cost, f_e, and/or a bad shock, δ, is low, so that firms can enter the market and survive relatively easily (cf. the definition of $\underline{z}$). The lower the level of f_e and δ, the higher the cutoff productivity level (see Eq. (10)). The demand for goods (hence, production) then increases because of an increase in price (see Eqs. (1) and (3)). This increase in goods production requires a lower level of emission-abatement rate ($\because 1 - \varepsilon = A/q$), and hence the required emission standard level is also lower ($\because z = 1 - \varepsilon$). In contrast, in the latter case, the threshold value is smaller than the lower bound (lies outside) of the parameter constraint, as shown in Figure 5b. In this case, $\underline{z}$ is relatively high (i.e., regulations are strict). This situation is realized when firms face a relatively difficult situation in terms of market entry and operation. In short, in the case of $\underline{z} \le -k + \sqrt{1+k^2}$, the sign of $\Theta(z)$, and hence the sign of $\partial E/\partial z$, can be either positive or negative. In other words, the effect of emission-abatement policy is ambiguous. By contrast, if $-k + \sqrt{1+k^2} < \underline{z}$, both signs of

$\Theta(z)$ and $\partial E/\partial z$ are strictly be negative, i.e., tighter emission regulations reduce emissions.

The analytical results in this section can be summarized as the following Proposition:

Proposition 2: Contrary to conventional wisdom, a tightening of emission standards does not necessarily reduce emissions but may increase them if the regulation level is low at the beginning (when the policy is implemented). This paradoxical result is due to the reshuffling of intra-industry resources as a result of emission-abatement policy. The analytical prediction implies that if the government boldly tightens emission standards, emissions can be reduced, but if it strengthens them only halfway, emissions might increase rather than decrease.

4. Empirical verification

The theoretical analysis in Section 3 concludes that the emission-abatement policy effect (the sign of $\partial E/\partial z$ in Eq. (12)) is uncertain. Specifically, in contrast to the general view, this policy might increase emissions rather than reduce them. Such an ambiguous result in the purely theoretical analysis motivates us to check it empirically. So, to clarify whether emission-abatement policy actually reduces emissions, in Section 4 we conduct an empirical analysis using actual data in India during the period 2005–2012. That sampling period seems suitable for estimating the effect of the PAT Mechanism for Energy Efficiency, initiated in 2008.

4.1 Estimation strategy

Suppose that $(1-z)\Omega$ in Eq. (11) is related to a fixed asset for emission-abatement activity, which is a proxy variable of the regulation for the emissions, z, and vector of observable country-specific characteristics, X, through the following equation;

$$(1 - z)\Omega = \beta z + \gamma X + \varepsilon,$$

where ε is an error-term. Using this equation and Eq. (11), we have

$$E_{it} = \alpha + \alpha_i + \alpha_t + \beta z_{it} + \gamma X_{it} + \varepsilon_{it}, \quad (13)$$

where E_{it} is the CO_2 emission amount within industry i in year *t*, and z_{it} is the fixed asset for pollution control equipment within industry i in year *t*. The vector X_{it} includes the labor number, volume of gross value added, and wage premium within industry i in year *t*. Although the estimation of Eq. (13) may show the correlation between the emission amount and fixed asset for pollution control equipment, we use the difference in difference (DID) approach to identify the causality between the emission amount and emission standard. We regard the industries under the PAT system as a treatment group, and other industries as a control group. The PAT is proposed at 2008, so that the post-period is a dummy variable taking 1 after 2008. Under these conditions, we estimate the following equation,

$$E_{it} = \zeta + \eta_1 Treatment_i + \eta_2 {Post_{period}}_t + \eta_3 Treatment_i * {Post_{period}}_t + \theta X_{it} + \omega_{it}, \quad (14)$$

where ω_{it} is the error term.

We also estimate the effect of the increase in the fixed assets for pollution control equipment on the emission amount under the PAT by the difference in difference in difference (DDD) approach. The fixed assets for pollution control, the interaction terms of that with $Post_{period}$, $Treatment_i$, and both are added in the equation of the DID approach. We could divide the effects of PAT on emission into an effect of the increase in the fixed asset for pollution control and that of other factors. The estimation equation is as follows,

$$E_{it} = a + b_1 Treatment_i + b_2 {Post_{period}}_t + b_3 Treatment_i * {Post_{period}}_t + b_4 z_{it}$$

$$+b_5 Post_{period_t} * z_{it} + b_6 Treatment_{i\ t} * z_{it} + b_7 Treatment_i * Post_{period_t} * z_{it}$$

$$+cX_{it} + \eta_{it}. \tag{15}$$

The coefficient, b_7, shows the impact of the increase in the fixed asset for pollution control equipment on the emission amount under the PAT, and η_{it} is the error term.

4.2 Estimation Results

Descriptive statistics

Table 1 presents the descriptive statistics for the main variables at the industry level. Emission amounts of each industry might be related not only to the fixed asset for an emission-abatement activity, but also to the other characteristics of firms, such as the volume of gross value added, wage premium, and labor number. We therefore control those variables in the estimation. The volume of gross value added is deflated at the 2005 price as output, and controls the production scale. We also control the wage premium, which is the wage inequality between skilled and unskilled labor. It is measured by the ratio of the average wage of nonproduction workers to the average wage of production workers. The labor number is measured by the firm's total labor force counted as man-days. This variable controls the size of firm.

Table 1 Descriptive statistics of main variables

Fixed-effect estimation

Table 2 lists the results of the OLS fixed-effect estimation. In column (1), we find a positive relationship between the emission amount and fixed assets for pollution control, i.e., emission-abatement activity, without any control for other firm-specific factors. Even if we add the gross value added, wage premium, and labor number as control variables in columns (2)-(4), the coefficient of the fixed assets for abatement activity remains positive and significant. These paradoxical outcomes could be caused by the *reshuffling effect* discussed in the theoretical section. Also, like Melitz (2003), we confirm that a shuttered plant is less productive than an existing plant in Figure 6. Therefore, we can conclude that our estimation results would support the notion that the *reshuffling effect* works in Indian manufacturing.

Table 2 Effects of abatement activity on CO_2 emissions

Figure 6 Labor productivity: the existing and shuttered plants

Proposition 3: The OLS fixed-effect estimation suggests that the emission amount and fixed asset for pollution control are positively related in Indian manufacturing. This estimation result supports the paradoxical prediction in our theoretical analysis: i.e., a tightening of emission-abatement policy might increase emissions because of the reshuffling effect.

DID approach

In the estimation using the DID method, we should confirm that the emission trends are indifferent between treatment groups, which is the regulated industry under PAT, and the control group in the pre-treatment period. Table 3 shows the results of the falsification test. We do not recognize the difference in the time trend of emission between treatment and control groups for 2005–2007, since the interaction term between treatment and time trend is insignificant. Figure 7 contains a box plot of emission amounts comparing treatment groups. The figure suggests the median and variance are larger in the treatment group than in the control.

Table 3 Falsification test

Figure 7 Box plot of emission amount

Table 4 presents the results of the DID approach. The interaction term between *Treatment* and *Post period* is positive and significant in column (1).[15] This suggests the treatment industries increase emissions after the implementation of PAT. Of course, this is paradoxical, because PAT tightens the emission standard due to the rigid penalty rule. While we control for other firm specific characteristics in columns (2)-(4), the results remain the same quantitatively.

Table 4 Results of DID approach

DDD approach

As we see that PAT can increases the amount of emissions, we are also interested in how investment in pollution control equipment acts upon the results of the DID approach. Table 5 presents the DDD approach results. The interaction term between *Treatment*, *Fixed asset for pollution control*, and *Post period* is positive and significant in column (1). This suggests that a larger fixed asset for pollution control equipment increases the emission amount under PAT. The results remain the same quantitatively after controlling for the other firm-specific factors in columns (2)-(4). The results of DID and DDD approaches can be summarized as Proposition 4:

[15] We also conducted the placebo test, changing the treatment year 2008 to other years, and did not find any significant signs of the interaction term between *Treatment* and *Post period*.

Table 5 Results of DDD approach

Proposition 4: The result of the DID approach reveal that tighter emission standards can increase emissions from Indian manufacturers in more regulated industries. Moreover, from the DDD approach, we find that the investment for emission-abatement activity motivated by tighter emission standards contributes to the increase in emissions from the manufacturers in more regulated industries.

5. Conclusions

Do emission standards really reduce emissions? To clear up doubts, we theoretically and empirically explored the effect of emission-abatement policy. Our analysis using a firm-heterogeneity model suggests the possibility that strengthening emission standards might increase the amount of emissions via the *reshuffling effect*, despite a decrease in the aggregate output. The empirical analysis using industry-level data from the manufacturing sector in India, one of the largest contributors to CO_2 emissions in the world, also supports this paradoxical prediction. Moreover, the result of the DID approach shows that tighter emission standards increase emission amounts within regulated industries under PAT.[16] Furthermore, the estimation result of the DDD approach shows that the increase in investment for pollution control equipment or abatement activity can increase the amount of emissions.

We also notice an important policy implication in our analytical results. In this paper, we show that

[16] As noted above, the Indian government tightened the emission standard in particular industries under the PAT Mechanism for Energy Efficiency in 2008.

the PAT scheme leads to an increase in CO_2 emissions of regulated industries. Bhandari and Shrimali (2018), however, shows that each regulated plant successfully met the emission target during the first implementation period of PAT from 2012–2015, even though the target was not strict and the PAT did not stimulate the investment of energy saving falsities during the period. Although it sounds contradictory, it is possible to increase emissions at the industry level even when regulated plants successfully reduce emission per unit of product. The plants not regulated directly but in the regulated industry of PAT might change their production plan and invest in emission control because they expect regulations will also become stronger on them. If they are too unproductive to survive because of the cost increase due to emission control, their resources will move to the productive but regulated plant, leading to an increase in its output and emission amount. This process leads to the increase in CO_2 emission of regulated industries. Hence, in terms of policy implementation, we should consider not only effective enforcement of policy but the *reshuffling effect* as an external effect when introducing the environmental regulations.

Finally, we briefly mention some future tasks. Further considerations are required to address some additional issues. From UNCTAD statistics of international trade in goods and services, India's export and import values in 2018 were 332,139.8 and 519,590.9 million US dollars, respectively. The trade balance reached the highest trade deficit ever. Hence, we need to examine the impact of trade expansion on the amount of emissions within our model's framework. Moreover, we pointed out that the government should not put too much faith in the standards on emissions per unit of production based on the tested result using the data of the manufacturing sector in India. Therefore, in terms of policy implementation, environmental regulations on total emissions such as cap and trade should be examined.

Appendix A Derivations

Using Eqs. (4)-(6), we derive Eq. (7) as follows:

$$r(\tilde{\varphi}) = \left(\frac{\tilde{\varphi}}{\varphi^*}\right)^{\sigma-1} r(\varphi^*) = \frac{k}{1+k-\sigma} r(\varphi^*) = \frac{k}{1+k-\sigma}\sigma z. \tag{7}$$

Next, using Eqs. (4), (6), and (7), the aggregate profit of all firms, Π, is derived as

$$\Pi = \int_{\varphi^*}^{\infty} \pi(\varphi) M\mu(\varphi) d\varphi = \int_{\varphi^*}^{\infty} \left(\frac{r(\varphi)}{\sigma} - z\right) M \frac{g(\varphi)d\varphi}{1-G(\varphi^*)}$$

$$= M \int_{\varphi^*}^{\infty} \left[\left(\frac{\varphi}{\tilde{\varphi}}\right)^{\sigma-1} \frac{r(\tilde{\varphi})}{\sigma} - z\right] \frac{g(\varphi)d\varphi}{1-G(\varphi^*)} = M\left(\frac{r(\tilde{\varphi})}{\sigma} - z\right) = M\frac{\sigma-1}{1+k-\sigma} z. \tag{A1}$$

Considering Eq. (A1) and $\pi(\tilde{\varphi}) \equiv \Pi/M$, we obtain Eq. (8).

The average value function before entry, $\left(1 - G(\varphi^*)\right)F(\tilde{\varphi})$, can be written as $\varphi^{*-k}\pi(\tilde{\varphi})/\delta$ ($\because G(\varphi) = 1 - \varphi^{-k}$ and $F(\tilde{\varphi}) = \pi(\tilde{\varphi})/\delta$). Considering this average value must equal the fixed entry cost, f_e, we obtain Eq. (9). Moreover, substituting Eq. (8) into Eq. (9) and rearranging, we obtain the cutoff productivity shown as Eq. (10). Note that as we assumed that $\varphi^* \geq 1$, the parenthesis in Eq. (10) has to be larger than or equal to 1. Therefore, we find the following:

$$\frac{\sigma-1}{1+k-\sigma}\frac{1}{\delta f_e} z \geq 1 \leftrightarrow z \geq \frac{1+k-\sigma}{\sigma-1}\delta f_e \equiv \underline{z} > 0.$$

Taking into account this condition and $z < 1$, we impose the parameter constraint, $\underline{z} \leq z < 1$, in our analysis.

Using Eq. (4), the aggregated revenue is derived as

$$R = \int_{\varphi^*}^{\infty} r(\varphi) M\mu(\varphi) d\varphi = M \int_{\varphi^*}^{\infty} \left(\frac{\varphi}{\tilde{\varphi}}\right)^{\sigma-1} r(\tilde{\varphi}) \frac{g(\varphi)d\varphi}{1-G(\varphi^*)} = Mr(\tilde{\varphi}).$$

The aggregated revenue is equal to labor income, i.e., $R = wL = L$; therefore $Mr(\tilde{\varphi}) = L$. Then, using Eq. (7), we derive the equilibrium value of the number of firms as follows:

$$M = \frac{L}{r(\tilde{\varphi})} = \frac{1+k-\sigma}{k\sigma}\frac{L}{z}. \tag{A2}$$

The price index is derived as follows:

$$P = \left(\int_{\varphi^*}^{\infty} p(\varphi)^{1-\sigma} M\mu(\emptyset)d\emptyset\right)^{\frac{1}{1-\sigma}} = \left[\int_{\varphi^*}^{\infty} \left(\frac{\varphi}{\tilde{\varphi}}\right)^{\sigma-1} p(\tilde{\varphi})^{1-\sigma} M \frac{g(\varphi)d\varphi}{1-G(\varphi^*)}\right]^{\frac{1}{1-\sigma}} \ (\because \text{ Eq. (4)})$$

$$= M^{\frac{1}{1-\sigma}} p(\tilde{\varphi}) = \left(\frac{1+k-\sigma}{k\sigma}\frac{L}{z}\right)^{\frac{1}{1-\sigma}} \frac{1+z}{\rho\tilde{\varphi}} \ (\because \text{ Eqs. (3) and (A2)}). \tag{A3}$$

Using Eq. (A3) and $L = R = PY$, we derive the solution of Y as follows:

$$Y = \frac{L}{P} = \left(\frac{1+k-\sigma}{k\sigma}\frac{L}{z}\right)^{\frac{1}{\sigma-1}} \frac{\rho\tilde{\varphi}}{1+z} L = \left(\frac{L}{\sigma}\right)^{\frac{1}{\rho}} (\sigma-1)^{\frac{1+k}{k}} \left(\frac{1}{1+k-\sigma}\frac{1}{\delta f_e}\right)^{\frac{1}{k}} \frac{z^{\xi}}{1+z}, \ (\because \text{ Eqs. (6) and (10)}) \tag{A4}$$

where $\xi \equiv k^{-1} - (\sigma-1)^{-1} = -(1+k-\sigma)/k(\sigma-1) < 0$.

Total emissions can then be derived as follows:

$$E \equiv \int_{\varphi^*}^{\infty} \big(q(\varphi) - A(\varphi)\big) M\mu(\varphi)d\varphi = \int_{\varphi^*}^{\infty} (1-z)q(\varphi) M \frac{g(\varphi)d\varphi}{1-G(\varphi^*)}$$

$$= \int_{\varphi^*}^{\infty} (1-z)\left(\frac{\varphi}{\tilde{\varphi}}\right)^{\sigma} q(\tilde{\varphi}) M \frac{g(\varphi)d\varphi}{1-G(\varphi^*)} \ (\because \text{ Eq. (4)})$$

$$= (1-z)\left(\frac{k}{1+k-\sigma}\right)^{\frac{-\sigma}{\sigma-1}} \frac{r(\tilde{\varphi})}{p(\tilde{\varphi})} \frac{L}{r(\tilde{\varphi})} \frac{k}{k-\sigma} \ (\because r = pq \text{ and Eqs. (6) and (A2)})$$

$$= (1-z)\left(\frac{k}{1+k-\sigma}\right)^{\frac{-\sigma}{\sigma-1}} \frac{\rho\tilde{\varphi}}{1+z} L \frac{k}{k-\sigma} \ (\because \text{ Eq. (3)}). \tag{A5}$$

Considering Eqs. (6) and (10), Eq. (A5) can be rewritten as Eq. (11).

Appendix B The reason for the division into two cases

As $\Theta(z) = -z^2 - 2kz + 1 = -(z+k)^2 + (1+k^2)$ is a quadratic function, this function can be shown as a hump-shaped curve, as illustrated in Figures 5a and 5b. From the quadratic formula, we find that a unique intersection of this function with horizontal (z-)axis within the range of $0 < z < 1$ is $z = -k + \sqrt{1+k^2}$, because the sign of the other solution, $z = -k - \sqrt{1+k^2}$, is negative. The proof of $0 < z = -k + \sqrt{1+k^2} < 1$ is as follows:

Proof: *We find that* $-k + \sqrt{1+k^2} > 0$, *because* $-k + \sqrt{1+k^2} = \sqrt{1+k^2} - \sqrt{k^2} > 0$. *Similarly,* $-k + \sqrt{1+k^2} < 1$ *can also be confirmed from* $1 - \left(-k + \sqrt{1+k^2}\right) = \sqrt{(1+k)^2} - \sqrt{1+k^2} > 0$. *According to* *these results, we can see that* $0 < -k + \sqrt{1+k^2} < 1$. ■

However, the magnitude relation between $-k + \sqrt{1+k^2}$ and the lower bound of z, i.e., $\frac{1+k-\sigma}{\sigma-1}\delta f_e \equiv \underline{z}$, is not strictly determined. Therefore, in Section 3, we separately conduct our analysis under the two cases: $\underline{z} \leq -k + \sqrt{1+k^2}$, and $-k + \sqrt{1+k^2} < \underline{z}$, paying attention to $0 < z < 1$.

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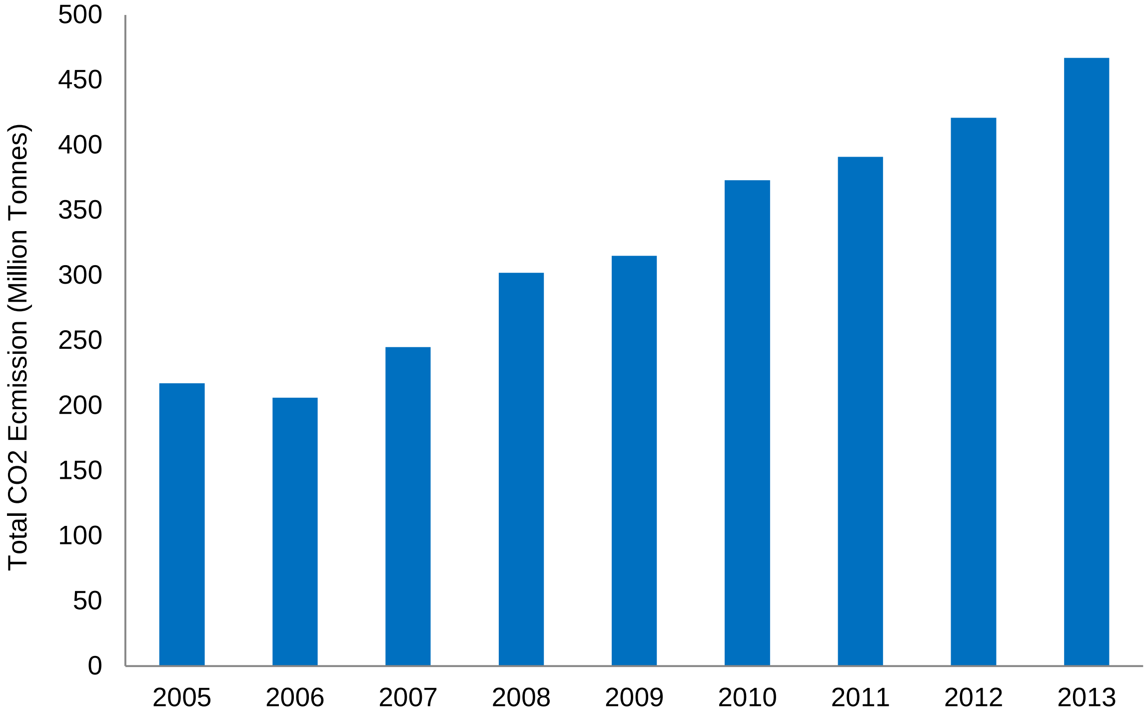
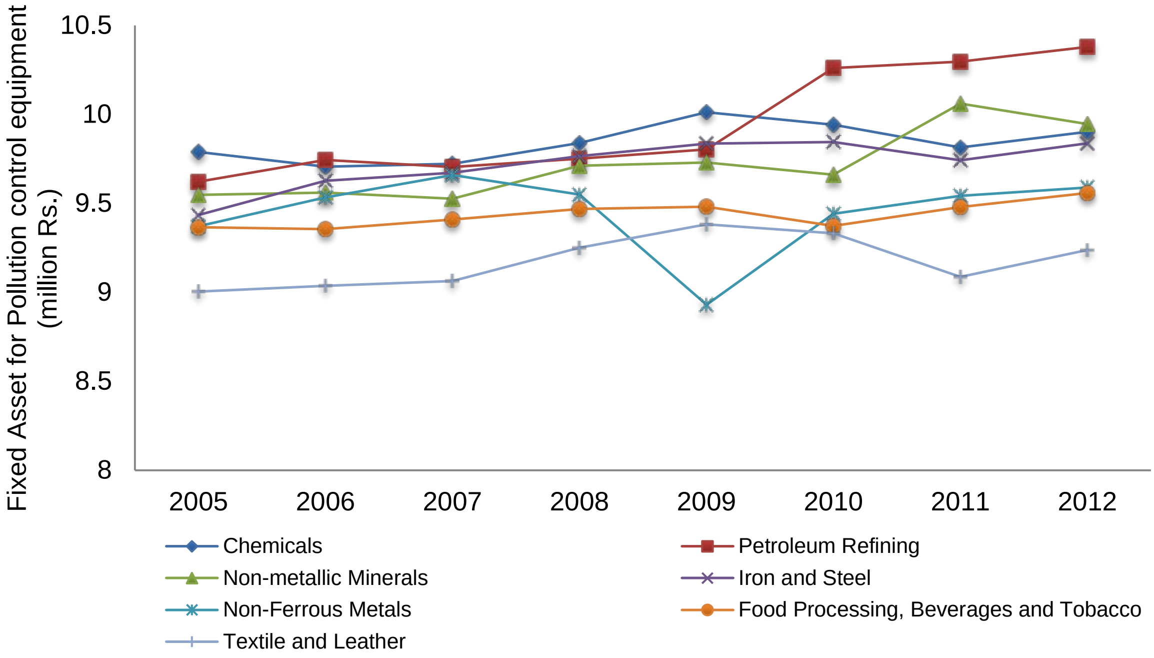
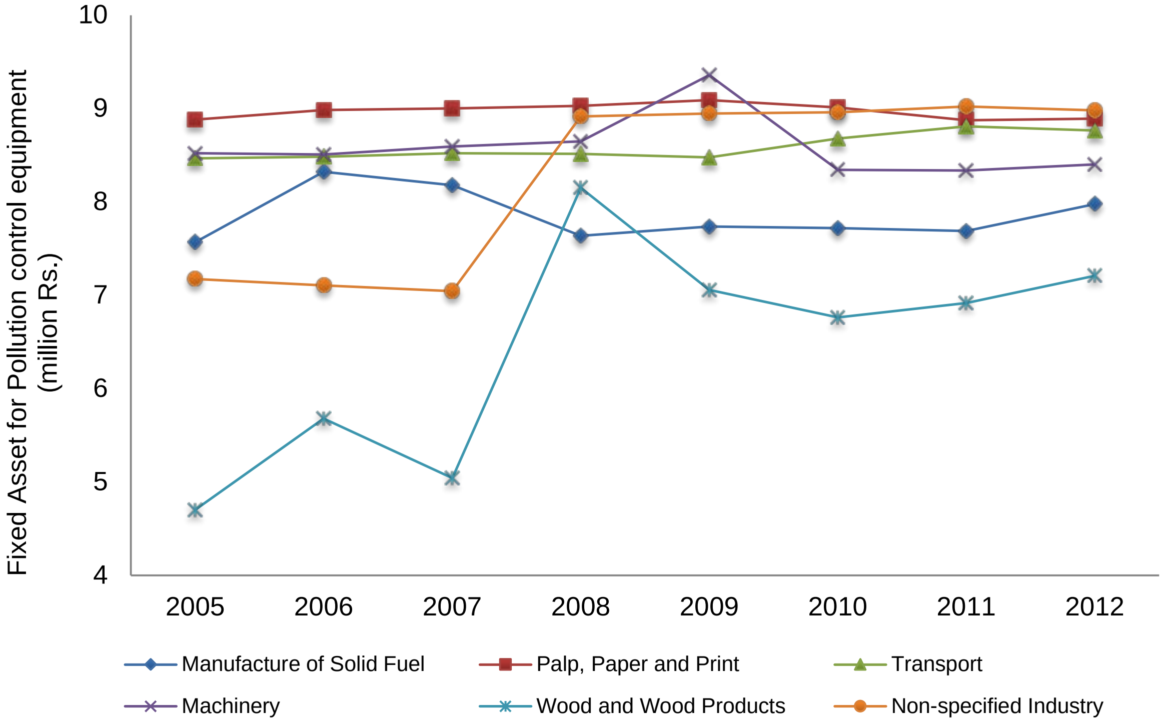
Figure1 Overall CO_2 emissions in India due to various fuel uses within manufacturing



Source: This figure is adapted from Gupta et al. (2017)

Figure 2 Time series of fixed assets for pollution control equipment





Source: Author's calculation from ASI data.

Figure 3 Distribution of fixed assets for pollution control equipment: existing and shuttered plants

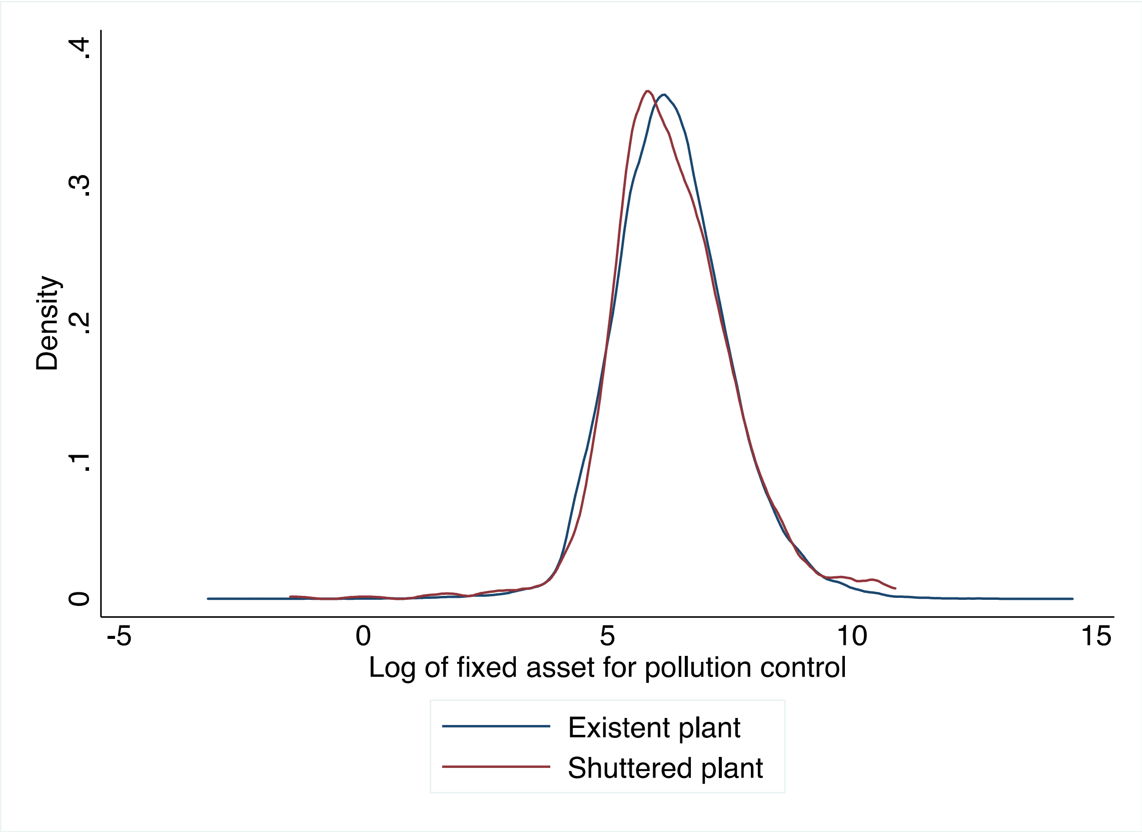
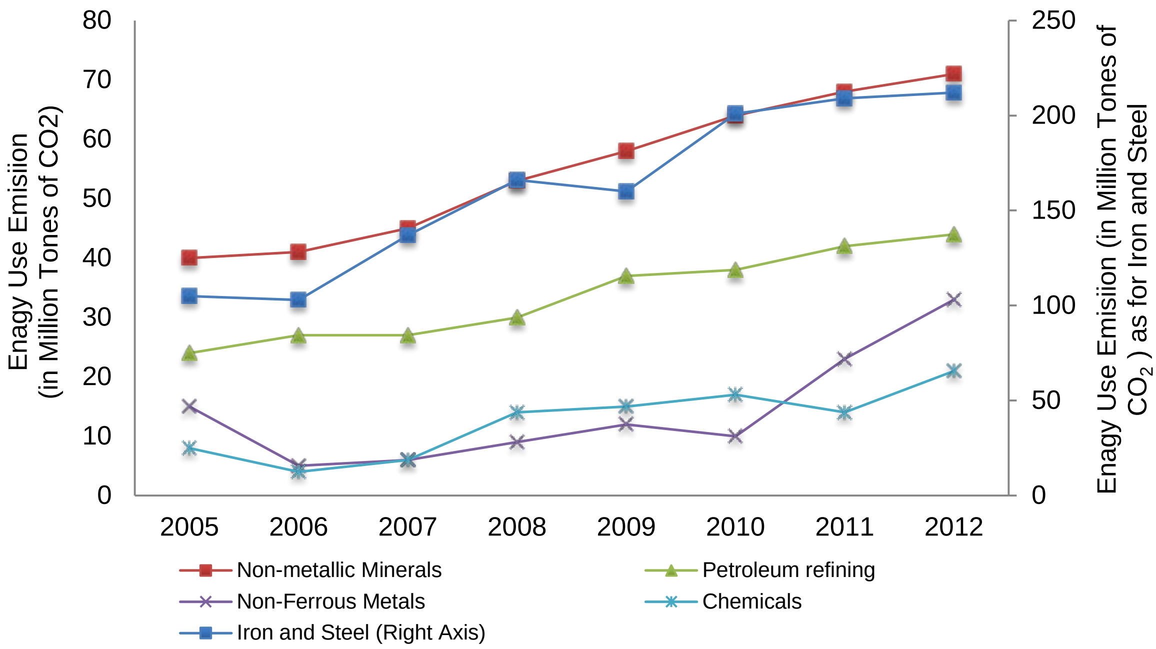
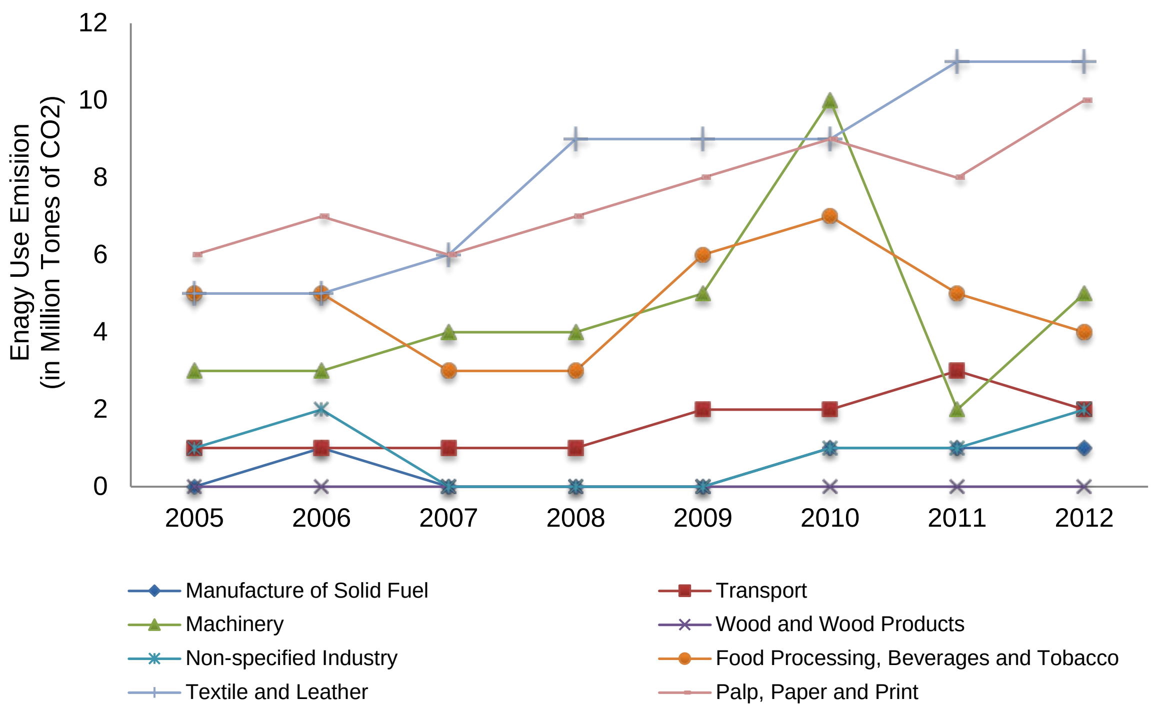


Figure 4 Time series of CO_2 emission estimates for the manufacturing sector





Source: Re-product from Gupta et al. (2017).

Note: Figure 4 (the upper figure) has Iron and Steel industry on the right ordinate and the others on the left.

***Figure 5a** $\boldsymbol{\Theta(z)}$**-function under lax regulations in the beginning:** $\underline{\boldsymbol{z}} \leq \boldsymbol{-k+\sqrt{1+k^2}}$*

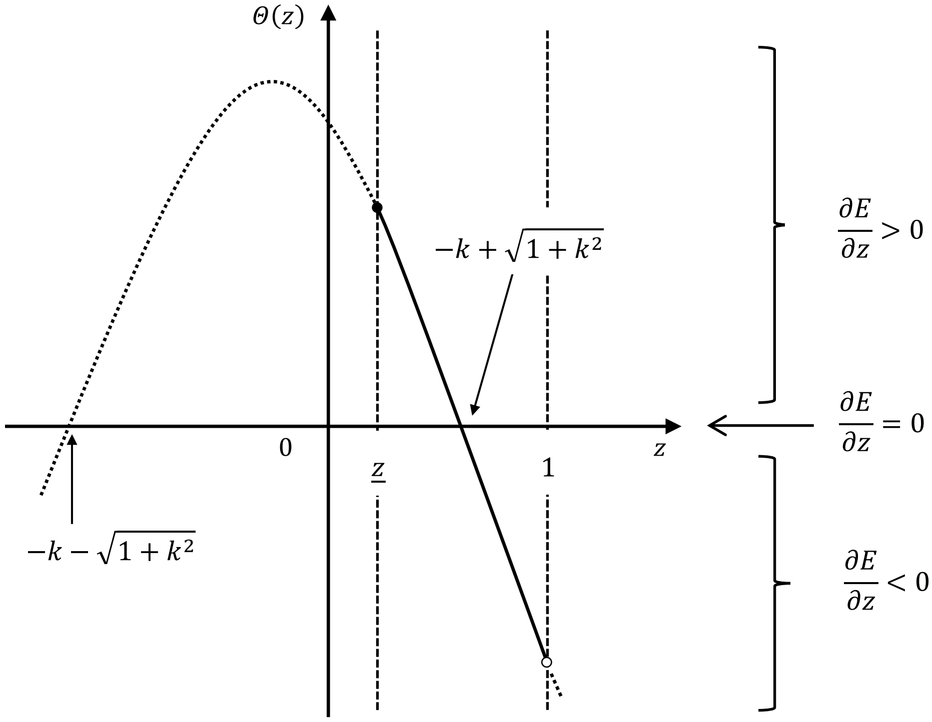


Figure 5b **$\Theta(z)$-function under strict regulations in the beginning:** $-k+\sqrt{1+k^2}<\underline{z}$

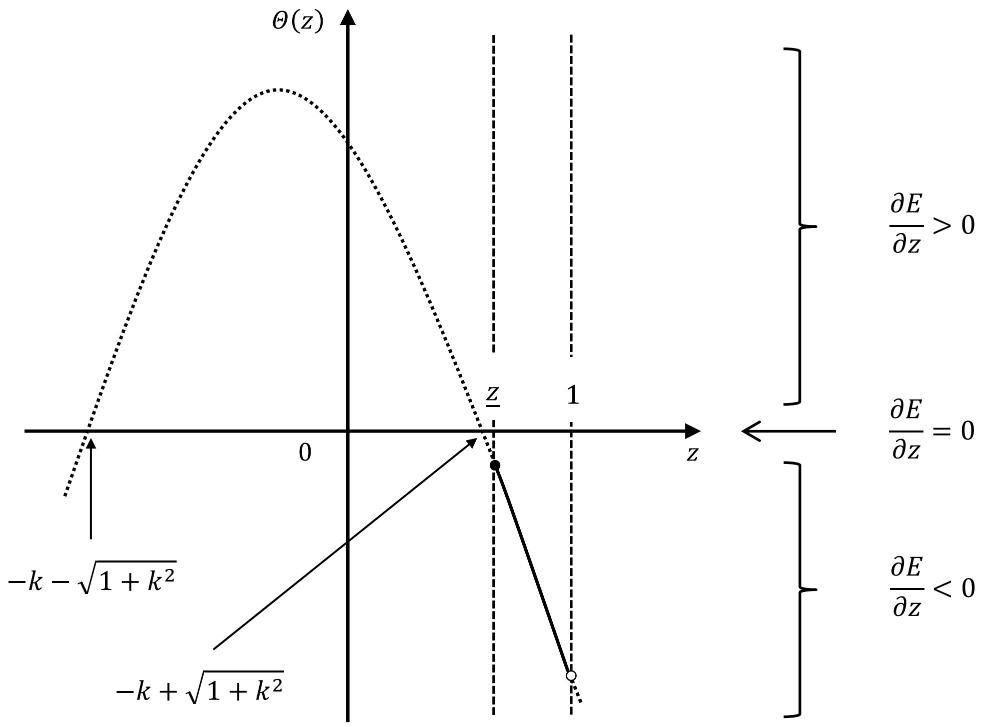
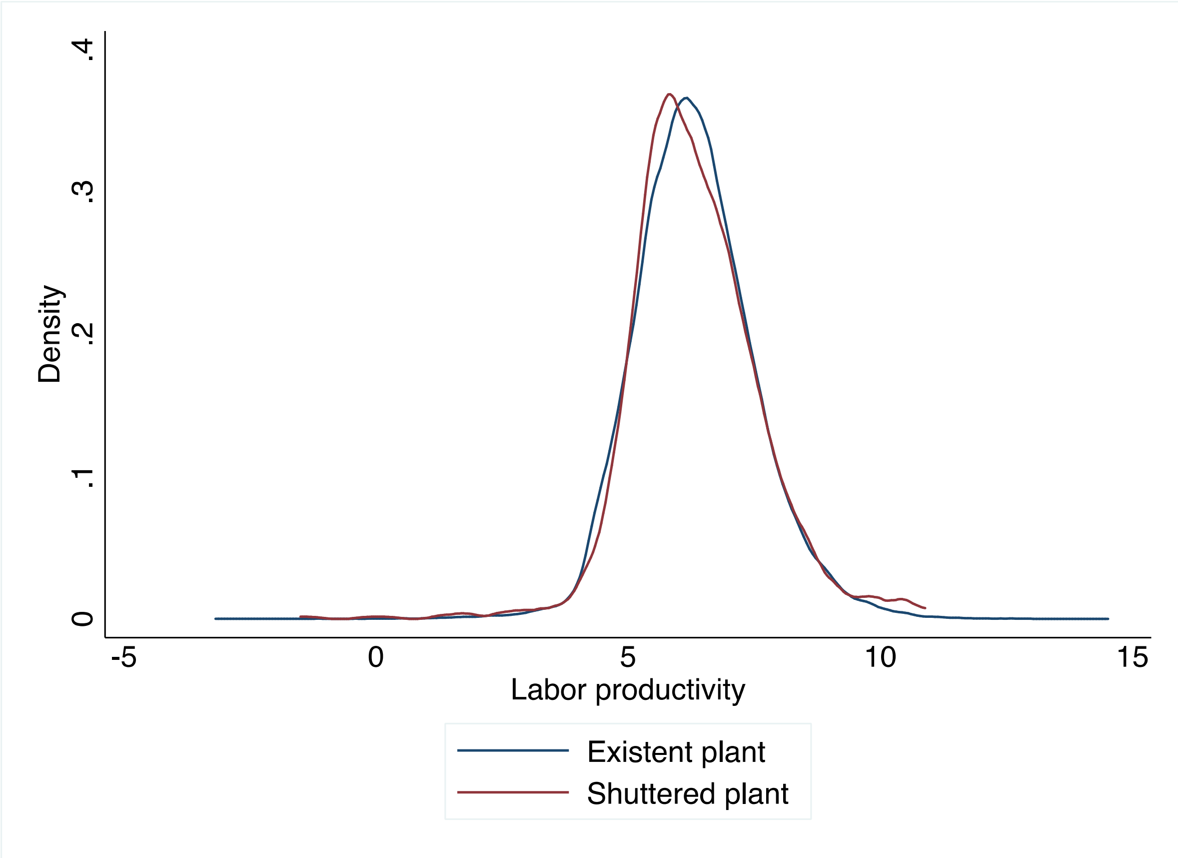
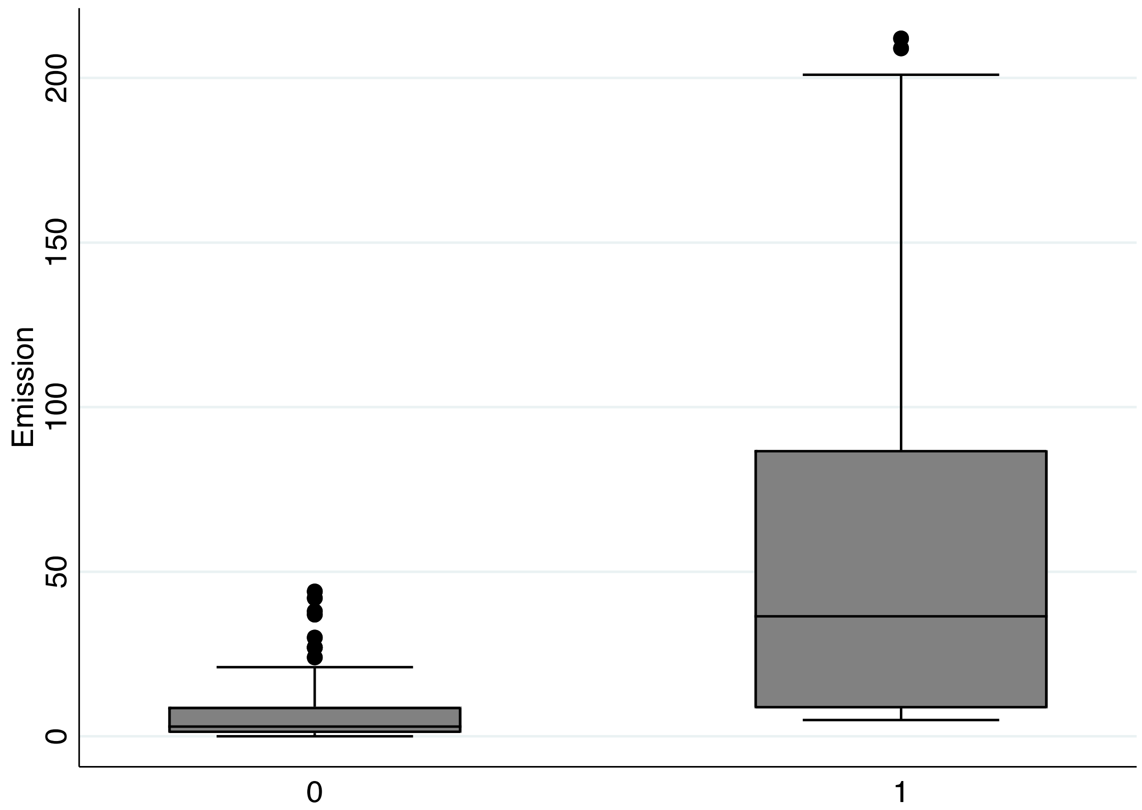


Figure 6 Labor productivity: the existing and shuttered plants



Note: The labor productivity in Figure 6 is calculated as the ratio of gross value added to the number of employees.

Figure 7 Box plot of emission amount



Source: Author's calculation.

Note: Treatment group takes one, and control group takes zero.

Table 1 Descriptive statistics of main variables

Variable	Obs	Mean	SD	Min	Max
Emission	104	23,400,000	44,600,000	0	212,000,000
Fixed asset for pollution control	104	3,470,000,000	4,630,000,000	182,903	23,500,000,000
Gross Value Added	104	173,000,000	165,000,000	6,451,590	616,000,000
Wage Premium	104	94	906	0	9,241
No. of Labor	104	174,000,000,000	151,000,000,000	0	622,000,000,000

Table 2 Effects of abatement activity on CO_2 emissions

	(1)	(2)	(3)	(4)
Fixed asset for pollution control	0.000968*	0.000978*	0.000960*	0.00104*
	(0.000531)	(0.000552)	(0.000553)	(0.000557)
Gross Value Added		1.46e-06	7.50e-07	-1.48e-05
		(2.08e-05)	(2.09e-05)	(2.47e-05)
Wage Premium			-1,159	-1,249
			(1,383)	(1,382)
No. of Labor				0.0841
				(0.0714)
Year	2.106e+06***	2.073e+06***	2.165e+06***	1.608e+06*
	(546,003)	(727,852)	(737,288)	(874,751)
Constant	-4.212e+09***	-4.145e+09***	-4.330e+09***	-3.222e+09*
	(1.097e+09)	(1.459e+09)	(1.478e+09)	(1.750e+09)
Observations	104	104	104	104
R-squared	0.242	0.242	0.248	0.260
Number of Industry	13	13	13	13

Notes: Standard errors are in parentheses. ***Statistical significance at the 1% level. **Statistical significance at the 5% level. *Statistical significance at the 10% level.

Table 3 Falsification test

	(1)
Treatment	-6.987e+09
	(4.690e+09)
*Treatment*Time trend*	3.500e+06
	(2.337e+06)
Time trend	-9.48e-06
	(1.296e+06)
Constant	5.259e+06
	(2.602e+09)
Observations	39
Number of Industry	13

Notes: Standard errors are in parentheses. ***Statistical significance at the 1% level. **Statistical significance at the 5% level. *Statistical significance at the 10% level.

Table 4 Results of DID approach

	(1)	(2)	(3)	(4)
Treatment	3.774e+07	3.901e+07*	3.900e+07	4.739e+07*
	(2.319e+07)	(2.282e+07)	(2.390e+07)	(2.564e+07)
Post period	3.385e+06	-188,249	-107,975	-2.274e+06
	(2.652e+06)	(3.216e+06)	(3.224e+06)	(3.279e+06)
Treatment Post period*	2.316e+07***	2.542e+07***	2.535e+07***	2.599e+07***
	(4.780e+06)	(4.865e+06)	(4.871e+06)	(4.739e+06)
Gross Value Added		3.36e-05*	3.34e-05*	6.34e-06
		(1.75e-05)	(1.76e-05)	(2.07e-05)
Wage Premium			-314.7	-609.0
			(1,250)	(1,221)
No. of Labor				0.108**
				(0.0471)
Constant	5.259e+06	830,825	850,604	-1.447e+07
	(1.286e+07)	(1.286e+07)	(1.345e+07)	(1.575e+07)
Observations	104	104	104	104
Number of Industry	13	13	13	13

Notes: Standard errors are in parentheses. ***Statistical significance at the 1% level. **Statistical significance at the 5% level. *Statistical significance at the 10% level.

Table 5 Results of DDD approach

	(1)	(2)	(3)	(4)
Treatment	4.765e+07**	5.171e+07**	5.193e+07**	5.823e+07**
	(2.189e+07)	(2.273e+07)	(2.431e+07)	(2.664e+07)
Fixed asset for pollution control	-0.000498	0.000611	0.000573	-0.000702
	(0.00150)	(0.00159)	(0.00159)	(0.00163)
Post period	430,561	-2.137e+06	-2.066e+06	-5.324e+06
	(2.994e+06)	(3.237e+06)	(3.229e+06)	(3.421e+06)
*Treatment * Post period*	-3.811e+06	-2.139e+06	-2.288e+06	975,763
	(8.681e+06)	(8.554e+06)	(8.520e+06)	(8.352e+06)
*Post period * Fixed asset for*	0.00114	0.000339	0.000369	0.00147
pollution control	(0.00123)	(0.00129)	(0.00129)	(0.00133)
*Treatment * Fixed asset for*	-0.00315	-0.00462	-0.00468	-0.00347
pollution control	(0.00320)	(0.00322)	(0.00321)	(0.00316)
*Treatment * Fixed asset for*	0.00693**	0.00777***	0.00779***	0.00639**
*pollution control * Post period*	(0.00277)	(0.00275)	(0.00274)	(0.00272)
Gross Value Added		3.16e-05*	3.13e-05*	4.64e-07
		(1.69e-05)	(1.69e-05)	(2.09e-05)
Wage Premium			-351.2	-664.9
			(1,096)	(1,067)
No. of Labor				0.108**
				(0.0460)
Constant	6.073e+06	94,336	196,633	-1.247e+07
	(1.142e+07)	(1.232e+07)	(1.323e+07)	(1.549e+07)
Observations	104	104	104	104
Number of Industry	13	13	13	13

Notes: Standard errors are in parentheses. ***Statistical significance at the 1% level. **Statistical significance at the 5% level. *Statistical significance at the 10% level.