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RESEARCH ARTICLE

Environmental regulation, local legislation and pollution control in China

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Abstract

This paper conducts a novel empirical analysis of the effect of environmental regulation on local pollution emissions by taking 84 cases of local legislation among 31 provinces in China during 1990–2009. We combine the matching methodology and difference-in-difference method to estimate the causal effect of provincial environmental legislation. Our estimation uncovers that there is no significant pollution abatement effect, however, environmental legislation helps to decrease local pollution emission only for those provinces that have stricter enforcement. Such results remain robust while considering the time lag effect, different types of pollutants, choice of different comparison groups and using of synthetic control method. Generally, our study shows the importance of the enforcement for environmental legislation in China.

Keywords: enforcement of law; environmental regulation; local legislation

JEL classification: K32; L51

1. Introduction

China has experienced strikingly rapid economic growth since its opening up, which comes at enormous costs, among which pollution emissions and deteriorating environment have been one key issue. Many previous studies have empirically examined various determinants of pollution emission in China, such as economic growth (Shen, 2006; Song *et al.*, 2008), foreign direct investment (Bao *et al.*, 2011) and trade openness (Dean *et al.*, 2009; Jayanthakumaran and Liu, 2012). These studies help us to understand how pollution has changed in China; however, it is also very important to know how environmental regulation works in China.

The key issue of evaluating the outcome of environmental regulation is that it is usually hard to directly observe and measure the degree of regulation efforts. Pollution tax rate and pollution abatement cost are widely used in the empirical analysis regarding developed countries such as the U.S. (Keller and Levinson, 2002; Cole *et al.*, 2005; Yang *et al.*, 2012). However, China's current pollution levy system is quite specific. Under the pollution levy system, firms are required to self-report their pollution to the local

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environmental authorities, and pay a fee only on the quantity of effluent discharge that exceeds the legal standard. Obviously, such a system design makes it quite difficult to evaluate the policy outcome of environmental regulation in China, as we cannot observe the stringency of pollution monitoring and regulation directly. Some recent studies adopt China's environmental policy regulation adjustment to examine the effectiveness of regulation. For example, both Hering and Poncet (2014) and Cai *et al.* (2016) use the Two Control Zones (TCZ) policy implemented by the Chinese government in 1998 to study how the TCZ policy affects Chinese cities' export and FDI entry. Liu *et al.* (2017) use the wastewater discharge standard adjustment in the Lake Tai, Jiangsu province to examine how the more stringent discharge standard affects local labor demand. While these studies help to understand the importance of environmental regulation, however, they mainly focus on the effect of regulation policies implemented by various levels of Chinese governments and much less is known regarding the role of environmental legislation.

Therefore, this paper evaluates the effect of environmental regulation from a very novel perspective of local environmental legislation at the provincial level.[1] Since local People's Congresses and governments in China have extensive flexibility in formulating and enforcing environmental laws, provinces promulgate their own laws tailored to the local environmental problems in addition to those of the central government, which provides an ideal experiment for our study of environmental regulation. First, the passing of environmental law is approved by the local People's Congresses in response to the worsening of the local environment, which implies that this regulation action is hard to be perfectly predicted by the local firms and hence is an exogenous shock to this study. Second, there are significant variations regarding the content, patterns and passing time of local environmental laws across Chinese provinces. Hence it allows us to divide our sample provinces into treated groups and comparison groups for different periods and for different targeted pollutants. Specifically, we exploit two sources of variations to identify the causal effect in this study: cross-provincial variation (those provinces which pass environmental laws in certain years and those which do not) and time variation (before and after the passing of environmental law). We adopt the difference-in-difference (DID) methodology to perform our evaluation effectively by capturing the significant variation among local environmental legislation. The advantage of the DID design is that we can effectively separate the regulation effect of local law from that of unobservable factors such as the business cycle. Meanwhile, the conventional DID estimator requires that, in the absence of the treatment, the average outcomes for the treated and control groups would have followed parallel paths over time. So, we follow Abadie (2005) to use a nonparametric technique, propensity score matching combined with DID estimation to identify the causal effect. We also employ alternative matching methodology such as the synthetic control method proposed by Abadie and Gardeazabal (2003) as our robustness check.

[1] Local environmental legislation has been undertaken in China since 1989 when the Environmental Protection Law of the People's Republic of China was passed. So far the National People's Congress and its Standing Committee has already formulated 29 laws concerning environmental and resource protection. With several local laws stipulated by local People's Congresses and complementary administrative regulations by the State Council and environmental protection authorities at each level, a system of environmental regulation has gradually been set up.

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We collect local laws and rules relevant to environmental regulation across the 31 provinces (municipalities) in China, of which 84 pieces of local environmental legislation are sorted out. The treated provinces are defined as those having approved certain environmental legislation. We find that pollutant emissions per GDP declined in the treatment provinces during the sampling period. However, it is not wise to attribute such change to the approval of environmental legislation in the treated province. The reason is that, even in the absence of legislation adoption, the same change also happened in the untreated provinces as increasing attention has been paid to environmental protection in China as a whole. Our DID estimation results show that local environmental legislation fails to help ameliorate environmental quality. We also conducted a series of robustness tests under several circumstances, such as different matching criteria, various sorts of pollutants and the time lag effect of regulation enforcement, as well as using the newly-developed synthetic control method. Our key conclusion remains robust.

To further investigate the reason why local environmental legislation in China fails to reduce pollution emission as we expected, we highlight that it is far from enough to only focus attention on the passing of environmental legislation. The enforcement of laws is not a trivial issue in transitional economies like China (Wang *et al*., 2003; Allen *et al*., 2005; Du *et al*., 2008).[2] In spite of the pollution charges imposed by the central government, local authorities of environmental protection vary in efforts to implement them. For example, Chinese firms usually have strong bargaining power relative to the local environmental protection agencies, which means that environmental legislation at large cannot be completely enforced (Wang *et al*., 2003). Obviously, the effect of environmental legislation will be weakened if the approved laws are not vigorously enforced. To examine the strength of enforcement, we used the amount of fines specific to the environment pollution to measure it. While the effectiveness of environmental legislation is jointly determined by the passing of environmental law and the stringency of its enforcement, we use the difference-in-difference-in-difference (DDD) methodology to identify the causal effect of environmental legislation: whether provinces pass environmental law, when they pass it, and whether it is strictly enforced. We use those provinces that pass legislation and also enforce it strictly as our treated group, and those that pass legislation but enforce it loosely as the untreated group in our DDD design. We expect that those provinces that have passed environmental laws but not yet firmly enforced them are less likely to receive the treatment effect. Our estimation supports that the strength of enforcement is cardinal to the effectiveness of environmental legislation, while local pollutant emissions have been significantly reduced exclusively in provinces with stringent enforcement.

Our study contributes to the literature in the following aspects. Firstly, while many researchers have examined the effect of environmental regulation on pollution emissions, they mainly focus on regulation policies or acts implemented by various levels of Chinese governments (Hering and Poncet, 2014; Cai *et al*., 2016; Liu *et al*., 2017), and few studies have looked into the important role of environmental legislation. In this sense we contribute to the literature by considering the importance of environmental regulation from the novel perspective of local legislation. Secondly, our study helps to reconcile

[2]Some literature suggests the inefficiency of the enforcement of legislative texts in China. Allen *et al.* (2005) noted that despite the fact that the legislative texts concerning investor protection are already well-rounded, their enforcement is terrible when they investigated the financial development in China. Du *et al.* (2008) also pointed out that there exists great variance of contract enforcement across regions in the framework of a nationwide uniform legal system.

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the mixed empirical findings in previous literature regarding the regulation effect by highlighting the key role of regulation enforcement. The effect of environmental regulation on pollution control has been widely examined by previous literature. However, the empirical findings are mixed. While some studies support the important role of regulation in improving environmental quality (Dasgupta *et al*., 2002; Shapiro and Walker, 2018), others have concluded that environmental regulation could not solve pollution problems effectively (Greenstone, 2004; Blackman and Kildegaard, 2010; Zhong *et al*., 2017). Our study contributes to this literature by addressing the importance of environmental law enforcement, as it reveals that even after the local environmental legislation is passed, it possibly fails to achieve the desired regulation effect if it cannot be strictly enforced in practice.

2. The development of local environmental legislation in China

According to the principal of *giving full play to local initiative under the unified leadership of the central authorities* specified in the Constitution of 1982, the Constitution, the legislative law and relevant laws make up China's current legislative system. The legislative body is divided into the central and local levels. While the National People's Congress (NPC) and its Standing Committee exercise the legislative power at the national level, the People's Congress and its Standing Committee in each province, autonomous region and municipality may formulate their local laws at the local level. A few notes are made here while sorting out the experiments of local environmental legislation. First, generally local environmental legislation can be divided into two categories according to its contents: general and pollutant-specific legislation. The former covers environmental governance, enforcement measures and the general technical standards, while the latter only aims at certain pollutant emissions. Obviously, it is very hard to accurately assess the effects of those general laws in that we can pinpoint neither appropriate indicators for them nor the channels through which they take effect. Hence, we exclude the general environmental legislation, and limit our analysis to the legislation specific to certain pollutants, for which we are able to observe its actual impact more concretely. Second, there are some circumstances under which a regulation was adjusted or amended, for example, when the environmental legislation has been revised several times in one province. We handled these situations as follows: if the revision was made five years or even longer after its first coming out, we considered them to be two different regulations; otherwise, the regulations were treated as one.

Figure 1 shows the evolution of environmental legislation every year since 1990. The early 1990s to 1996 was the incipient period of local environmental legislation, which indicates that environmental protection laws were put on the agenda but limited to only a handful of provinces. The local legislation of environmental protection soared from 1996 to 2004. In these years up to six laws were passed on average, outnumbering other years significantly. Especially in 2002, the highest ever number – eleven laws – were approved in total. This change reflects that under the stronger pressure of environmental protection in the wake of lasting rapid economic growth, more attention has gradually been paid to juridical regulation of environmental protection by the local legislative bodies. Since 2005, the amount of local environmental legislation has started to move downward.

Local environmental legislation also presents a high degree of regional variations. Shanxi Province outnumbered other provinces with nine laws in total approved under environmental legislation. It is not surprising as economic growth in this province heavily depends on resource-intensive industries such as coal-mining. The consequent

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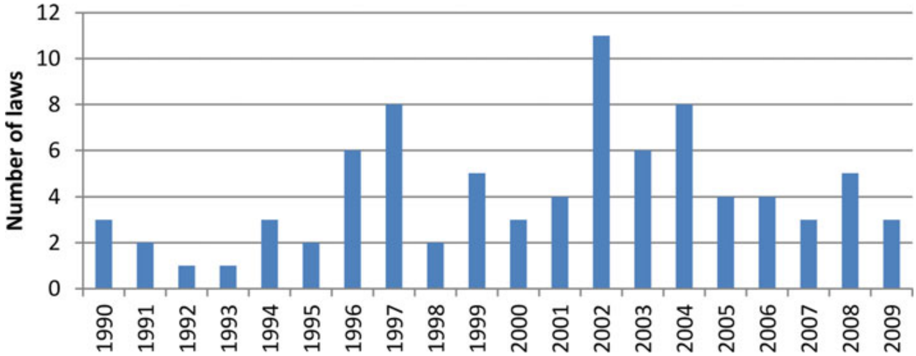

Figure 1. The timetable of local environmental legislation in China.
Source: Authors' own calculation.

serious environmental pollution problem results in the high requirements of stricter regulation in Shanxi province. Meanwhile, economically-developed provinces such as Guangdong and Jiangsu that suffer from pollution – the byproduct of rapid economic growth – also tend to adopt more stringent legislation. In both, the number of approved laws reached eight, second only to Shanxi. In comparison, the underdeveloped central and western regions are not so keen on environmental legislation. For example, Guizhou, Heilongjiang and Jiangxi, three inland provinces, each passed only one law, which is significantly lower than those of developed coastal provinces. In addition, environmental legislation is also closely associated with the variety of pollutants. Among all 84 cases, environmental legislation against water pollution is most intense, accounting for 49 cases. It is followed by environmental legislation against atmospheric pollution (23) and solid wastes (12). Particularly in regard to solid waste, only nine provinces adopted the relevant regulatory laws.

3. Estimation strategy

We sort provinces having approved environmental legislation into the treatment group. A binary dummy variable $du_i = \{0, 1\}$ is constructed: $du_i = 1$ indicates that province i has passed a certain environmental law and $du_i = 0$ otherwise. We also use $dt = 0$ to indicate the year before legislation and $dt = 1$ the year after legislation. The emission levels of sewage, sulfur dioxide, dust and solid waste alike are widely used to measure the change in environmental quality. We choose the intensity of pollutant emissions per unit of GDP, namely the ratio of the pollution emission levels to the local GDP, as the outcome of legislation regulation. This indicator has the advantage of standardizing the pollution emissions by local economic scales to pin down the legislation's regulatory effect. Specifically the outcome variable P_{it} denotes the pollutant emissions per GDP (emission intensity) in province i at time t. We also use level of pollutant emissions (P'_{it}) as our alternative dependent variable as robustness checks. Table 1 shows statistical information for both the level of pollution emissions and pollution emission intensity before and after the passing of environmental laws. Hence, we estimate the following model to capture the causal effect:

$$\ln(P_{it}) = \beta_0 + \beta_1.du + \beta_2.dt + \gamma.du \times dt + \varepsilon_{it}.$$

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Table 1. Pollutant emissions before and after legislation

	Pollutant emission level		Pollutant emissions per GDP	
	Before legislation	After legislation	Before legislation	After legislation
Industrial Sewage	104, 027.4	106, 945.6	37.513	27.191
Sulfur dioxide	64.212	68.495	0.017	0.013
Dust	33.527	30.634	0.009	0.007
Solid waste	31.532	40.614	0.026	0.113

Notes: The statistics are obtained from the original data collected from various issues of *Chinese Environmental Statistical Yearbook*. The unit of all the pollutants above is million tons. Pollutant emissions per GDP is the pollutant emissions per hundred million yuan of GDP.

The coefficient γ of the interaction term $du \times dt$ measures the causal impact of environmental legislation on pollutant emissions, which is the estimator of our interest: $\gamma = E(\Delta P_i^1 | du_i = 1) - E(\Delta P_i^0 | du_i = 0)$. If $\gamma < 0$, we can tell that the treatment provinces go through a larger decline in pollutant emissions than the control provinces before and after environmental legislation.

It is well-known that the accuracy of the results estimated by the DID method seriously relies on our choice of control groups, whose pollutant emissions have to evolve similarly to those of the treatment group in the counterfactual sense. This strong parallel assumption may be implausible if pre-treatment characteristics that are thought to be associated with the dynamics of the outcome variable are unbalanced between the treated and the untreated (Abadie, 2005). Therefore, we adopt the widely-used propensity score matching method to select the comparable untreated groups. We also employ the newly-developed synthetic control method (Abadie and Gardeazabal, 2003; Abadie *et al.*, 2010) as our robustness checks. Besides, as Bertrand *et al.* (2004) highlighted, the standard errors are likely to be underestimated when heteroskedasticity or serial correlation occurs in the DID estimation. In this regard, we follow their suggestion by using the clustered standard error at the province level.

We also follow previous studies to control other variables which may affect pollution emissions. The variables are as follows. (1) Local economic development (*agdp*) indexed by the log value of GDP per capita in a province or municipality. As pollution emissions cause larger marginal welfare loss to the local people among more developed regions, we expect GDP per capita to have a negative effect on pollution emission. (2) Investment in local industrial pollution abatement (*invsh*), indexed by the ratio of the value of the investment in local industrial pollution abatement to its GDP. (3) The size of staff employed in the environmental protection agencies (*rensh*), indexed by the ratio of the number of staff in the environmental protection agencies to the size of the population at the end of a year. (4) We also use regional dummy, year dummy variables as well as the interaction terms of regional and year dummy to control for the regional environmental heterogeneity and the time trend of pollution emissions.

4. The empirical analysis of environmental legislation

4.1 Propensity score matching

We follow the two-step strategy suggested by Abadie (2005) to estimate the average treatment effect of local legislation. We first use the Probit model to estimate the probabilities of environmental legislation for all provinces, namely the propensity scores of

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Table 2. Probit estimation of the adoption of legislation

Explanatory variables	*pint*	*gpint*	*lagdp*	*indus*	*year*	*region*	*form*
Coefficient	0.002***	−0.028***	0.234*	1.028***	−0.039**	0.026***	0.014*
	(0.000)	(0.008)	(0.131)	(0.276)	(0.018)	(0.005)	(0.008)

Notes: Robust standard errors in parentheses. Significant at *10%, **5% and ***1%.

legislation. Then we select provinces whose propensity scores are closest to those of the treatment province in the control group (the nearest neighbor matching). Specifically, we use the following matching variables to predict the local legislation probability. (1) Pollution emissions per GDP one year before legislation (*pint*). This pollution emission intensity reflects the local environmental quality in the initial year before they pass an environmental law. In general, legislative authorities, in the face of marked deterioration of local environmental quality, are more likely to approve environmental legislation in order to improve the local environmental condition. (2) The growth rate of pollution emissions per GDP one year before legislation (*gpint*). Similarly, the rapid increase in local pollution emissions forced the legislation authorities to approve environmental legislation and strengthen environmental regulation. (3) Log value of GDP per capita one year before legislation (*lagdp*). Higher GDP per capita implies larger negative utility provided by pollutant emissions for the inhabitants (Copeland and Taylor, 2003). As a result, environmental legislation is perhaps more likely to get adopted. (4) Local industrial structure indicated by the ratio of industrial production to local GDP (*indus*). The more the industrial output accounts for local GDP, the more harmful the effect of intense industrial production on local environment will be. Environmental legislation is therefore more likely to be induced. (5) Time trend terms indicating local legislation intensity (*year*). (6) Regional dummy (*region*), which is 1 for coastal provinces, and 0 for inland ones. (7) Various pollutant form dummy variables indicating industrial dust, sulfur dioxide, dust and solid waste (*form*). The explained variable is a dummy variable indicating whether legislation is passed or not.

The Probit model estimation result is shown in table 2. Generally, the estimation result explicitly explains why certain provinces would pass an environmental law. Specifically, provinces with increasing pollution emissions and worsening local environmental quality are more likely to approve environmental legislation. Those with higher GDP per capita may possibly pass an environmental law as the local people in more developed provinces can tolerate less the deterioration of environmental quality. Meanwhile, a larger share of manufacturing output in the total output leads to a higher probability of passing a law, which reflects the fact that manufacturing activities are the main source of pollution emissions. These results support our viewpoint that local environmental legislation is closely endogenous to the local environmental condition and economic growth as well as industrial structure.

We also check whether the treated groups and the comparison groups are well-balanced after matching. The balancing test results are reported in table 3. It can be seen that the treated groups are quite different from the control groups before matching. These differences are visible in most matching variables including pollution emissions per GDP, GDP per capita and ratio of industrial production to local GDP. It implies that the two groups are unbalanced in our test before matching, pointing to the importance of addressing the selection issue. There is no statistically-significant difference in terms of any provincial characteristics between the treated and the control group after matching.

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Table 3. Summary statistics for the unmatched and matched sample

	Treated	Control (Unmatched)	*p*-value	Treated	Control (Matched)	*p*-value
pint	12.310	17.129	0.083	12.310	13.158	0.385
gpint	−0.193	−0.165	0.287	−0.193	−0.183	0.451
lagdp	9.144	8.864	0.000	9.144	9.139	0.479
indus	0.389	0.358	0.000	0.389	0.395	0.296

Note: All the variables listed in the table pertain to the pre-treatment period.

This indicates that the two groups are balanced and our matching procedure performs quite well.

4.2 The baseline DID estimation

Table 4 presents the basic regression results. We find that there is little evidence that local environmental legislation helps abate the pollutant emissions, since the estimated coefficients of the variable of interest *du*dt* are statistically insignificant. We also take the log value of pollutant emission level as the dependent variable and re-estimate the model. Similarly, we still find no significant negative effect of legislation. Our results indicate that the effect of environmental legislation turns out to be inconsequential. For the provinces in the control group, which do not adopt legislation, their emission intensities decline much the same as the treatment group. Take industrial sewage emission for an example: the emission per GDP one year before legislation in the control province was 37.5 ton/thousand yuan, which dropped by 27.4 per cent to 27.2 ton/thousand yuan after legislation. At the same time, for the control province, the indicator also went down by 27.3 per cent. As for the control variables, the increase in GDP per capita and investment in pollution governance both help reduce the pollutant emissions. These results are consistent with previous studies (Copeland and Taylor, 2003; Bao *et al.*, 2011). For example, higher GDP per capita implies a more advanced phase of economic development in which more negative marginal utility would be brought about by pollutant emissions.

As the baseline estimation results find no evidence of the causal effect of environmental legislation, we try to use different matching criteria as our robustness exercises. Firstly, as our nearest neighbor matching uses some untreated provinces as a matched comparison group more than once, we consider a new matching without replacement. In other words, each individual untreated province will be used only once for a certain year. Secondly, as our nearest neighbor matching only uses one untreated group for each treated province, we also consider using more than one comparison province in our matching analysis. Specifically, we allow for two untreated provinces as the comparison groups for each treated case. Additionally, we adopt kernel matching, which uses the weighted averages of many untreated provinces – depending on the choice of the kernel function – as our comparison groups. It shows that all the above robustness checks fail to support the regulation effect of local legislation, which confirms our main finding in the baseline DID regression.

We also try to add another matching criterion that provinces in the control group have to be in close proximity to the treatment province to control for the geographical impact. Specifically, we divide all 31 provinces into three big regions: Coastal, Central

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Table 4. The baseline DID estimation results

	ln*P*	ln*P*	ln*P*′	ln*P*′
du	−0.198 (0.541)	−0.071 (0.602)	0.169 (0.557)	0.085 (0.589)
dt	−0.227* (0.129)	0.066 (0.237)	0.039 (0.127)	0.461 (0.612)
du*dt	**0.113** (**0.183**)	**0.271** (**0.167**)	**0.137** (**0.179**)	**0.291** (**0.783**)
agdp		−1.974*** (0.696)		−2.317** (0.896)
invsh		−0.042* (0.025)		−0.042* (0.023)
rensh		1.676** (0.757)		1.342* (0.649)
region	No	Yes	No	Yes
year	No	Yes	No	Yes
*region*year*	No	Yes	No	Yes
N	424	408	424	408
adj. R^2	0.039	0.223	0.038	0.246

Notes: Robust standard errors in parentheses. Significant at *10%, **5% and ***1%.

and Western. Hence, we only use those provinces which are located in the same region as the treated one as the comparison group. As remarkable regional disparity exists among different regions in China in terms of economic growth and pollution emissions as well as environmental regulation; such selection criteria can exclude the effect of geographic location. Again, the new estimation result does not support that local environmental law helps to reduce pollution emissions. Finally, the key assumption of using the DID method is the common trend of the treatment and control groups before the environmental legislation was issued. We follow Autor (2003) to test the common trend assumption by constructing two dummies: *before* is defined as 1 for $du = 1$ and $dt = 0$, and otherwise zero; *after* is 1 for $du = 1$ and $dt = 1$, and otherwise zero. Thus, we have the following estimation model:

$$\ln P = c + \alpha_0 * dt + \alpha_1 * \text{before} + \alpha_2 * \text{after} + \text{CV} + \varepsilon,$$

where the coefficient α_1 measures the difference between the treated groups and the control groups before the environmental legislation was issued, and α_2 measures the difference between the two groups after legislation. The new estimation result is reported in table 5. It indicates that α_1 fails to show statistical significance, which implies that there is no significant difference between the treated groups and the controls before the passing of legislation.

4.3 Is there a time lag effect of legislation?

The enforcement of policies usually takes time. The lag of their functioning may be one of the reasons that cloud our assessment of their effectiveness. In our case of environmental legislation, when firms wonder whether local government may envisage more

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Table 5. Common trend test of the treated groups and the control groups

	ln*P*	ln*P*′
dt	0.064 (0.234)	0.458* (0.265)
before	−0.049 (0.589)	0.082 (0.615)
after	0.210 (0.586)	0.375 (0.628)
CV	yes	yes
N	408	408
adj. R^2	0.198	0.144

Notes: Robust standard errors in parentheses. Significant at *10%. CV stands for the control variables including GDP per capita, investment in pollution governance, the share of environmental protection staff, and province dummies as well as year dummies.

Table 6. The lag impact of environmental legislation

	ln*P*	ln*P*	ln*P*′	ln*P*′
du	−0.367 (0.548)	−0.116 (0.585)	0.238 (0.561)	0.419 (0.624)
dt	−0.357** (0.175)	0.088 (0.317)	0.003 (0.177)	0.652* (0.369)
du*dt	−**0.168** (**0.252**)	−**0.115** (**0.199**)	−**0.122** (**0.247**)	−**0.058** (**0.197**)
CV	no	Yes	no	yes
N	418	401	418	401
adj. R^2	0.036	0.275	0.030	0.212

Notes: Robust standard errors in parentheses. Significant at *10% and **5%. CV stands for the control variables including GDP per capita, investment in pollution governance, the share of environmental protection staff, and province dummies as well as year dummies.

demanding environmental regulation to ameliorate environmental quality, they would take time to adjust their production blueprints and technologies accordingly. In this way, we investigate the pollutant emissions two years after legislation instead of only one year. The results in table 6 show that while the coefficient of the interaction term *dudt* now turns out to be negative, it fails to show statistical significance. We also estimate the lag effect using the level of pollution emissions as the dependent variable, and the results remain the same. Therefore, we have not found evidence of significant regulation effect of local legislation even though we take the time lag effect into account.

4.4 The emissions of different pollutants

We also wonder whether the regulation effects may vary for different pollutants: industrial dust, sulfur dioxide, dust and solid waste. For example, it is natural to expect that the legislation regulation effect may be more significant for a pollutant which is easily monitored and regulated. In this sense, we will separately study how their emissions would be affected. Table 7 presents the estimated DID results of different pollutants. Though

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Table 7. The estimation results of different pollutants

	Industrial sewage	Sulfur dioxide	Dust	Solid waste
du	−0.005 (0.091)	0.078 (0.152)	−0.031 (0.138)	1.218** (0.516)
dt	−0.186 (0.105)	−0.054 (0.098)	0.234 (0.226)	−1.125* (0.596)
du*dt	**0.072** (**0.121**)	−**0.061** (**0.068**)	−**0.046** (**0.057**)	**0.591** (**0.785**)
CV	yes	yes	yes	yes
N	182	90	90	46
adj. R^2	0.772	0.692	0.783	0.855

Notes: Robust standard errors in parentheses. Significant at *10% and **5%.

the estimated coefficients of *du*dt* vary with the pollutant form, none of them are statistically significant nonetheless. Such results imply that the environmental legislation still does not work, even if we consider the different forms of pollution emission.

4.5 Environmental legislation versus policy acts

On top of legislation approved by legislative authorities, environmental regulation also includes a quantity of policy acts promulgated by governments at all levels. Particular attention should be given to the joint impact of legislation and policy act regulations, as our findings may be challenged if we incorrectly exclude the regulation effect of policy acts. For example, if we choose a province without legislation but which passed some policy regulation papers as the comparison group, it inevitably causes a biased result since such a province is not actually untreated in this case. Furthermore, it would be interesting to compare the effectiveness of local legislation and administrative regulation. We wonder whether these regulations promulgated by administrative authorities would have better regulatory impacts or be implemented more forcefully, especially considering the important role administrative authorities and regulations play in a transitional economy. Besides, if one province in the treatment group passed local legislation and administrative regulations simultaneously, we may expect that the impact of pollution regulation would be significant in this case.

We follow the same principles when collecting administrative policy regulations at the provincial level as we do for legislation. Firstly, the policy regulation must concern only one certain type of pollutant. It excludes the general regulations on environmental protection and technical standards. Secondly, the regulatory effects of such administrative regulation must be measurable. We sort 51 qualified pieces out of the total provincial 95 policy acts between 1994 and 2008, and estimate the regression model below:

$$\ln(P_{it}) = \beta_0 + \beta_1.du + \beta_2.dz + \beta_3.duz + \beta_4.dt + \gamma_1.du \times dt + \gamma_2.dz \times dt + \gamma_3.duz \times dt + \varphi.CV_{it} + \varepsilon_{it}.$$

A province that has ever passed environmental regulation policy is denoted $dz = 1$ while the year in which the regulation policy is passed is denoted $dt = 1$. *duz* denotes the case in which one pollutant is targeted both by local legislation and administrative regulations in the same year. For instance, the municipality of Tianjin passed both local

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Table 8. The joint impact of local legislation and administrative regulations

	One year later		Two years later	
	ln*P*	ln*P′*	ln*P*	ln*P′*
du	−0.135 (0.331)	−0.051 (0.296)	−0.147 (0.332)	−0.066 (0.305)
dz	−0.648 (0.669)	−0.743 (0.539)	−0.636 (0.664)	−0.736 (0.534)
duz	4.775*** (0.652)	4.661*** (0.515)	4.796*** (0.661)	4.692*** (0.534)
dt	−0.289*** (0.072)	0.054 (0.099)	−0.405*** (0.106)	0.087 (0.103)
*du**dt*	−0.001 (0.132)	0.033 (0.187)	−0.014 (0.182)	0.036 (0.189)
*dz**dt*	−0.083 (0.165)	−0.072 (0.166)	0.262 (0.378)	0.225 (0.247)
*duz**dt*	0.268 (0.183)	0.181 (0.149)	0.278 (0.363)	0.152 (0.262)
CV	Yes	Yes	Yes	Yes
N	664	664	668	668
adj. R^2	0.295	0.248	0.217	0.255

Notes: Robust standard errors in parentheses. Significant at ***1%.

legislation and regulations concerning water pollution and protection of water resources in 2002. γ_1 and γ_2 measure the actual impacts of local legislation and administrative regulation respectively, while γ_3 their joint impact.

The results are given in table 8. Environmental legislation and administrative regulation remain insignificant as does their combination. In other words, even if both legislative and administrative authorities take their own regulatory measures, they just do not succeed in getting pollutant emissions down as they are supposed to do. It should be noted that the estimated coefficient of *duz* is positive and it is also significant. In fact, *duz* indicates the pollutant emissions at the very beginning before any regulatory measure is taken. The negative coefficient therefore tells us that provinces which passed legislation and administrative regulations at the same time suffer from heavier environmental pollution and they were more motivated to impose strict regulation on pollutant emissions.

4.6 Does environmental quality matter?

We wonder whether the legislative consequences should be heterogeneous, and especially whether they should be subject to the current environmental quality and pollution level.[3] It is not surprising to expect that the regulation effect of local legislation would be more significant among provinces with worsening environmental quality. For example,

[3] For example, Cole *et al.* (2005) highlight marked differences across industries when assessing the impact of environmental legislation in Britain. They also find that legislative consequence is closely related to the size, productivity, R&D and other features of an industry.

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for provinces having passed legislation, local inhabitants in those with severe pollution and deterioration of environmental quality tend to impose more pressure on environmental protection agencies to preserve their living space, while the latter are inclined to take demanding regulatory measures. Hence, we want to further know whether the regulation effect of local legislation closely depends on the local environmental condition.

We use the officially-reported incidence of environmental accidents to indicate the quality of local environment, specifically the ratio of the number of environmental accidents to the number of companies. A higher ratio implies that potential pollution or environmental degradation is more serious in this area, obliging local environmental protection agencies or legislative authorities to take rigid measures. We calculate the average number of environmental accidents for provinces, and divide the treated group into two types: severely-polluted areas ($dh = 1$) and mildly-polluted areas ($dl = 1$). To examine the heterogeneous effect of environmental legislation, we now consider the following regression model:

$$\ln(P_{it}) = \beta_0 + \beta_1.dh + \beta_2.dl + \beta_3.dt + \gamma_1.dh \times dt + \gamma_2.dl \times dt + \varphi.CV_{it} + \varepsilon_{it},$$

where γ_1 and γ_2 measure the actual impact of legislation in severe pollution areas and mild pollution areas respectively. Table 9 presents the estimation results of the two subsamples one year and two years after legislation. Our expectation turns out to be true that the legislative consequence of local environmental protection is indeed closely related to local environmental quality. In the mild pollution sample, we again find no evidence of the effectiveness of environmental legislation. The estimated coefficients of *dldt* are always insignificantly positive in all cases, indicating that local legislation does not achieve the desired effect in these areas. In contrast, in severe pollution areas, pollutant emissions saw a marked decline two years after legislation though the effect in the first year is inconsequential. For instance, the estimated coefficient of *dhdt* is −0.173, implying that local pollutant emission intensity dropped by 17.3 per cent two years after legislation compared to the provinces that did not pass legislation. It is also true for the absolute values of pollutant emissions which went down by 19.7 per cent on average two years after legislation.

We also use the local pollutant emission level one year before legislation to conduct a robustness check. Specifically, we divide our samples into the same two types according to local pollutant emissions one year before legislation: severe pollution areas and mild pollution areas. We identify provinces with actual emissions higher than the average value as severe pollution areas ($dh = 1$), and we identify provinces with below-average pollutant emissions as mild pollution areas ($dl = 1$). Table 9 shows the estimation results. Similarly, the impact one year after legislation is not significant, but another year later, provinces with a high incidence of environmental accidents do see the legislative impact. Both the emission intensity and emission level went down. However, it did not occur in provinces with a low incidence.

4.7 The importance of enforcement of environmental legislation

It is well-known that the effectiveness of environmental legislation is jointly determined by the adoption of legislative texts and stringent enforcement. As our study only focuses on the passing of environmental legislation, we worry that the regulation effect of local

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Table 9. Does local environmental quality matter?

	Incidence of environmental accidents				Severe versus mild pollution areas			
	One year later		Two years later		One year later		Two years later	
	ln*P*	ln*P*′	ln*P*	ln*P*′	ln*P*	ln*P*′	ln*P*	ln*P*′
dh	−0.194 (0.337)	−0.162 (0.383)	−0.157 (0.192)	−0.124 (0.457)	0.162 (0.183)	0.479 (0.348)	0.388*** (0.002)	0.546*** (0.006)
dl	0.947 (0.753)	0.891 (0.648)	0.914 (0.351)	0.859 (0.625)	−0.252 (0.297)	−0.306 (0.308)	−0.833* (0.122)	−0.749 (0.142)
dt	0.614* (0.262)	1.098** (0.308)	0.887 (0.520)	1.564* (0.519)	0.075 (0.114)	0.459** (0.124)	−0.006 (0.083)	0.551 (0.102)
*dh***dt*	−0.079 (0.078)	−0.110 (0.106)	**−0.175**** (**0.012**)	**−0.197*** (**0.082**)	−0.058 (0.103)	−0.044 (0.093)	**−0.259*** (**0.024**)	**−0.188**** (**0.013**)
*dl***dt*	0.067 (0.065)	0.125 (0.098)	0.119 (0.022)	0.185 (0.097)	0.522 (0.359)	0.555 (0.363)	0.564 (0.267)	0.649 (0.293)
CV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	406	406	402	402	358	358	352	352
adj. R^2	0.299	0.247	0.272	0.311	0.232	0.289	0.328	0.267

Notes: Robust standard errors in parentheses. Significant at *10%, **5% and ***1%. CV stands for the control variables including GDP per capita, investment in pollution governance, the share of environmental protection staff, and province dummies as well as year dummies.

legislation will be insignificant if the environmental laws have not been strictly enforced in practice after they are passed. Additionally, the legislation enforcement in China is particularly problematic, as many studies point out that incomplete enforcement of written environmental legislation prevails in China (Wang *et al.*, 2003; Wang and Jin, 2007; Lin, 2013). For example, the pollution penalties in China are so low in many cases that it is cheaper for firms to violate environmental laws than install pollution-reducing equipment. Furthermore, Chinese firms usually have strong bargaining power relative to the local environmental protection agencies, which leads to the incomplete enforcement of environmental legislation in many areas (Wang *et al.*, 2003).

The common approaches to law enforcement by environmental protection administrative authorities include administrative inspection and supervision, administrative licensing and approval, administrative penalties and so on. Based on the data availability, the main consideration in the choice of indicators of local law enforcement in this paper is administrative punishment practices by environmental protection authorities. Fines are collected by the local environmental administrative agencies from those plants and individuals who break environmental protection laws. It is worth mentioning that the local environmental administrative agencies in China are very flexible in collecting the pollution fines in practice, so the amount of penalties directly measure the monitoring efforts the local environmental administrative agencies have taken.

Therefore, we select the total fines of environmental administrative penalties as the environmental legislation enforcement indicator, and we use the ratio of the total fines of environmental administrative penalties to the number of firms to measure the strength of enforcement. Specifically, we first calculate the average amount of fines one year before legislation was passed, and divide the treated groups into two parts: those with fines higher than the median value are set $dm = 1$, indicating stringent environmental law enforcement, and those with fines less than the median are set $dm = 0$, indicating

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that environmental legislation is weakly enforced. The median amount of administrative fines in provinces with stringent enforcement (3,380 yuan per firm) is about a hundred times more than that in provinces with loose enforcement (30 yuan per firm), which shows that the enforcement of environmental laws does significantly vary among different provinces. The passing of environmental laws brought about variations in three dimensions: years before and after the legislation; legislation provinces and non-legislation ones; provinces with stringent enforcement of environmental laws and those with loose enforcement. These variations allow us to conduct the empirical analysis in a DDD framework:

$$\ln(P_{it}) = \beta_0 + \beta_1.du + \beta_2.dm + \beta_3.dt + \gamma_1.du \times dt + \gamma_2.dm \times dt + \gamma_3.du \times dm + \mu.du \times dm \times dt + \varphi.CV_{it} + \varepsilon_{it}.$$

From this estimation design we can see that the actual impact of environmental legislation remains γ_1 for provinces with loose enforcement, while the impact for provinces with stringent enforcement turns out to be $\gamma_1 + \mu$. μ is therefore the variable of our interest and it indicates the joint impact of environmental legislation and law enforcement. Table 10 shows the estimation results. In line with our expectations, the estimation results indicate that local law enforcement does have a key influence on legislative effect. Strict enforcement of environmental legislation brings about a better result of pollution regulation. The estimated coefficient of μ is -1.751 after controlling for economic development and other factors, which means that compared to the provinces with weaker law enforcement, stringent penalties show a pollutant emission decline of 175 per cent. Another striking fact is that even after the local environmental legislation is passed, we may fail to achieve the desired effect or even receive a negative regulation effect if the enforcement is weak. To our surprise, γ_1 is significantly positive, indicating that pollutant emissions have actually increased in these provinces with the adoption of legislation, compared to the provinces without legislation. This result suggests that the mere legislative texts have quite limited effect. When heavily polluting firms notice that local environmental legislation has been passed, they will probably expand their production of pollution-intensive products as a reasonable response to this policy change if they know their pollution behavior will not be effectively punished. As a result, it unexpectedly leads to a rise in pollutant emissions after legislation instead.

We also take several other estimations as our robustness checks. Firstly, we tried to use other pollution indicators: the log value of the pollutant emission ($\ln P'$) and the log value of the pollutant emission per capita ($\ln P''$). The corresponding estimation results are shown in table 10. The results again confirm the importance of law enforcement. Strict enforcement guarantees that pollution emissions are suppressed after legislation. Conversely, if the law enforcement is not stringent enough, environmental legislation alone fails to achieve the desired results. Secondly, we also want to know whether enforcement still matters even two years after the passing of legislation. It shows that the same conclusion still remains valid even allowing for the time lag effect of legislation.

To sum up, we found that environmental enforcement plays a vital role in preserving local environmental quality and lowering pollutant emissions. In those provinces where environmental legislation is strictly enforced, they are able to achieve significant environmental improvement. The emission intensity, the absolute value of pollutant emissions and emissions per capita will all go down significantly. Conversely, the desired effects cannot be achieved by environmental legislation alone. To serve the purpose of environmental regulation, legislation and enforcement are indispensable.

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Table 10. The importance of law enforcement

	One year later			Two years later		
	ln$P$	lnP'	lnP''	ln$P$	lnP'	lnP''
du	−0.203 (0.796)	0.017 (0.798)	−0.351 (0.812)	−0.093 (0.838)	0.122 (0.854)	−0.258 (0.838)
dm	−0.625 (0.604)	−0.642 (0.668)	−0.517 (0.635)	−0.555 (0.646)	−0.582 (0.723)	−0.518 (0.699)
dt	−0.617 (0.544)	−0.242 (0.571)	−0.299 (0.437)	−0.718 (0.677)	−0.155 (0.678)	−0.262 (0.554)
*du*dt*	**1.001*** (**0.570**)	**1.086*** (**0.571**)	**1.133*** (**0.614**)	0.502 (0.347)	0.587 (0.358)	0.641 (0.405)
*du*dm*	1.963 (1.288)	1.866 (1.303)	2.047 (1.236)	1.893 (1.324)	1.811 (1.359)	1.975 (1.257)
*dt*dm*	0.703 (0.588)	0.658 (0.594)	0.694 (0.587)	0.645 (0.517)	0.573 (0.544)	0.761 (0.606)
du*dm*dt	**−1.751**** (**0.784**)	**−1.742**** (**0.760**)	**−1.832**** (**0.856**)	**−1.451**** (**0.634**)	**−1.429**** (**0.636**)	**−1.545**** (**0.724**)
CV	Yes	Yes	Yes	Yes	Yes	Yes
N	328	328	328	328	328	328
adj. R^2	0.227	0.263	0.249	0.205	0.236	0.228

Notes: Robust standard errors in parentheses. Significant at *10% and **5%. CV stands for the control variables including GDP per capita, investment in pollution governance, the share of environmental protection staff, and province dummies as well as year dummies.

4.8 Synthetic control method analysis

We also employ the synthetic control method as our robustness check. The main idea of the synthetic control method, developed by Abadie and Gardeazabal (2003) and Abadie *et al.* (2010), is to construct a synthetic match for each treated unit by using the comparison provinces in such a way that the synthetic group has a similar behavior to the actual treated province before the event of passing an environmental law. Hence the treatment effect of the event can be measured as a function of the difference between the pollution emission behavior of the treated province and its synthetic match after the passing of a law. As Abadie *et al.* (2010) emphasize in their study, the advantage of the synthetic match method is to control for the effect of unobservable factors that have an impact on the common time trend in the treatment and control groups.

Following Abadie and Gardeazabal's (2003) suggestions, we first use the same matching variables such as pollution emissions per GDP one year before legislation and GDP per capita one year before legislation to construct the synthetic matching unit for our treated provinces. Then we use the synthetic match groups to re-estimate our model, and the results are shown in table 11. The total sample estimation result indicates that there is no significant causal effect of legislative regulation even using the synthetic units as the control groups. However, we do find that environmental legislation helps to reduce pollution emissions among those provinces with stringent enforcement, and has little effect on pollution emissions for others whose environmental laws have not been strictly enforced, which are consistent with our DDD estimation results in table 10.

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Table 11. Estimation results using the synthetic match method

	Total	Samples with stringent enforcement	Samples with loose enforcement
du	−0.121* (0.064)	0.207*** (0.069)	−0.203*** (0.074)
dt	−1.697*** (0.055)	−1.654*** (0.056)	−1.648*** (0.054)
du*dt	−0.093 (0.088)	−0.188* (0.109)	−0.084 (0.102)
N	4,360	2,940	3,600
adj. R^2	0.899	0.924	0.901

Notes: Robust standard errors in parentheses. Significant at *10% and ***1%.

5. Conclusion

This paper collected 84 pieces of local environmental legislation from each province in China since the 1990s and empirically evaluated the causal effect of these local environmental laws. Our main conclusions are as follows.

Firstly, we found little evidence to show that local environmental legislation can effectively improve environment quality. The emission intensity in the treatment groups has declined indeed since legislation, but we cannot simply attribute it to legislation since the matched comparison group has seen a similar trend. In this sense, we conclude that the passing of the local environmental law does not significantly cause the local pollution emissions to decline. This result still holds even when we allowed for the various forms of pollutants, the time lag effect of legislation enforcement and the regulation effect of environmental policy acts. However, we found that local environmental legislation, to a certain extent, can improve the environmental quality in relatively heavily-polluted provinces indeed.

In stark contrast to the above conclusions, this study reveals the vital role of law enforcement. By identifying provinces with different enforcement strength, based on fines and penalties imposed by local enforcement agencies of environmental law, we found that in provinces where enforcement is strict, local environmental legislation has significantly curbed pollutant emissions in terms of the absolute value and emission intensity. This implies that the legislative texts alone are far from enough, and they have to be complemented with vigorous enforcement to guarantee the effectiveness.

While our study focuses on China's environmental legislation, our research has a policy implication in the global context, especially for developing economies. Environmental pollution has become a major concern in many developing countries such as China, with far-reaching adverse effects on public health and economic development. As the famous environmental Kuznets curve hypothesis states, while most developing economies are still in their early stage of economic development, economic take-off is usually achieved at the cost of deterioration of environmental quality. To achieve its rapid economic growth, China has followed the development model of 'pollute first, clean up later' (Azadi *et al*., 2011), which indicates the government's lax environmental regulation in favor of economic growth at first, and then strong pollution regulation for environmental protection after the economic take-off.

Additionally, many developing countries have the same implementation and enforcement problem as China has regarding effective environmental regulation. Therefore, China provides a useful example to understand why regulatory enforcement is so weak

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in developing countries. It is not rare to see that local environmental protection authorities usually take different efforts to implement the regulation standards imposed by the central government in developing countries. Meanwhile, local firms usually have strong bargaining power relative to the local environmental protection agencies, which leads to the fact that environmental legislation at large cannot be completely enforced. As Wang and Wheeler (2000) point out, in the formal regulatory system, the pollution levy should be based on standards which are supposed to be applied uniformly across China. However, the authors find that actual levy collections are sensitive to differences in economic development and environmental quality across different regions. As such an 'endogenous enforcement' pattern is quite pervasive in developing countries (Hettige *et al*., 1996; Pargal and Wheeler, 1996), our paper further reveals how law enforcement matters in terms of effective environmental regulation.

A comprehensive understanding of the relationship between environmental regulations and economic growth is essential for policy design and decision-making among developing economies. Greenstone and Jack (2015) have comprehensively analyzed the reasons why environmental quality in many developing countries is so poor and generates substantial health and productivity costs. They emphasize that, compared with developed countries, market failures such as weak property rights distort marginal willingness to pay for environmental quality and political economy factors undermine efficient policymaking among developing countries. It is not surprising to see that the cost of environmental improvements is usually higher due to weak policy design, implementation and enforcement in developing countries. If policymakers lack the means to collect tax revenue efficiently, then the very process of collecting revenue for environmental quality investments may be costly. In this sense, China is not the only case of a country which has achieved economic growth at the cost of environmental quality deterioration. Given the fact that the enforcement of laws is still quite problematic for such large, developing transitional economies like China, greater efforts should be taken to strictly enforce the laws after the legislative agency has passed them.

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