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RESEARCH ARTICLE

From race-to-the-bottom to strategic imitation: how does political competition impact the environmental enforcement of local governments in China?

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Abstract

In China, national environmental regulations have customarily found themselves to be inhibited by local government's ostensible obedience. This research investigates how local officials, motivated and constrained by political competition, dedicate themselves to the environment and interact with each other regarding environmental regulation implementation and actual regulatory performance. Based on a spatial econometric model using data from 30 provinces from 2000 to 2016, the empirical results document the spatial dependence of environmental regulatory enforcement among provinces of similar economic levels and reveal that since 2007, there has been a performance-oriented peer competition for SO_2 emission reduction but no similar competition for CO_2 emission reduction. The findings indicate a transformation of the regulatory behavior of local governments from a race-to-the-bottom to strategic imitation and provide institutional insight into the spatial attributes of environmental enforcement under the impact of the political regime in China.

Keywords Political competition · Environmental enforcement · Race-to-the-bottom · Strategic imitation

Introduction

In recent years, the unprecedented and increasing national haze events have aroused widespread public concern and drawn considerable attention from the executive authority in China. Civilians' apprehension about the health impacts of air pollution has provoked further skepticism towards the government's governance capacity, especially in a regime that actually relies on governance performance as the source of political legitimacy (Holbig and Gilley 2010; Yang and Zhao 2015; Zhao 2009; Zhu 2011). In addition, the authorities have been anxious about the empirical evidence of the negative impacts of air pollution on urbanization (Qin and Zhu 2018; Zhang et al. 2017).

It appears essential for China to rebuild its eco-friendly image to accomplish its aspiration of being a responsible country. China is determined to reverse the deterioration of air quality and has regarded it as the main indicator of public service performance since 2012 (Lv et al. 2017; Wang and Shen 2016; Wenbo and Yan 2018). Moreover, China officially promised that carbon emissions would be reduced by 40–45% in 2020 compared to 2006 and proposed its ambition of building "Beautiful China." To this end, the central government has launched a plethora of ambitious environmental regulations (ERs) and emission reduction policies.

However, there exist substantial suspicions about the actual effects of these national regulations and policies, in view of the historical experience of incomplete environmental regulatory enforcement and policy failure (Kostka and Mol 2013; Ran 2013; van Rooij et al. 2017; Wenbo and Yan 2018). Blame for this has typically been ascribed to the peculiar institutional arrangement in China, which is characterized by a combination of political centralization and economic regional decentralization (see, Blanchard and Shleifer 2001; Jin et al. 2005; Xu 2011). This system not only gives China's central authority substantial control over local governors through a top-down pattern of official promotion, thereby inducing subnational governments to compete with their peers in fulfilling

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the indicators appointed for assessing local officials, but also empowers subnational governments with some degree of local autonomy in economic development, regional governance, and policy making and enforcement, which provides local officials with modest discretion regarding development preference (e.g., either economically focused or environmentally concerned) and national regulatory enforcement (Kostka and Nahm 2017; Li and Zhou 2005; Yang and Zhao 2015). In order to bolster economic development and maintain political legitimacy, the Chinese central authority has appointed growth-oriented indicators for evaluating and promoting local officials since the economic reform (Li and Zhou 2005). Accordingly, local officials have presented an overwhelming preference for economic growth in order to increase their chances of promotion (Jin et al. 2005), even at the cost of loosening ER stringency and damaging regional ecological sustainability. Among others, Cai et al. (2016), Caldeira (2012), Zhang and Fu (2008), and Zhang (2016) have documented that there has appeared a kind of race-to-the-bottom interaction in environmental enforcement among Chinese local jurisdictions, which is typically ascribed to growth-oriented promotion competition.

Practical ecological transformation of political competition occurred in 2007, when the Chinese central authority began to include emission reduction performance as an important part of the promotion assessment system for local officials. According to this system, local officials may not be rewarded if they surpass reduction objectives, while they will definitely be punished if they fail to meet the appointed ecological indicators (Zhang 2016). Since then, local officials have had to give consideration to environmental enforcement in their growth-oriented yardstick competition in order to avoid any negativity bias in the higher authority's preferences (Hansen et al. 2015). Especially for jurisdictions of similar economic levels, among which there is stronger promotion competition (Yu et al. 2016), this has led to higher inter-jurisdictional imitation effects on environmental enforcement. In other words, the political competition has initiated an economic distance-weighted autocorrelation among Chinese jurisdictions, which is out of the scope of traditional geographical spatial models. However, as Song et al. (2018) have noted, research on the spatial interactions of local regulatory behavior in China remains rare, especially institutional studies focusing on spatial spillover effects of environmental enforcement among local Chinese governments based on economic-weighted spatial matrices (Yu et al. 2016).

This research empirically investigates the strategic interaction of environmental enforcement among local governments under the institutional impacts of political competition, Chinese style. Based on a spatial econometric model using data from 30 provinces from 2000 to 2016, empirical results demonstrate that local governments strategically implement national ERs and selectively pursue regulatory performance. Specifically, provincial officials exhibit performance-oriented regulatory competition targeting the indicators that are included in the officials' promotion assessment system by the central authority; that is, the officials follow a strategic imitation of environmental enforcement under the peculiar political regime of China. To the best of our knowledge, this is the first study to empirically investigate the environmental impacts of political competition and provide an institutional perspective in interpreting the spatial attributes of environmental enforcement in China.

The remainder of this article is organized as follows. The next section presents the literature and hypothesis development. Section 3 introduces the research design, including the spatial econometric model, variables, and data utilized in this study. The empirical results and an analysis of the hypotheses appear in the fourth section. Finally, Section 5 concludes the research and proposes relevant policy implications.

Literature and hypothesis development

Political competition among China's subnational governments

Chinese economic development is led by the central authority; however, subnational governments also play a prominent role in the process (Jin et al. 2005; Li and Zhou 2005). China is different not only from federalist regimes whose local governments are elected and fully represent and are accountable for their regional constituents, but also from centralized nations where local governments constantly attach themselves to the central government (Blanchard and Shleifer 2001; Xu 2011). There are two main reasons why local Chinese governments act so differently.

One of the reasons is that fiscal decentralization reform, including various forms of fiscal subcontracting systems, has been promoted and driven by the central government since 1978. By guaranteeing local governments more fiscal autonomy and increasing the finances at their disposal, the fiscal decentralization system effectively activates local government initiatives to try out reforms and promote regional growth (Jin et al. 2005; Xu 2011; Yu et al. 2016). It is noteworthy that a fiscal recentralization process appeared in China after 1994; this process was named "predatory fiscal federalism" by Shen et al. (2012) because the central government reinforced its fiscal influence by capturing core taxes and establishing central tax administration. Since then, local governments have received less financial income while taking on more expenditure responsibilities (Jin et al. 2005; Kostka and Nahm 2017). Consequently, with limited fiscal resources, local officials are more cautious in allocating public resources and only partially take on responsibility for providing services, which affects expenditure on pollution control and emissions abatement (Deng et al. 2012; Liu and Li 2019).

Though Russia and many other transitional countries have also undertaken a reform of fiscal decentralization, they have not achieved economic accomplishments as great as those China once did. Blanchard and Shleifer (2001) and Jin et al. (2005) boiled this discrepancy down to the absence of power in the central government, which was neither strong enough to set clear rules about the sharing of the proceeds of growth nor powerful enough to root out the rent-seeking behavior (the "grabbing hand") of local officials (Krueger 1974; Jin et al. 2005; Li and Zhou 2005). By contrast, the Chinese central government has been disciplined and powerful enough to impose its views and induce local officials to favor growth (Blanchard and Shleifer 2001; Li and Zhou 2005; Zhou 2007), which is the other explanation for the peculiar central-local relations in China and distinguishes Chinese decentralized reforms from others (Jin et al. 2005; Liu and Li 2019; Shen et al. 2012).

Learning from the past, the central committee of the Chinese Communist Party (CCP) has established an absolute personnel control system over the promotion and dismissal of local officials (Li and Zhou 2005) and created a promotion-targeted yardstick competition among subnational governments in China, which is widely known as the Official Promotion Tournament (OPT) based on the measurable indicators set by the central government (Zhou 2007; Li and Zhou 2005). The Chinese central authority initially set economic upturn as the primary objective and has selected economic-focused indicators to evaluate and promote local officials since its national reform and opening agenda (Landry et al. 2017; Liu and Li 2019; Li and Zhou 2005; Yang and Zhao 2015). Highly motivated by the growth-oriented OPT, local officials have maintained an overwhelming preference for better economic performance in order to increase the likelihood of promotion (Jin et al. 2005; Zhou 2007), and have referred to other jurisdictions of similar economic levels in their policy making to avoid any negativity bias in the higher authority's preferences (Hansen et al. 2015). In other words, the closer the economy levels of local governments, the stronger the promotion competition among those governments' executive officials will be (Yu et al. 2016; Zhou 2007).

Local governments' strategic enforcement of environmental regulation

Recognizing the significance and urgency of addressing environmental issues, the Chinese central government has adopted continuously strengthened ERs, from command and control regulations to market-based regulations, to achieve a comprehensive, coordinated, and sustainable method of development in the last two decades (Xie et al. 2017; Zhao et al. 2015; Ren et al. 2018). In terms of emission reduction, three major regulations are vertically enforced from central to local government, namely, the "Three Synchronizations Policy," "Environment Impact Assessment," and "Pollution Charge."[1]

Nevertheless, these national regulations and policies have been inadequately and strategically implemented by local Chinese governments. In order to achieve better economic growth performance and to seek a higher rank in the OPT, local executive leaders take full advantage of the policy instruments to attract the limited mobile capital (e.g., foreign investment), including tax allowances and exemptions, expenditure competition, and regulation stringency competition (Renard and Xiong 2012; Revelli 2005; Brueckner 2003). Environmental regulation, acting as one typical kind of policy instrument that raises the socio-economic costs of foreign investment, is doubtlessly utilized in the yardstick competition between local governments (Dean et al. 2009; Zhang and Fu 2008). Furthermore, China's environmental regulations are generally made and prompted by the central government but implemented by local governments (Deng et al. 2012; Zhang 2016). Granted with a modest latitude of administrative discretion in regional development and governance, local officials can autonomously implement national ERs based on their personal preferences between economic growth and environmental concern,[2] on the condition that no serious environmental emergency happens during this process (Kostka and Mol 2013). In general, local officials will strategically tailor their enforcement of ERs to balance and align their regulatory performance with other competitors in the OPT (Kostka and Mol 2013), especially provinces of similar economic levels, among which there is strong political competition. In such a way, they would neither suffer notably more economic damage than their competitors when increasing environmental regulatory stringency, nor fritter away any potential enhancement of their OPT rank from the loyal implementation of national regulations and policies.

The environmental corollary of local officials' imitation of regulatory enforcement is predetermined by their strategic competing behavior, which ranges from constructive competition that increases environmental standards, to destructive competition that leads to excessively lax ER stringency.

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[1] These are the three initial and most important regulations included in the Environmental Protection Law of China (since 1989). Regulated by the Law on Environment Impact Assessment, new projects are required to evaluate their environmental impact and submit reports for approval before construction. Also, these projects are required to be equipped with approved pollution prevention installations at all stages of the project, from design, to construction, to operation, according to the Three Synchronizations Policy. Additionally, polluters must submit for registration in local authorities and pay a sewage charge according to the Pollution Charge regulation.

[2] It was not until 2016 that the Ministry of Environmental Protection of China launched its reform of the vertical management system for the monitoring, supervision, and law enforcement of environmental protection organizations below the provincial level, which has institutionally prompted the independence of local environmental agencies from their peer administrative agencies. Access at: http://www.gov.cn/zhengce/2016-09/22/content_5110853.htm.

Constructive competition generally takes place in developed contexts where authorities are more likely to set higher environmental regulatory standards to drive out polluters and attract more technology-intensive industries (Vogel 1995; Fredriksson et al. 2004; Konisky 2007). On contrary, destructive competition mostly appears in developing regions where economic growth is prioritized and ER loosening is used as a competitive instrument to attract more foreign investment (Dasgupta et al. 2002; Woods 2006; Dinda 2004). China's miraculous economic development is highly dependent on foreign investments, some of which bring pollution-intensive industries transferred from developed and industrial countries (Dean et al. 2009). It has been documented in the literature that there has appeared a race-to-the-bottom strategic behavior in environmental regulatory stringency and enforcement, which has been regarded as a fact by Zhang (2016), Caldeira (2012), Zhang and Fu (2008), Cai et al. (2016), and others, despite some other opposing arguments[3] (Renard and Xiong 2012; Deng et al. 2012). It is noteworthy that the ecological transformation of the OPT, by assessing administrators partly with environmental performance since 2007, has only modified the objectives of yardstick competition between local officials rather than transcended the tournament's competing pattern. In other words, Chinese local governments as usual refer to their competitors when strategically implementing national ERs. In summary, we propose the following hypothesis:

> H_1: There exists an imitation effect in implementing ERs among local governments of similar economic levels.

The spatial correlation of local governments' regulatory performance

Environmental quality will not necessarily be improved by national ERs. In addition to the conventional arguments using the theory of the "policy implementation gap" (Kostka and Mol 2013; Liu and Diamond 2008; Ran 2013), fiscal limitation comes as another impediment for local governments in their environmental enforcement. Since 1994, maintaining a fiscal balance has been a must for local officials facing unbalanced financial revenue and expenditure responsibilities (Zhang 2016; Li and Zhou 2005; Jin et al. 2005). Local governments have to deliberately allocate public expenditure items and focus their limited fiscal resources on places that yield faster results and more prominent governance performance in order to attract attention from the central government and attain a higher rank in the OPT.

This was exactly the case for the remarkable change in the national ERs in 2007. The national 11th Five-Year Plan for Environmental Protection published by the State Council in 2007 clearly set specific indicators for emission reduction (see Table 1) and the specific mechanism for assessment and accountability. For the first time, it specifically announced that reduction performance would become an important part of the promotion assessment system for local officials. An official promotion veto mechanism was proposed in the national 12th Five-Year Plan for Environmental Protection (2011–2015), according to which local officials maintain their opportunity for promotion only if they meet the appointed reduction objectives, or at least if their reduction performance is not much worse than their peer competitors' (Kostka and Mol 2013). These policies provide energetic motivation for local officials to passionately fulfill environmental objectives and to improve enforcement performance regarding national ERs, referring to their competitors in order to avoid prejudice in the OPT (Wu et al. 2019; Hansen et al. 2015). We therefore presume that there exists a spatial correlation of regulatory performance among local governments of similar economic levels; that is, the strategic imitation of local governments in reducing pollutant emissions may have strong spatial effects (Cai et al. 2016; Wu et al. 2019; Yu et al. 2016; Hao et al. 2016). Given that these competing provinces can be geographically adjacent (for instance, Jiangsu and Zhejiang provinces) or not (for instance, Jiangsu and Guangdong provinces), the assumed spatial correlation in our study is beyond the scope of existing spatial analysis based on geographical and regional divisions, such as the customary east-mid-west division (Lv et al. 2017; Xie et al. 2017; Song et al. 2018; Ren et al. 2018). A more dynamic and comprehensive spatial econometric model should be created to capture and analyze the regional spatial interaction (Anselin 1988; LeSage and Pace 2009; Pinkse and Slade 2010).

It is noteworthy that though China has publicly expressed its concern about carbon emissions on many occasions and officially proposed its ambitious reduction plans, indicators of carbon emissions have not been included in the 11th and 12th Five-Year Plans for Environmental Protection, as shown in Table 1. In other words, the CCP has not taken the reduction of carbon emissions as an assessment indicator for the promotion of local officials during the period spanning the two national plans.[4] Zhao et al. (2015) also found that the ERs launched by the central Chinese government paid little attention to CO_2 emissions compared to other palpable damaging pollutant emissions, even though China has surpassed the USA to become the largest carbon emitter in

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[3] The opposing arguments principally include the race-to-the-top hypothesis and the free-rider problem (Wu et al. 2019; Renard and Xiong 2012; Deng et al. 2012). While it is remarkable that the race-to-the-bottom hypothesis has been abundantly testified to using Chinese evidence (Zhang 2016; Zhang and Fu 2008; Cai et al. 2016), it must be acknowledged that the strategic interaction of environmental enforcement and emissions reduction of various pollutants among local governments, especially for those of similar economic levels, remains underresearched in the current literature.

[4] It was not until 2014 that the first national restraint policy, including a carbon emission index and a responsibility allocation mechanism, was launched by the National Development and Reform Commission, a functional institution that is affiliated with the State Council. Access at: http://www.sdpc.gov.cn/gzdt/201408/t20140815_622318.html.

Table 1 Indicator and its change in the 11th and 12th Five-Year Plans for Environmental Protection

Item	11th Five-Year Plan (2005–2010)[a]			12th Five-Year Plan (2010–2015)[b]		
	Actual value in 2005	Target value in 2010	Increase in 2010 from 2005	Actual value in 2010	Target value in 2015	Increase in 2015 from 2010
Discharge of chemical oxygen demand (COD) (10,000 tons)	1414	1270	− 10%	2551.7	2347.6	− 8%
Emission of sulfur dioxide (SO_2) (10,000 tons)	2549	2295	− 10%	2267.8	2086.4	− 8%
Proportion of water quality worse than grade V in surface water monitored section (%)	26.1	< 22	− 4.1%	17.7	< 15	− 2.7%
Proportion of water quality better than grade III in main water system monitored section (%)	41	> 43	2%	55	> 60	5%
Proportion of air quality equal to or above grade II in prefecture level city (%)	69.4	75	5.6	72	≧ 80	8%
Discharge of ammonia nitrogen (10,000 tons)				264.4	238.0	− 10%
Emission of nitrogen oxide (10,000 tons)				2273.6	2046.2	− 10%

[a] Data source: access at http://www.gov.cn/zhengce/content/2008-03/28/content_4877.htm

[b] Data source: access at http://www.gov.cn/zwgk/2011-12/20/content_2024895.htm

the world (Lv et al. 2017; Yin et al. 2015). One possible explanation is that compared with pollutants such as SO_2 and COD, the health effects of CO_2 emissions are not as instant or visible enough to attract the widespread concern of the public or even to arouse legitimate anxiety in the CCP (Yaguchi et al. 2007). Local governments accordingly loosen the stringency of regional regulations on CO_2 emissions to avoid any potential damage to economic growth and their OPT standing. Instead, local officials focus their limited fiscal resources on SO_2 (and other pollutants such as COD and industrial smoke and dust which are included in the assessment indicator system) emission reduction (Wu et al. 2019) and imitate their peer promotion competitors in reduction performance so as to avoid any prejudice from the higher authority in assessing and prompting officials (Hansen et al. 2015). These arguments about the difference in reduction performance between SO_2 and CO_2 are consistent with the findings of the existing empirical literature (Stern 2002; Shafik 1994; Yaguchi et al. 2007), which reveals fewer incentives for carbon emission reduction than for that of sulfur. Based on this, we hypothesize the following:

> H_2: Since 2007, the imitation effects of ER performance among local governments have emerged more apparent for SO_2 emission reduction than for CO_2 emission reduction.

Research design

Methodology

The well-known Tobler's first law of geography, which states that "everything is related to everything else, but near things are more related to each other" (Tobler 1979), has found sufficient supporting evidence since Tobler's seminal work in 1979. The law proves true for environmental enforcement in China in two ways: the shorter the spatial distance between two provinces, the more characteristics they will share; in addition, the shorter their economic distance, the more spatial political correlation the provinces will exhibit due to the economic performance-based yardstick competition of local officials under the OPT.

Two types of spatial regression model have been generally used to capture universally existing spatial correlations: the spatial error model (SEM) and the spatial lag model (SLM, also known as the spatial autoregressive model). The SEM captures the ubiquitous common characteristics of adjacent jurisdictions, and the SLM reflects the fact that a given region's environmental enforcement is affected by that of other regions (LeSage and Pace 2009). The major difference between the two lies in how the spatial dependence is introduced into the regression equation (Bivand and Piras 2015; Hao et al. 2016).

The SEM is written as Eq. (1):

$$y = X\beta + \varepsilon, \quad \varepsilon = \lambda \boldsymbol{D}\, \varepsilon + \mu$$

The SLM is written as Eq. (2):

$$y = \rho \boldsymbol{E}\, y + X\beta + \nu$$

where λ and ρ are the spatial error coefficient and the spatial regression coefficient, respectively. In our research, for a given province, λ denotes the impact of the residual term of adjacent provinces, and ρ represents the effects of environmental enforcement of other provinces of similar economic levels. β represents the influence of a vector of explanatory variables, X, on the dependent variable, y. $\boldsymbol{D}$ and $\boldsymbol{E}$ are the spatial distance matrix and spatial economic matrix, respectively. The definitions of the two matrices can be found in the next section. ε and ν are the disturbance error items, and μ is the random error term that follows the normal distribution.

According to Anselin (1988) and Pinkse and Slade (2010), given the condition that the spatial lagged and error correlations do exist, there will be serious consequences of ignoring these spatial correlations. If spatial lag dependence is ignored, ordinary least squares (OLS) estimators will be biased and inconsistent. If spatial error dependence is ignored, OLS estimators will be unbiased but inefficient, and the standard errors of the estimators will be biased (Anselin 1988). In the existing literature, Liu et al. (2014), Zhang (2016), and others have demonstrated the spatial autocorrelation of environmental enforcement among local governments based on economic weights matrices. Meanwhile, Liu et al. (2018), Li et al. (2018), Hao et al. (2016), and others have documented the spatial disturbance effects of geographical distance on environmental engagement based on SEM. Therefore, it is essential to consider both the lagged spillover effects of economic distance and the disturbance effects of geographical distance. The spatial autocorrelation model (SAC) integrates the influence of both the spatial lagged and the spatial error correlations; that is, it captures not only the ubiquitous geographical characteristics of the adjacent provinces but also the spatial dependence of environmental enforcement among competing provinces.

The SAC is written as Eq. (3)[5]:

$$\mathrm{ER} = \rho_1 \mathbf{E}\mathrm{ER} + X_1\beta + \varepsilon, \quad \varepsilon = \lambda_1 \mathbf{D}\,\varepsilon + \mu$$

where *ER* denotes the ER enforcement of provincial governments. β represents the influence of a vector of explanatory variables X_1. In a given province, the spatial regression coefficient ρ_1 represents the effects of the environmental enforcement of other provinces of similar economic levels, while the spatial error coefficient λ_1 represents the undetected impacts of other adjacent regions. According to Bivand and Piras (2015), hypothesis H_1 is empirically supported if ρ_1 is positively significant; that is, if the spatial imitation effect exists among competing provinces in implementing national ERs.

Hypothesis H_2 is tested by Eq. (4), written as

$$\mathrm{P} = \rho_2 \mathbf{E}\mathrm{P} + X_2\beta + \varepsilon, \quad \varepsilon = \lambda_2 \mathbf{D}\,\varepsilon + \mu$$

where *P* denotes the pollutant emissions of provincial governments, proxied by CO_2 and SO_2 emission levels. β represents the influence of a vector of explanatory variables X_2. In a given province, the spatial regression coefficient ρ_2 represents the effects of the regulatory performance of other provinces of similar economic levels, while the spatial error coefficient λ_2 represents the undetected impacts of other adjacent regions. We expect the results of ρ_2 to be different before and after 2007, when taking the CO_2 and SO_2 emissions as dependent variables, indicating that the imitation effects of pollutant emission reduction among competing provinces have been different since the ecological indicators were included in the OPT. In that case, hypothesis H_2 would be supported.

Spatial weight matrix

For spatial econometric analysis, it is fundamental to define a particular spatial weight matrix to reflect the spatial correlations between regions. We first establish a binary contiguity matrix, ***D***, following Moran (1948), to capture the spatial dependence between adjacent provinces. ***D*** is a row-standardized spatial weight matrix of D_{ij}. If province *i* is adjacent to province *j*, $D_{ij} = 1$; otherwise, $D_{ij} = 0$.

Spatial economic matrix ***E*** is constructed to illustrate the economic distance between provinces *i* and *j*. As they are influenced by political competition, the closer the economic levels of the provinces, the stronger the competitive relationship among their provincial officials, regardless of whether they are adjacent (Yu et al. 2016; Zhang 2016; Liu et al. 2014). Matrix ***E*** is defined as Eq. (5):

$$E_{ij} = \begin{cases} \dfrac{1}{\left|\overline{G_i} - \overline{G_j}\right| + m} & \mathrm{i} \neq \mathrm{j} \\ 0 & \mathrm{i} = \mathrm{j} \end{cases}, \quad \overline{G_i} = \frac{1}{17}\sum_{t=2000}^{2016} G_{it}$$

where G_{it} denotes the per capita GDP (indicating economic level) of province *i* in year *t* (G_{it} is deflated by the price index in 2000). Only when provinces *i* and *j* have the same economic development level in the same period, m = 1; otherwise, m = 0. ***E*** is a row-standardized spatial weight matrix of E_{ij}.

We calculate the value of Moran's *I* (Moran 1948), the most widely used indicator when testing for the existence of spatial correlations, to investigate the spatial dependence of the environmental enforcement of provincial governments under the ***D*** and ***E*** spatial weight matrices in 2000 and 2016, respectively. Table 4 presents the test results.

Variables and data

In Eq. (3), we evaluate dependent variable *EP* by dividing the total amount of sewage charge by the number of charge units (that is, the intensity), a measurable ER of three major national Chinese regulations mentioned in Section 2.2, to proxy for local governments' ER enforcement. This is not only because sewage charge is typically considered a comprehensive indicator demonstrating the multiple effects of carbon trade, emission reduction, and other policies (Xie et al. 2017; Zhao et al. 2015; Ren et al. 2018), but also because the collection intensity of pollution charge, rather than the total amount, can identify symbolic or selective regulatory enforcement (Liu and Diamond 2008).

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[5] According to the classical spatial literature, the two spatial weight matrices may or may not be the same in the SAC (that is, matrices ***D*** and ***E*** in this research), which depends on the concrete spatial effects that exist both in explained variables and in regression disturbances (Bivand and Piras 2015).

The vector of explanatory variables (X_1) denotes impacting factors that influence the ER enforcement of local governments. Economic development (*income*) is taken as a regular factor that positively impacts environmental enforcement (Yu et al. 2016; Liu et al. 2018). Corruption (*corruption*) influences not only a local official's actual environmental engagement, but also the strategic interaction of ER enforcement among jurisdictions (Zhang 2016; van Rooij et al. 2017). The environmental impacts of industrialization (*industry*), trade (*trade*), and foreign direct investment (*FDI*) have been revealed to be different in developed and developing regions (see, Wang and Shen 2016; Dean et al. 2009; Liu and Diamond 2008; Yin et al. 2015). Education levels (*education*) and research and development investment (*R&D*) have been found to be positively correlated with environmental enforcement by Wang and Shen (2016), Yu et al. (2016), and others. Since the responsibilities of environmental protection in China are institutionally allocated by the central to local governments, fiscal decentralization levels (*decentralization*) are seen as critical for inducing provinces to make more emission reduction efforts (Deng et al. 2012; van Rooij et al. 2017; Shen et al. 2017), despite some opposing empirical evidence (Renard and Xiong 2012; van Rooij et al. 2017). Reflecting the disparity between fiscal revenue and expenditure, higher fiscal deficit (*Deficit*) would compel local governments to focus on economic growth and to attract pollution-intensive, high-taxation industries (Zhang 2016; Hansen et al. 2015).

In Eq. (4), the dependent variable P is proxied by CO_2 and SO_2 emissions. Because the central government takes the total amounts of indicators to assess regional emission reduction performance, we utilize the total amounts of pollutant emissions rather than emission intensity to evaluate the environmental effects of the Chinese political regime. Fourteen energy resources are covered in the calculation of the amount of CO_2 emissions: coal, coke, coke oven gas (COG), other gas, crude oil, gasoline, kerosene, diesel oil, fuel oil, liquefied petroleum gas (LPG), natural gas, blast furnace gas (BFG), Linz-Donawitz process gas (LDG), and liquefied natural gas (LNG) (the last three energy resources have been covered since 2010). A widely used calculation model provided by the Intergovernmental Panel on Climate Change (IPCC 2007) is utilized here and is written as Eq. (6):

$$TCO_2 = \sum_{i=1}^{14} CO_{2,i} = \sum_{i=1}^{14} E_i \times NCV_i \times CEF_i$$

where

$$CEF_i = CC_i \times COF_i \times \frac{44}{12}$$

TCO_2 is the total amount of CO_2 emissions to be estimated. $CO_{2,i}$ represents the estimated CO_2 of energy type i. E_i denotes the energy consumption of energy type i. NCV_i refers to the net heating value of the ith energy used to transfer the energy consumption to the energy unit. CEF_i denotes the carbon emissions factor of energy type i. Values and data sources of the *NCV* and *CEF* of the 14 energy resources are shown in Table 2. CC_i and COF_i represent the carbon content and carbon oxidation factor of ith energy, respectively. The COF_i values of coal and coke are set at 0.99, and the others are 1. The molecular weights of carbon dioxide and carbon, respectively, are 44 and 22.

The explanatory variables (X_2) of Eq. (4) include *ER*, *income*, *corruption*, *trade*, *R&D*, *industry*, *urbanization*, and *population*. China's miraculous economic growth is typically embodied by the national process of urbanization and industrialization, which implies a positive correlation between pollutant emissions and *urbanization* and *industry* (Hao et al. 2016; Li et al. 2018). Larger populations generally require much more energy consumption while also bringing greater environmental pressure on the executive authority to mitigate the increased health detriment, all of which collectively leads to controversial results in the existing literature (Liu and Diamond 2008; Zhang and Fu 2008). The quadratic item of economic development, $income^2$, is introduced into Eq. (4) to investigate the validity of the EKC hypothesis, which postulates an inverted U-shaped relationship between economic growth and pollutant emissions (Maddison 2006; Dinda 2004; Dasgupta et al. 2002). STATA 14.0 is used for the calculating process in examining the two hypotheses in this research, and both Eq. (3) and Eq. (4) are performed based on estimation models with fixed effects. All spatial models are estimated using maximum likelihood.

The reasons why we used the period from 2000 to 2016 are as follows: First, since the 11th Five-Year Plan for Environmental Protection (2006–2010) initially set ecological indicators for the performance evaluating of local officials, we introduce the previous (2001–2005) and subsequent (2011–2015) Five-Year Plans to investigate the shift in officials' strategic interaction in environmental enforcement by a comparative analysis. Second, most of recent literature on Chinese environmental governance has taken 2000 as the beginning of the research period, given the fact that in this year environmental pollution became the public issue about which civilians were most concerned.[6] Third, it was in 2016 that the Chinese central authority launched its centralized reform of environmental protection and supervision (as discussed in the preceding section), implying a transformation of the institutional context of our research.

Table 3 presents the definitions, data sources, and descriptive statistics of variables in this research. All economic variables are deflated at a 2000 constant price. As the table shows, the mean value of *ER* increased from 1.203 in 2000–2007 to

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[6] The research indicating this was conducted and published by a well-known independent investigator. Access at: http://www.cctv.com/news/china/20001230/54.html.

Table 2 Data on NCV and CEF of 14 energy resources

Energy	Coal	Coke	COG	BFG	LDG	Crude oil	Other gas
NCV (kj/kg)	20,908	28,435	17,981	3855	8585	41,816	18,273.6
CEF (kg/TJ)	95,977	105,996	44,367	259,600	181,867	73,333	44,367
Energy	Gasoline	Kerosene	Diesel oil	Fuel oil	LPG	Natural gas	LNG
NCV (kj/kg)	43,070	43,070	42,652	41,816	50,179	38,931	44,200
CEF (kg/TJ)	70,033	71,500	74,067	77,367	63,067	56,100	64,167

The calculation of coal's emission factors refers to Wenbo and Yan (2018). Other data in this table is drawn from the China Energy Statistical Yearbook (2017) and the IPCC (2007)

3.13 in 2008–2016, while the standard deviation also increased from 0.707 to 1.62. The results demonstrate that although ER enforcement has generally improved, the disparity between provinces has widened as well, indicating an intensifying strategic interaction among local governments.

Regarding regulatory performance, there appears to have been an obvious increase in CO_2 emissions from 9.426 in 2000–2007 to 10.126 in 2008–2016, which goes against China's ambitious goal of achieving a low-carbon economy. In contrast, there was a slight decrease in SO_2 emissions (from 13.016 to 13.001), which is the promotion assessment indicator used by the central authority. The apparent difference in regulatory performance between CO_2 and SO_2 emissions supports hypothesis H_2 to some degree.

Results and analysis

Spatial autocorrelation test

The results of Moran's I test for the global spatial autocorrelation of ER implementation (ER) and regulatory performance (CO_2 and SO_2) under matrices $\boldsymbol{D}$ and $\boldsymbol{E}$ are shown in Table 4. As the table shows, under matrix $\boldsymbol{D}$, the values of Moran's I in 2000 and 2016 are both greater than zero, implying positive correlations between adjacent provinces in ER enforcement and pollutant emissions. Under matrix $\boldsymbol{E}$, the values of Moran's I are all less than zero with $p > 0.1$ in 2000, implying that there are no spatial correlations between ER enforcement and regulatory performance. In contrast, environmental enforcement appears to be positively significant by 2016 (Moran's $I = 0.106$, $p = 0.087$), implying positive correlations in ER enforcement among provinces of similar economic levels. As a consequence, there also exist positive correlations in SO_2 emissions among economically similar provinces (Moran's $I = 0.131$, $p = 0.049$), while no significant spatial correlation exists for CO_2 emissions (Moran's $I = 0.029$, $p = 0.269$). Based on this, we conclude that current ERs have exerted diverse impacts and caused different performances regarding CO_2 and SO_2 emissions under China's peculiar political regime.

In addition, Table 4 shows that there exist spatial correlations in SO_2 emissions in 2000 between adjacent provinces (Moran's $I = 0.133$, $p = 0.069$), but not between provinces with close economic levels (Moran's $I = -0.004$, $p = 0.378$), while in 2016, spatial correlations in SO_2 emissions can be found among provinces with close economic levels (Moran's $I = 0.131$, $p = 0.049$), but not among adjacent provinces (Moran's $I = 0.084$, $p = 0.149$). The results imply that the spatial spillover effect of SO_2 emissions between adjacent provinces has been gradually replaced by the imitation effect among provinces of similar economic levels, just as hypothesis H_2 states.

Taking the results together, the environmental enforcement and regulatory performance of all provinces are not completely random but are in a positively related state of spatial dependence. This relationship will be biased if the estimation models are constructed without spatial effects (Anselin 1988; Cole et al. 2013; Maddison 2006; Pinkse and Slade 2010).

Results of the regression analysis

Table 5 shows the empirical results of the test for hypothesis H_1, that is, spatial dependence in the ER implementation of provincial governments. The estimation results of OLS, SLM (Eq. 2), and SEM (Eq. 1) are shown successively in the first three columns. As shown in the table, both the spatial lagged ER implementation ($\boldsymbol{EER}$) and the spatial error ($\boldsymbol{W}\varepsilon$) are positively significant ($\rho_1 = 0.2958$ with $p < 0.01$; $\lambda_1 = 0.8558$ with $p < 0.01$), demonstrating the existence of the lagged spillover effects of economic distance and the disturbance effects of geographical distance, and implying that both of these two spatial effects should be fully accounted for. The results of the SAC (Eq. 3), which simultaneously considers the spatial lagged effect (matrix $\boldsymbol{E}$) and spatial error effect (matrix $\boldsymbol{D}$), are demonstrated in columns 4–6. According to Anselin et al. (2006) and Elhorst (2010), the results of the (robust) LM test testify to the existence of spatial correlation ($p < 0.01$, except the robust LM spatial error in column 5); therefore, the analysis based on OLS model, which does not consider the spatial effect, is subject to bias and hence not reliable. According to the results of the *Wald* and *LR* tests, both the null hypotheses

Table 3 Definitions, data sources, and descriptive statistics of variables

Variable	Definition	Source	Mean	Min	Max	S.D.
Year 2000–2016 ($N = 510$)						
CO_2	The logarithm of carbon dioxide emissions amount	Get by calculation [Eq. (6)]	9.797	6.707	11.46	0.862
SO_2	The logarithm of sulfur dioxide emissions amount	China Environmental Yearbook	13.01	9.739	14.36	0.934
ER	Real sewage charge per paying unit (2000 Yuan)	China Environmental Yearbook	2.223	0.336	10.92	1.596
Income	The logarithm of per capita real GDP (2000 Yuan)	China Statistical Yearbook	2.175	0.274	10.22	1.629
Corruption	Duty criminals per 10,000 civil servants serving the public sector	China Procuratorial Yearbook	28.77	7.880	139.1	11.26
Industry	The ratio of industrial added value to GDP	China Statistical Yearbook	0.388	0.119	0.532	0.081
Trade	The ratio of total volume of import/export to GDP	Provincial Statistical Yearbook	31.42	3.215	169.9	38.47
FDI	The ratio of foreign direct investment to GDP	Provincial Statistical Yearbook	2.571	0.000	14.65	2.203
Education	The ratio of educated population to total population (over 6 years old). The educated population = primary×6 + junior×9 + high×12 + college×16 + graduate×19	China Statistical Yearbook	8.404	5.438	12.39	1.056
R&D	The ratio of R&D expenditure to GDP (%)	China Statistical Yearbook on Science and Technology	1.255	0.146	5.843	1.012
Decentralization	The ratio of local government to central government per capita expenditure	China Financial Yearbook	4.786	1.078	14.87	2.959
Deficit	The ratio of government deficit to GDP	China Statistical Yearbook	0.103	0.008	0.516	0.082
Urbanization	The ratio of urban population to total population	China Statistical Yearbook	0.493	0.233	0.896	0.152
Population	The logarithm of total population	China Statistical Yearbook	8.152	6.247	9.306	0.759
Year 2000–2007 ($N = 240$)						
CO_2			9.426	6.707	11.16	0.811
SO_2			13.02	9.867	14.36	0.962
ER			1.203	0.336	5.421	0.707
Year 2008–2016 ($N = 270$)						
CO_2			10.13	7.778	11.46	0.769
SO_2			13.01	9.739	14.30	0.911
ER			3.130	0.821	10.92	1.620

are rejected at the 1% significance level, indicating that the SAC is more appropriate than the SLM and SEM in this analysis (LeSage and Pace 2009; Hao et al. 2016; Liu et al. 2014).

The results of the SAC show that the spatial lagged item (***EER***) is positively significant at the 10% significance level ($\rho_1 = 0.2132$), implying that the environmental regulatory enforcement of a certain province is indeed positively affected by that of other economically similar provinces (Liu et al. 2018; Li et al. 2018; Bivand and Piras 2015; Zhang 2016). For these provinces, in which existing strong political competition is embedded by the OPT, there has appeared a kind of spatial spillover effect in environmental enforcement. These results document the imitation effect of ER implementation among provinces of similar economic levels and thus support hypothesis H_1. Further tests, based on the division of the time period, find that the imitation effect does not exist in 2000–2007 ($p > 0.1$), but becomes very strong after 2007 ($\rho_1 = 0.3989$, $p < 0.01$). The results demonstrate the spatial dependence of environmental enforcement among competing provinces, which are not necessarily adjacent but still have similar economic levels. This finding can supplement the existing ER research focusing on the geographical spillover effects between adjacent regions (Lv et al. 2017; Xie et al. 2017; Ren et al. 2018).

In terms of the explanatory variables, the results show that the ER enforcement of provincial governments in the 2008–

Table 4 Moran's *I* for global spatial autocorrelation in the years 2000 and 2016

Weight	Year	Variable	*I*	*Z* value	*p* value
Matrix ***D*** (distance)	2000	ER	0.167	1.977	0.024
		CO_2	0.185	1.927	0.027
		SO*2*	0.133	1.482	0.069
	2016	ER	0.242	2.515	0.006
		CO_2	0.119	1.313	0.095
		SO_2	0.084	1.041	0.149
Matrix ***E*** (economy)	2000	ER	− 0.001	0.372	0.355
		CO_2	− 0.016	0.189	0.425
		SO_2	− 0.004	0.311	0.378
	2016	ER	0.106	1.420	0.087
		CO_2	0.029	0.614	0.269
		SO_2	0.131	1.651	0.049

2016 period is positively associated with income, trade, and education at the 10% significance level. Meanwhile, ER implementation is adversely influenced by fiscal deficit ($\beta = -4.6431$, $p < 0.1$) and industrialization ($\beta = -4.4392$, $p < 0.01$). This could be because provinces with higher fiscal deficits give more priority to the development of industry and, accordingly, tend to loosen the stringency of regulations in order to achieve faster economic growth (Yin et al. 2015; Shen et al. 2017).

Table 6 presents the regression results for regional emission amounts when CO_2 and SO_2 are separately taken as proxies for pollutants. The estimation results of the OLS model are also reported in the first two columns. The estimation results of the SAC are demonstrated in Model 2 when calculating based on Eq. (5). As shown in the table, the LM (robust) tests are mostly significant (especially during the period of 2008–2016) and consequently demonstrate the spatial dependence of regional pollutant emissions, indicating that the OLS model could be subject to bias and hence not reliable because of its ignorance of spatial effects.

The results in columns 3 and 6 demonstrate the positive spatial correlations of CO_2 and SO_2 emissions among provinces ($\rho_2 = 0.3997$ with $p < 0.01$ and $\rho_2 = 0.2391$ with $p < 0.05$, respectively), implying the existence of an imitation effect in pollutant emissions among local governments of similar economic levels. The results also show that the ERs significantly reduced SO_2 emissions ($\beta = -0.1054$, $p < 0.1$) while exerting adverse and insignificant impacts on CO_2 emissions ($p > 0.1$) from 2000 to 2016. Further tests were conducted based on the period division (that is, the 2000–2007 and 2008–2016 periods), as presented in columns 4 and 5 for CO_2 emissions and 7 and 8 for SO_2 emissions. There appears to be a significant spatial dependence of CO_2 emissions among provinces of similar economic levels in the 2000–2007 period ($\rho_2 = 0.2364$, $p < 0.05$), while this becomes insignificant after 2007 ($p > 0.1$). This change is probably caused by the strengthening spatial spillover effects of energy consumption structure in China's regional economic development (Hao et al. 2016), considering the positive and significant autocorrelation of CO_2 emissions among adjacent provinces ($\lambda_2 = 0.4336$ with $p < 0.01$) in the 2008–2016 period compared to that in the 2000–2007 period ($\lambda_2 = -0.2755$ with $p < 0.1$). In contrast, the spatial dependence of SO_2 emissions among competing provinces changes from insignificant in the former period to significant in the later period ($\rho_2 = 0.321$, $p < 0.01$). The results support hypothesis H_2; that is, after 2007, the spatial correlations of reduction performance are significant for SO_2 emissions but not for CO_2 emissions. Supplementary evidence supporting H_2 is embedded in the differences in emission reduction performances of ER. Specifically, during the period of 2008–2016, ER significantly reduced SO_2 emissions ($\beta = -0.1661$, $p < 0.05$) while exerting adverse and insignificant impacts on CO_2 emissions ($p > 0.1$). These findings imply a transformation of local officials' regulatory behavior from a race-to-the-bottom to strategic imitation; that is, a race-to-the-top has appeared in SO_2 emission reduction but not in CO_2 emission reduction, since the latter is not a mandatory assessment indicator in the 11th and 12th Five-Year Plans for Environmental Protection.

This research also documents the existence of an inverse U-shaped relationship between income and CO_2 emissions, thus supporting the environmental Kuznets curve (EKC) hypothesis. As the table shows, the logarithm of per capita GDP corresponding to the turning point of EKC is 5.044 based on the OLS model, while it increases to 14.563 under the SAC when taking the spatial effect into consideration. This indicates that the economic level corresponding to the peak of pollutant emissions is estimated to be higher when spatial effects are fully accounted for and is much higher than the present economic level (2.175), which is consistent with the findings of Hao et al. (2016), Maddison (2006), and Yin et al. (2015). In addition, the EKC no longer exists for SO_2 emissions after 2007, when the central government launched its mandatory assessment indicator for SO_2 emissions, implying that the elaborated ERs could interrupt the traditional income-pollution nexus and reverse the environmental evolution of continued deterioration.

Conclusions and policy implications

Based on a spatial econometrics model using data from 30 provinces from 2000 to 2016, this research investigates how political competition impacts the environmental enforcement of local governments in China. The results demonstrate a spatial correlation of environmental enforcement among provinces of similar economic levels and reveal that there has been

Table 5 Results of OLS and spatial regression analysi for Eq. (3)

Variable	OLS	SLM	SEM	SAC		
	2000–2016	2000–2016	2000–2016	2000–2016	2000–2007	2008–2016
EER (ρ_1)		0.2958*** (0.1142)		0.2132* (0.1183)	− 0.2393 (0.2169)	0.3989*** (0.1032)
$\boldsymbol{W}\varepsilon$ (λ_1)			0.8558*** (0.0737)	0.3714 (0.2931)	0.8253*** (0.1137)	0.2311 (0.3343)
Income	0.9601*** (0.0622)	0.4909*** (0.1515)	0.3789 (0.2627)	0.4837*** (0.1675)	0.4557 (0.3733)	0.2162* (0.1228)
Corruption	0.0014 (0.0048)	0.0010 (0.0045)	− 0.0004 (0.0032)	− 0.0009 (0.0045)	0.0001 (0.0011)	− 0.0043 (0.0081)
Industry	1.1676* (0.5968)	− 1.3116 (1.5173)	− 2.9370** (1.4575)	− 2.1230 (1.4243)	− 0.5913 (1.0799)	− 4.4392*** (1.6464)
Trade	− 0.0005 (0.0021)	0.0044 (0.0038)	0.0050 (0.0039)	0.0073* (0.0044)	0.0036 (0.0030)	0.0064* (0.0049)
FDI	− 0.1245*** (0.0272)	0.0338 (0.0366)	0.0050 (0.0378)	0.0391 (0.0346)	0.0002 (0.0079)	0.0233 (0.0479)
Education	0.0279 (0.0882)	0.2704*** (0.0868)	− 0.0314 (0.1812)	0.2683** (0.1101)	0.0605 (0.0404)	0.1604* (0.0989)
R&D	− 0.0079 (0.0764)	0.5950* (0.3472)	0.2297 (0.2747)	0.5909 (0.4496)	0.1928 (0.1479)	0.8109 (0.6152)
Decentralization	− 0.1024** (0.0448)	− 0.0291 (0.1037)	0.0426 (0.1118)	0.0063 (0.1077)	0.0950* (0.0519)	0.1083* (0.0653)
Deficit	3.2765 (1.2396)	1.9106 (2.4835)	0.8559 (2.6179)	1.6470 (2.6660)	1.4993 (1.6615)	− 4.6431* (2.9187)
Constant	− 0.0958 (0.7601)	− 2.2901*** (0.7840)	2.0328 (1.6684)			
R^2	0.6093	0.8776	0.8267	0.8743	0.8024	0.8758
Log-pseudolikelihood		− 394.6175	− 383.8862	− 292.1453	141.4029	−47.2402
Moran's *I*				6.714***	3.475***	3.590***
Wald		126.29***				
LR			121.99***			
LM spatial error				38.591***	9.183***	9.996***
Robust LM spatial error				14.993***	0.295	15.948***
LM spatial lag				101.205***	16.000***	39.574***
Robust LM spatial lag				77.607***	7.112***	45.525***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Standard errors in parentheses

a performance-oriented peer competition for SO_2 emission reduction but no similar competition for CO_2 emission reduction since the former was appointed as the assessment indicator for official promotion in 2007. The findings imply an overall conversion of local Chinese governments' environmental enforcement from a race-to-the-bottom to strategic imitation, influenced by the ecological transformation of local officials' promotion tournament competition.

The results also support the EKC hypothesis in China regarding the relationship between income and emissions, and demonstrate that the economic levels corresponding to the peak of CO_2 emissions are estimated to be higher when spatial effects are fully accounted for. However, the EKC became invalid for SO_2 emissions after 2007, implying that the central authority is actually capable of interrupting the traditional inverted U-shaped income-pollution nexus by utilizing political competition and introducing ecological indicators into the official promotion assessment system. This study sheds light on the environmental effects of political competition in China and provides an institutional explanation for the strategic interaction of environmental enforcement among local governments.

The main contributions of this research to the literature are summarized as follows. First, this research presents the impacts of political competition among local governments on environmental regulation enforcement and on actual

Table 6 Results of OLS and spatial regression analysis for Eq. (5)

Variables	Model 1: OLS		Model 2: SAC					
	CO_2	SO_2	CO_2			SO_2		
	2000–2016	2000–2016	2000–2016	2000–2007	2008–2016	2000–2016	2000–2007	2008–2016
EP (ρ_2)			0.3997*** (0.0706)	0.2364** (0.1078)	0.1236 (0.1104)	0.2391** (0.0967)	0.0472 (0.1954)	0.3210*** (0.0919)
$\boldsymbol{W\varepsilon}$ (λ_2)			0.1899** (0.0832)	− 0.2755* (0.1717)	0.4336*** (0.0896)	0.4459*** (0.1346)	0.3299 (0.2997)	0.2803** (0.1321)
ER	0.0928*** (0.0153)	0.1609*** (0.0204)	0.0052 (0.0318)	0.2159*** (0.0773)	0.0160 (0.0405)	− 0.1054* (0.0671)	0.1285 (0.1711)	− 0.1661** (0.0847)
Income	0.2724*** (0.0504)	− 0.2620*** (0.0672)	0.1867** (0.0781)	0.4936** (0.2354)	0.1120 (0.0898)	0.0993 (0.0910)	0.3884* (0.2422)	− 0.1241 (0.1075)
Income^2	− 0.0270*** (0.0046)	0.0101 (0.0061)	− 0.0118* (0.0064)	− 0.0738* (0.0422)	− 0.0070 (0.0058)	− 0.0103 (0.0074)	− 0.0723 (0.0544)	0.0074 (0.0069)
Corruption	− 0.0101*** (0.0016)	− 0.0112*** (0.0022)	− 0.0012 (0.0016)	0.0007 (0.0009)	− 0.0046 (0.0028)	− 0.0067*** (0.0026)	− 0.0051*** (0.0012)	0.0004 (0.0033)
Trade	− 0.0051*** (0.0007)	− 0.0009 (0.0009)	− 0.0004 (0.0008)	0.0005 (0.0011)	− 0.0007 (0.0019)	− 0.0013 (0.0021)	− 0.0050** (0.0023)	0.0005 (0.0019)
Urbanization	1.3192*** (0.3535)	0.2171 (0.4714)	2.1548*** (0.6576)	1.9858 (1.6590)	2.1096*** (0.5283)	1.0420 (1.0511)	− 1.7899 (2.0850)	4.1600*** (1.2282)
R&D	− 0.0556** (0.0258)	− 0.0535 (0.0344)	− 0.1422** (0.0664)	− 0.1236* (0.0688)	− 0.1511** (0.0723)	− 0.1757 (0.1249)	− 0.0173 (0.1251)	− 0.0933 (0.1270)
Population	0.7087*** (0.0277)	0.6649*** (0.0370)	0.2753 (0.4800)	− 0.2309 (1.2542)	0.2239 (0.2860)	0.4786 (0.8472)	1.8648 (1.9933)	0.4723 (0.3036)
Industry	3.1508*** (0.2328)	5.4600*** (0.3105)	1.0382*** (0.3586)	0.8601 (0.7236)	0.2977 (0.3511)	0.8166 (0.7889)	3.3477** (1.5906)	0.3385 (0.5568)
Constant	2.0655*** (0.2536)	6.0366*** (0.3381)						
R^2	0.8417	0.7601	0.8904	0.8468	0.5934	0.4149	0.6148	0.6157
Log-pseudolikelihood			291.9731	185.9908	273.3582	69.5751	118.2887	143.3159
Moran's *I*			4.507***	0.754	4.506***	4.917***	0.257	4.467***
LM spatial error			16.828***	0.227	16.202***	20.204***	0.000	15.904***
Robust LM spatial error			8.022***	0.203	9.553***	6.309**	1.479	6.266**
LM spatial lag			51.912***	27.021***	29.156***	127.759***	51.934***	78.044***
Robust LM spatial lag			43.107***	26.997***	22.506***	113.864**	53.413***	68.406***

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Standard errors in parentheses

regulatory performance, which is a new and more integrated perspective compared to those of previous studies (Kostka and Mol 2013; Ran 2013; Wang and Shen 2016). Second, we provide an institutional explanation for why the emission of various pollutants evolves so differently alongside economic development, which is quite a controversial and far-from-conclusive topic in the environmental literature (Hao et al. 2016; Maddison 2006; Dinda 2004). Third, the findings of this research document the existence of interaction in environmental enforcement among provinces of similar economic levels, thus providing an important supplement to the existing spatial environmental analysis in China, which is mostly based on considering geographical attributes or regional division models (e.g., Lv et al. 2017; Song et al. 2018; Xie et al. 2017).

The results bring profound practical enlightenment. Even though the EKC hypothesis postulates that the threshold of environmental degradation will finally be reached after surpassing a certain income level, the turning point may not be reached in the near future in China, as postulated by Yaguchi et al. (2007), Hao et al. (2016), Yin et al. (2015), and other recent EKC studies. This research demonstrates that the ecological shift in political competition exerted positive effects on the EKC and caused the inflection point to appear earlier. Therefore, local officials' promotion-oriented inspiration should be fully engaged by applying ecological assessments in the OPT, and a set of more detailed and forceful ecological assessment systems for promoting local officials should be developed and instituted nationally. Some specific policy implications arise from this point, including more stringent supervision of government information disclosure in order to inhibit misrepresentation of data on emission reduction (Chen et al. 2018), and coordination between maintaining local officials' autonomous governing capacities and strengthening central-local vertical linkages under the recentralization trend of environmental governance in recent years (Kostka and Nahm 2017).

Particularly, our findings indicate that the promotion-oriented race-to-the-top imitation of environmental enforcement only exists among provinces of similar economic levels; that is, it would be difficult for political competition to provide coherent inspiration for environmental enforcement by local officials with apparent economic disparity between them (that is, incentive failure). Therefore, in addition to the geographical differences between regions and spatial spillover effects (Hao et al. 2016; Lv et al. 2017), the economic disparities between jurisdictions and the imitation effects among them should be taken into consideration in the process of policy formation and implementation. For example, measures should be taken to counterbalance the concern of underdeveloped provinces regarding the economic cost of environmental preservation and pollution control, including the increase of environment-based special transfer payments from the central government to underdeveloped provinces, the functional improvement of "green taxes" in balancing the environmental cost-benefit across provinces, and the development and national diffusion of clean production technology.

Though the environmental impacts of political competition have been basically and robustly revealed in this study, this topic needs to be further explored from a more comprehensive perspective. The national environmental regulation in China, which is proxied principally by pollution charge in this paper, can be furtherly divided into three types: command-and-control regulation, market-based regulation, and informal voluntary regulation (see, Ren et al. 2018; Xie et al. 2017). Applying the different regulation types separately into the spatial spillover analysis would present a much more nuanced illustration of the strategic behavior of local officials, with their varying preferences for economic growth and environmental protection. Furthermore, it would be worthwhile to analyze the potential economic impacts of ecological shifts in political competition, and to expand the discussion on environmental policy recommendations to take account of local officials' economy-environment preferences. We leave this work for the future.

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