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Environmental Regulation and Development Transformation in the Tropical and Subtropical Cities of China: A Big Data Analysis

Zhituan Deng[1], Jiaojiao Kang[2] and Haobin Fan[1]

Abstract

This paper studies the effects of Key Control Areas (KCA) policy implemented by the Chinese government in 2012 on city development transformation, in which strict environmental regulations were imposed in KCA cities in both tropical and subtropical zone. Based on the panel data of 155 tropical and subtropical cities in China from 2000 to 2017, we use a simple Differences-in-Differences approach to estimate the effects. Results show that more draconian environmental regulation has significant positive effects on city transformation. Furthermore, the designation of key areas leads to a screening effect on firms, that is, some of them increase technology investment in green production, while other firms are not capable to shoulder the rising cost and choose to reduce production or even shut their business, which ultimately promotes the city transformation. Meanwhile, with the expansion of the service industry, the relative proportion of manufacturing has declined, which brings about the upgrading of the industrial structure, and in turn promotes the city transformation.

Keywords

tropical and subtropical cities, environmental regulation, city transformation, big data, China

The widely accepted concept of "innovation, coordination, green, openness, and sharing" along with the in-depth advancement of the new urbanization strategy in China make city transformation an urgent topic. Increasing resources pressure on environment is a long-lasting issue within the pattern of traditional economic development, characterized by high pollution and large energy consumption. After deducting the cost of resource consumption and environmental damage, the real growth of a city is actually low. According to the "2018 Environmental Performance Index", China ranked 120th among 180 participating entities, and ranked 177th in the field of air quality. Such poor performance shows that the environmental problem in China is particularly serious. Environmental problem should be addressed appropriately, otherwise there is no so-called "high-quality development of the economy" (Chen & Chen, 2018), the happiness of residents could be negatively affected (Lelieveld et al., 2015), and disasters happen more frequently (Wu et al., 2018).

The whole process of city transformation accompanied by urban development, which involves with the continuous evolution of major changes and development methods in various fields of the city, is closely related to the time and space background of the entire country. As the resource and ecological constraints become stronger and globalization and informatization further infiltrate the economy and society, more and more attention is paying to environmental issues (Kala et al., 2020; Mehta et al., 2019). The traditional urban development

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model is unsustainable. By far, the discussion of city transformation has become a theoretical frontier in academia. However, existing studies on city transformation mainly focus on urban sustainable development (Fowke & Prasad, 1996; Krueger & Savage, 2007; Myllyla & Kuvaja, 2005), and the eco-city analysis largely pays attention to the environment and resources (Adegunwa et al., 2019; Song, 2011). Research about the impacts of environmental regulations on city transformation mostly involves analysis of the transformation of resource-based cities (Chen et al., 2018). Major changes in the urban development process and direction are a structural transformation of cities to meet the needs of economic and social development. Environmental regulations could reduce the level of pollution emissions to a certain extent (Shen et al., 2017), while environmental regulations are also the government's mandatory intervention in the production activities of enterprises. This definitely puts extra cost to firms. Pollution control is regarded as a public product with negative externalities. Under the old assessment and promotion mechanism for officials that only emphasize economic growth, local governments usually have no strong motivation to implement those environmental policies since they are not part their KPI.

Are strict environmental regulations at the expense of reducing productivity and economic growth? Or are these regulations promoting city transformation when enhancing environmental quality? The answers to both questions not only help to clarify the theoretical differences between the relationship between environmental regulation and economic growth, but also have important practical significance for the revision of China's environmental policies and the city transformation. In 2012, the "Twelfth Five-Year Plan for Air Pollution Prevention in Key Areas" was formulated, which defined key areas to focus on solving pollution problems such as SO_2, nitrogen oxides, and PM2.5. in order to strictly control the total discharge of major pollutants. coordinate control of multiple pollutants, strengthen comprehensive management of multiple pollution sources, and strive to promote joint prevention and control of regional atmospheric pollution to effectively improve the quality of the atmospheric environment. These policies do not cover all cities in China, which can be regarded as a natural experiment to determine the relationship between environmental regulation and city transformation. So, it provides a good scenario to respond to our questions.[1]

By taking advantage of this, our study contributes to the literature on environmental regulation, and provide empirical test for development transformation in cities.

Methods

Background and Study Area

To control environmental pollution, the Chinese government has done a lot of work and formulated a series of environmental policies. Some environmental regulations and policies have also achieved certain results (Yu et al., 2019). For example, the State Council promulgated the "Two Control Zones" policy for 175 cities, and proposed phased control targets for the "Two Control Zones" in 1998. In 2005, the State Council of China promulgated the "Decision on Implementing the Scientific Concept of Development and Strengthening Environmental Protection" to incorporate environmental protection into the assessment indicators or KPI for local officials. Due to the complexity of environmental issues, the main responsibility of pollution control tends to be attributed to the government (Konisky, 2011). Firms with more pollution are often the main contributors to local GDP, employment and taxation. Therefore, prior to the implementation of restrictive pollution control, key polluting units were often tacitly approved or even protected by local governments to avoid the environmental regulations (Jia & Nie, 2017).

During the "Twelfth Five-Year Plan" period, the severe atmospheric environment and regional air pollution problems were becoming pressing issues. China's industrialization and urbanization were still in a period of rapid development, and resource and energy consumption kept increasing. Thus, in accordance with the Law of the People's Republic of China on Air Pollution Control" and the "Outline of the Twelfth Five-Year Plan for National Economic and Social Development of the People's Republic of China", China formulated the "Twelfth Five-Year Plan for Air Pollution Prevention and Control in Key Areas" (the 12th plan hereafter), which was immediately put into effect. Based on geographical characteristics, socioeconomic development, air pollution, urban spatial distribution, and the air pollutants in the area, the 12th plan categorized cities in different areas into two groups: one is the planning area, namely Key Control Areas (KCA), the other is the general control areas (non-KCA). If a city was designated as a KCA city, by 2015, the total emissions of SO_2, nitrogen oxides, industrial smoke and dust must decline by 12%, 13%, and 10%, respectively. The average concentration of inhalable particulate matter (PM_{10}), sulfur dioxide, nitrogen dioxide, and fine particulate matter ($PM_{2.5}$) decreased by 10%, 10%, 7%, 5%. The annual average concentration of fine particulate matter in the Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta areas decreased by 6%. According to the "The KCA policy", the goals, tasks, and governance were decomposed and implemented at

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the levels of municipal and county-level governments and related entities. The central government used rewarding polies such as "substituting awards for replacement", "promoting prevention with awards" "promoting governance with awards", etc. to support pollution-reduced projects.

Since the last two decades of 20th century, China's economy has continued to grow, and the city transformation has gradually become an inevitable trend. The economic growth in urban area can no longer be blindly and disorderly expanding, and wastewater and exhaust emissions were gradually reducing. From 2000 to 2017, the average GDP per square kilometers showed an upward trend, especially in the Yangtze River Delta and Pearl River Delta regions. Foshan, Shanghai, Changzhou, Yangzhou, and Wuhan had relatively rapid growth, respectively, up to \$82,400/km^2, \$36,450/km^2, \$28,660/km^2, \$25,900/km^2, \$24,710/km^2. There were also areas where the relative growth rate was low, and even showed negative growth. For instance, Zhongshan was negative \$13,160/km^2. The possible reason was that the GDP growth rate was slow, but the urban construction area growth was too high, then the relative growth rate of GDP per square kilometer got a negative growth. The regions with relatively low growth rates of GDP per square kilometer were mainly Bazhong, Nanyang, Zhoukou, and Huangshan, respectively, \$1,460/km^2, \$2,870/km^2, \$3,040/km^2, \$3,670/km^2.

From 2000 to 2017, the amount of SO_2 emissions basically showed a decreasing trend, especially in Chengdu, Laibin, Shanghai among others. The reductions in emissions were relatively large: 524,000 tons, 335,000 tons, and 314,000 tons, respectively. However, some cities, especially those in the western region, their emissions increased instead. Comparing to eastern coastal regions, those western cities performed much worse in economic development, so their environmental regulations were much looser. Therefore, the western region attracted a large number of polluting enterprises transferred from the eastern region (Shen et al., 2017). Emissions in cities in the Midwest of China have not decreased but increased in recent years. Among them, the emissions in Zunyi, Yuxi, Pu'er increased to 78,000 tons, 43,000 tons, 23,000 tons.

From 2000 to 2017, wastewater discharge showed a decreasing trend. The largest drop in emissions were Chongqing, Nanjing, and Shanghai, with 650 million tons, 490 million tons, and 400 million tons, respectively. The discharge of wastewater from Guangdong, Dongguan, Foshan, etc. has increased significantly, with increases by 1.489 billion tons, 787 million tons, and 258 million tons, respectively (Figure 1).

Hypothesis

The city transformation is mainly influenced by factors such as resource and environmental constraints, economic development stage, and technological progress. The development and transformation of a city depends on the changes in the allocation of factors within a city, such as transformation of the production model of enterprises and adjustment of urban industrial structure. The transformation of high-end and service-oriented directions has shifted from simply pursuing the expansion of the economic aggregate to a more scientific and adaptable model for urban development. Only the success of city transformation could bring the improvement of city efficiency.

As the main body of city production, firms' production models directly affect the development and transformation of cities. The strengthening environmental regulations would increase the cost of compliance (Kneller & Manderson, 2012). Since existing equipment, technology, and system have the "lock-in effect", regulations would also increase the internal cost of firms. Appropriate but strict environmental regulations help to promote technological innovation, and the resulting first-mover advantage could compensate for environmental costs and achieve a win-win situation between economy and environment (Lee et al., 2011; Porter & van der Linde, 1995). Environmental regulations also motivate companies to increase their investment in fixed capital, which in turn leads to efficiency gains resulting from technological improvements (Yuan & Zhang, 2017). Simultaneously, the introduction of technology will bring a certain technology spillover effect (Takao & Noriaki, 2014). Certainly, internal adjustments brought about by environmental regulations would also have internal technology spillover effects as well (Galloway & Johnson, 2016). The compliance costs also made the environmental regulation have an extrusion effect on corporate investment, resulting in a decline in scale and output (Burton et al., 2011). Melitz and Polanec (2015) found that the dynamic effect of enterprise resource allocation would also squeeze some firm out of the market. Wang et al. (2019) found that environmental regulation mainly optimizes the allocation of resources among enterprises by affecting the entry and exit of firms. There is also a certain product market risk in the transfer of enterprise costs, such as higher product pricing may lead to consumption transfer or substitution, which is detrimental to a firm's productivity (Clarkson et al., 2015). The impact of environmental regulations on enterprise production has not always been beneficial, Jiang et al. (2013) found that the relationship between environmental regulation and enterprise technological innovation presents a U-shaped pattern, that is, descending first and then rising.

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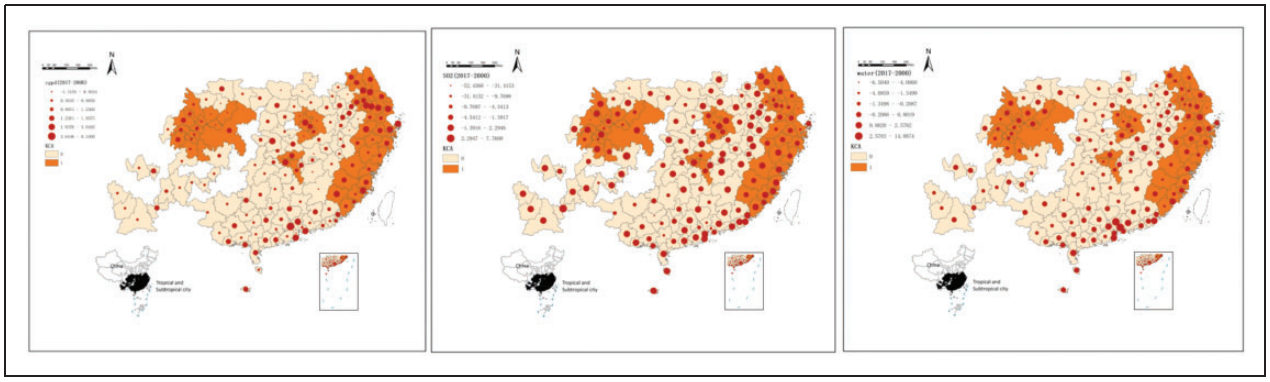


Figure 1. Changes in cgdp, SO_2, and Waste Water Discharge of Tropical and Subtropical Cities in China From 2000 to 2017(Review Number: GS(2016)2929).

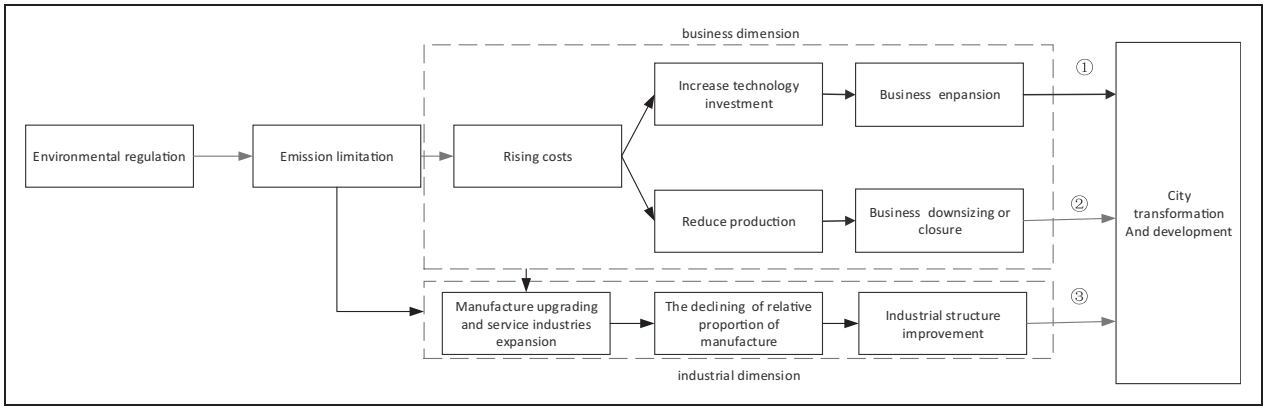


Figure 2. Logic Diagram of the Transmission Mechanism of Environmental Regulation to Promote Urban Development and Transformation.

Albrizio et al. (2017) found that the increase in enterprise productivity may be contributed to environmental regulations that promote enterprise innovation, or it may be because environmental regulations have pushed resource allocation to tilt high-productivity firms (Figure 2).

> **Hypothesis1:** The strict environmental regulations promote city transformation, which leads to firms internalize production cost and substitute production technology to adjust.

Of the government's performance in environmental policies, studies often discussed industrial structure changes (Fan & Liu, 2017; Zheng & Shi, 2017). The improvement of environmental regulations would promote the R&D, environment-friendly and innovative technologies of enterprises, and improve the productivity of enterprises to further increase their performance (Feng et al., 2017; Kumar, 2019; Long & Wan, 2017). Rubashkina et al. (2015) suggest that "appropriate" environmental regulation is conducive to technological innovation and technological progress based on European manufacturing data. The strengthening of environmental regulations would lead to green technology-oriented innovation (Acemoglu et al., 2012). Environmental regulations can also encourage companies to discover new opportunities for innovation (Tang et al., 2016). An improvement in the intensity of environmental regulations was a compulsory "refinement cleaning" or selecting the superior firms and eliminating the inferior ones, leading to industrial transformation and upgrading (Berman & Bui, 2001). The KCA policy was concentrated in the secondary industry, by implementing stricter environmental access conditions in key control areas, setting special discharge limits for pollutants in key industries, taking stronger pollution control measures, and speeding up the elimination of outdated production process. The KCA policy strictly reviewed investment projects involved with environment protection and suspended the approval and filing procedures for construction projects in key industries such as thermal power, steel, non-ferrous petrochemicals, cement, and chemical industries in areas if their elimination tasks were not completed on time.

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For firms that were not eliminated on schedule, the pollutant discharge permits and production permits shall be revoked according to the policy (Figure 2).

Hypothesis2: City transformation is a function of industrial restructuring, that is, as the implementation of environmental regulation, secondary industrial activities reduce, service activities increase.

Data and DID Method

We complied a panel dataset including 155 tropical and subtropical cities in China from 2000 to 2017 from the "China City Statistical Yearbook", "China City Construction Statistical Yearbook", "China Regional Economic Statistical Yearbook", and the China Economic Information Network statistical database. For those missing values, we searched the regional city statistical yearbooks and statistical bulletins to replenish them. Since the observations last 18 years, to consider the impact of inflation, all nominal variables were adjusted using the provincial consumer price index (Li et al., 2016).

Our study applies a simple difference-in-differences (DID) method. DID is an econometric method based on experimental design or quasi-experimental design, which uses the idea of random experiment as the basis of causal effect and could effectively solve the endogeneity problem in regression (Angrist & Pischke, 2008; Ashenfelter, 1978). The implementation of KCA policy targets only the KCA cities, which provides a "perfect" natural experiment. So, the treatment group includes those designated KCA cities in 2012, and control group is consisting of non-KCA cities. The regression model is specified as follows:

$$Y_{it} = \beta_0 + \beta_1 DID_{it} + \beta_2 X_{it} + \eta_i + \gamma_t + \varepsilon_{it} \qquad (1)$$

where Y_{it} is the measurement of development transformation flows in city i at year t;

$$DID_{it} = KCA_i \times p\text{ost}_t$$

$KCA_i = 1$ If city i is a KCA city and $= 0$ if a non$-$KCA city and $p\text{ost}_t$ indicates the post-treatment period, i.e., $p\text{ost}_t = 1 \; \forall \; t \geq 2012$ and $= 0$ otherwise. η_i and γ_t are city fixed effects and time fixed effects, respectively, capturing city i' s time-invariant characteristics such as geographic features, climate, natural endowment and year-invariant factors. ε_{it} is the error term. β_1 represents the effect of implementing KCA policy.

Dependent variable includes GDP per square kilometers (cgdp), sulfur dioxide emissions (SO_2) and wastewater discharge (water), measuring the development transformation of cities in China.

X_{it} represents control variables. Specifically, the first one is urban fixed asset investment. Since reduction of fixed asset investment improves air quality (Li & Zheng, 2016), as a part of city construction it might relate to urban development transformation. The second control variable is the index of openness to the outside world (fdi). Foreign direct investment as part of urban development, our measurement is consistent with Chen and Chen (2018) that uses the ratio of the level of foreign direct investment to the actual GDP of the city's jurisdiction. Because municipal governments in China play an important role in guiding urban industrial development and urban transformation (Zhou et al., 2015), so we select the ratio of the government's general budget expenditure to the population (govpo) as a control as well. The public services would affect the convenience and quality of life for urban residents through public education resources, comprehensive medical and health services, and transportation and communication facilities, thereby affecting the distribution of the population (Da Silva et al., 2017), so we control the level of public services by including log number of teachers in higher education, hospital beds per 10,000 population, and public shutter bus numbers per 10,000 population. we also control for production efficiency of industrial enterprises, a measurement of output value of enterprises above designated size/number of enterprises greater than designated size. The pattern of industrial development shows that the three industrial structure evolutions could be divided into two stages (Herrendorf et al., 2014). The advanced stage is the service-oriented process. The service industry gradually replaces manufacturing industry and becomes the largest industry in the national economy (Gao, 2019), so we use the output value of the tertiary industry over secondary industry to measure the urban industrial structure. In order to make the data stable and address the collinearity and heteroscedasticity, we take log values of Fai, Fdi, Teacher, Industry. Table 1 shows the summary statistics of major variables and interpretation of variables.

Pre-Policy Common Trend Illustration

In Figure 3, both the treatment group and the control group show similar trend for all the three measures of dependent variables in the period 2000–2012. After 2012, however, the treatment group and the control group illustrate significant differences. It can be seen that the economic status of the treatment group is better than the control group, and the urban transformation and development of the treatment group is faster than the control

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Table 1. Summary Statistics and Description of Variables.

	KCA			non-KCA			
Name	Mean	sd	N	Mean	sd	N	Description
cgdp	0.78	0.49	1008	0.63	0.69	1782	Jurisdiction GDP(One hundred million dollars)/Built-up area(km^2)
SO_2	6.47	8.48	1008	4.04	4.52	1782	SO_2 emissions(Ten thousand tons)
Water	1.38	1.65	1008	0.61	0.85	1782	Waste water discharge(100 million tons)
Fai(log)	1.46	0.73	1008	1.16	0.64	1782	Investment in fixed assets(Ten thousand dollar)
Fdi(log)	4.08	0.98	1008	3.64	0.89	1782	Actual use of foreign capital(Ten thousand dollars)/ GDP(Ten thousand yuan)
govpo	2.69	0.45	1008	2.60	0.47	1782	General government expenditure(Ten thousand dollar)/ Population in urban areas(Ten thousand)
Teacher(log)	26.93	23.65	1008	20.74	21.33	1782	Number of full-time teachers in ordinary universities
Bus	7.49	8.43	1008	6.80	10.39	1782	Number of buses/Population in urban areas(Ten thousand)
Medical	55.92	25.31	1008	55.83	29.32	1782	Number of hospital beds/Population in urban areas(Ten thousand)
Productivity	0.21	0.17	1008	0.26	0.28	1782	Output value of enterprises above designated size(hundred million dollar)/ Number of enterprises above designated Size
Instr	0.87	0.33	1008	1.03	0.60	1782	Proportion of secondary industry/percentage of tertiary industry

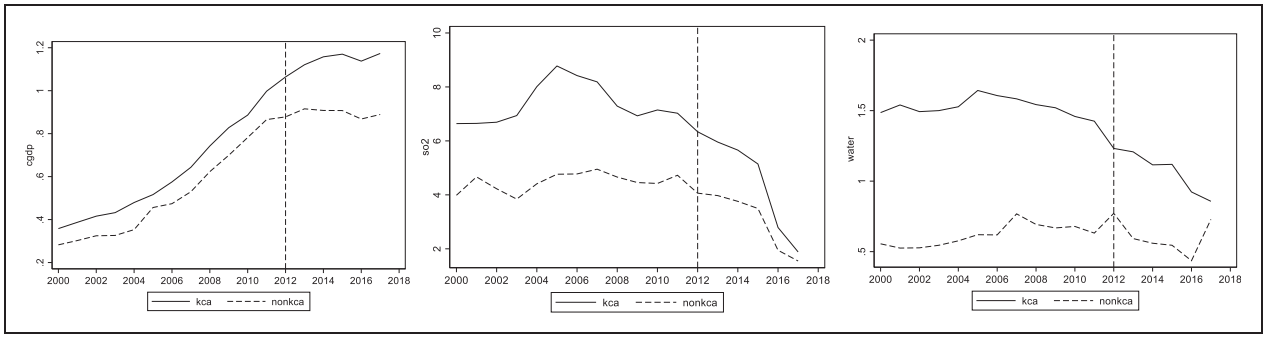


Figure 3. cgdp, SO_2, Water Parallel Trend Test.

group. The purpose of the preliminary illustration is to enhance the intuitive experience. The following part will also make a more accurately empirical test on the hypothesis of common trends.

Results

The main empirical results of environmental regulation assessment are divided into three parts. DID method is used to estimate the impact of environmental regulation on city transformation. We discuss the heterogeneity of the impact of environmental regulations on the city transformation in terms of "two control areas" and population size. Robustness test is applied to identify the estimation bias caused by missing variables.

Main Results

As an important part of the "Twelfth Five-Year Plan", the KCA policy inevitably has a certain impact on the development and transformation of cities. The division of air pollution prevention and control in key areas provides a natural experiment for the study.

In Table 2, the regression (1), (3), (5) have no time fixed effects and city fixed effects, which shows that comparing to those non-KCA cities, those KCA-cities endure significant effects from the policy after its implementation in 2012. Similar effects still hold in regression (2), (4), (6) with time fixed effects and city fixed effects. It indicates that the KCA policy brings about the growth of cgdp and reduction of SO_2 and waste water emission, consistent with the discussion in our Hypothesis1–the strict environmental regulations promote city transformation. Fixed asset investment promotes the city transformation, but the impact becomes insignificant after adding the fixed effects of cities and periods. The ability of cities to attract foreign direct investment has no significant impact on the city transformation. Government's emphasis on urban development has a significant positive impact on the city transformation when time and regional fixed effects are not included,

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Table 2. Basic Regression.

	(1) cgdp	(2) cgdp	(3) SO_2	(4) SO_2	(5) water	(6) water
DID	0.1961*** (0.0263)	0.1404*** (0.0282)	−2.1392*** (0.2190)	−1.2928*** (0.2318)	−0.4310*** (0.0491)	−0.4408*** (0.0544)
fai	0.1627*** (0.0227)	0.0208 (0.0254)	−0.6832*** (0.1894)	0.1981 (0.2086)	0.027 (0.0424)	−0.0177 (0.0490)
fdi	0.001 (0.0175)	−0.0218 (0.0171)	0.0595 (0.1454)	−0.0959 (0.1403)	−0.0321 (0.0326)	−0.0523 (0.0329)
govpo	0.3996*** (0.0371)	−0.1028** (0.0502)	0.2156 (0.3094)	2.2599*** (0.4128)	0.0683 (0.0693)	−0.0673 (0.0969)
Control	YES	YES	YES	YES	YES	YES
City fixed effect	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES
_cons	−0.5616*** (0.0759)	0.6704*** (0.1152)	5.7065*** (0.6320)	0.3011 (0.9471)	0.9817*** (0.1416)	1.2884*** (0.2223)
R2	0.3585	0.4086	0.0955	0.1871	0.0432	0.0563
N	2790	2790	2790	2790	2790	2790

Standard errors in parentheses.
**$p < 0.05$, ***$p < 0.01$.

but has a significant negative impact on city transformation after taking in time and city fixed effects.

Heterogeneity Analysis

Cities vary due to their heterogeneity of the economic base, factor endowment structure, geographical environment, among others. In 1998, 175 cities in China were designated into Two Controlled Zones(TCZ) based on their severity of SO_2 and acid rain pollution, and the government applied a much draconian environmental policies in both controlled zones due to their serious pollution problems. The regression results in Table 3 show that the impacts of environmental regulations on GDP per square kilometer are significant in both TCZ and non-TCZ. The coefficients for discharge of sulfur dioxide and waste water in the TCZ are significantly positive, but they are not significant when a city belong to a non-TCZ, which implies that pollution status or climate is closely connected to urban development (Mi et al., 2019).

In addition, residents are the basic and major activity subject of a city, and they are producers and consumers. Human activities affect the implementation of environmental regulations and the city transformation. Therefore, we did the following heterogeneity analysis: identify whether a city belongs to TCZ, and identify whether a city is a small (population less than 1 million) or a medium-sized (population more than 1 million) city according to the 2012 population data.

The impacts of environmental regulations on city transformation by population size are more significant when environmental regulations are further strict in cities with larger populations. The impacts on GDP per square kilometer are greater in large cities than in smaller ones. The impacts on sulfur dioxide and waste water discharge are not significant in small-scale cities but significantly negative in large-scale cities which means significant suppression of sulfur dioxide emissions. The impacts of setting of key pollution areas on waste water discharge are greater in large-scale cities (Table 4).

Robustness Check

Based on above results, the strengthening of environmental regulations could inevitably promote the transformation of cities. However, this conclusion may still be affected by missing variables. In order to verify the robustness of the DID identification strategy, we conduct a robustness analysis as follows.

In order to further test the common trends prior to the implementation of environmental regulation in 2012 and observe whether the policy has a time lag effect, we apply an event study to discover the dynamic effects of

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Table 3. Heterogeneity Analysis1.

	(1)	(2)	(3)	(4)	(5)	(6)
	Two control zones			Non-two control zones		
	cgdp	SO_2	water	cgdp	SO_2	water
DID	0.0928** (0.0409)	−2.0760*** (0.2880)	−0.6006*** (0.0770)	0.1825*** (0.0225)	0.8113* (0.4211)	0.0587 (0.0593)
control	YES	YES	YES	YES	YES	YES
R2	0.3771	0.231	0.0753	0.7289	0.1506	0.0551
N	1800	1800	1800	990	990	990

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

Table 4. Heterogeneity Analysis2.

	(1)	(2)	(3)	(4)	(5)	(6)
	Population size < 100 Ten thousand			Population size ≥ 100100 Ten thousand		
	cgdp	SO_2	water	cgdp	SO_2	water
DID	0.1240*** (0.0184)	−0.2825 (0.2750)	−0.3066*** (0.0404)	0.1198** (0.0531)	−1.2587*** (0.3679)	−0.5390*** (0.1018)
Control	YES	YES	YES	YES	YES	YES
R2	0.7234	0.1409	0.1236	0.3511	0.2817	0.0600
N	1440	1440	1440	1350	1350	1350

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

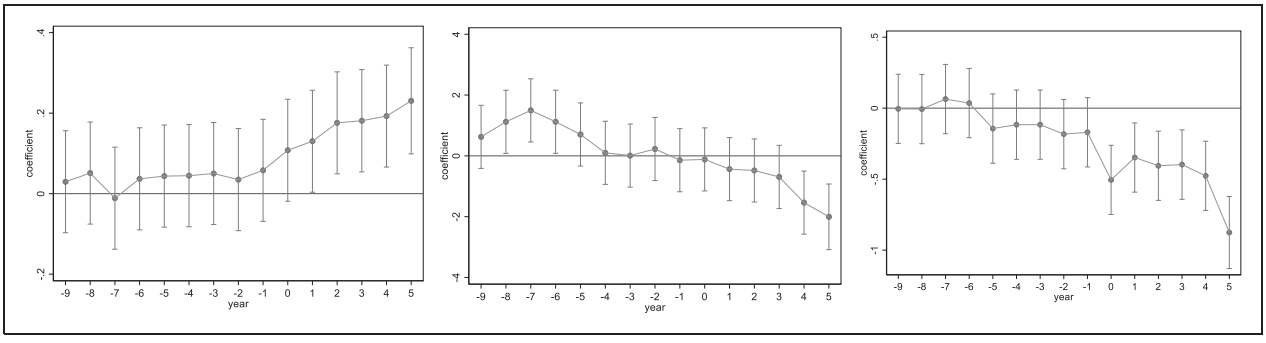


Figure 4. The Dynamic Impact of Environmental Regulations (cgdp, SO_2, Water).

KCA. The research framework is from Li et al. (2016). More specifically, we replace DID variable in Equation (1) with the a few time dummies including 9 years before and 5 year after the implementation.

$$Y_{it} = \alpha_0 + \prod_{s\geq -9}^{5} \beta_s D_s + \alpha_1 control_{it} + \eta_k + \gamma_t + \varepsilon_{it} \quad (2)$$

D_0 is a dumb variable in the year when the KCA policy was implemented,

s<0, these are the years before policy implementation,

s > 0, these are the years after policy implementation.

Figure 4 reports the estimated parameters $\{\beta_{-9}, \beta_{-8}, \beta_{-7}, \beta_{-6}, \beta_{-5}, \beta_{-4}, \beta_{-3}, \beta_{-2}, \beta_{-1}, \beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5\}$ with the corresponding 90% confidence interval. Figure 4 reports the dynamic effects of the estimated coefficients of the explained variables cgdp, SO_2 and water respectively. The estimation results not only verified the common trends, but also showed that the policy have positive impacts on urban transformation. It has a certain continuity, including promoting the growth of GDP per square kilometer and reducing the discharge of sulfur dioxide and wastewater.

In order to ensure the robustness of the above regression results, this paper further uses the PSM-DID method to analyze the policy effects of the establishment of atmospheric prevention and control planning in key regions. For comparison, we apply above control variables to predict the probability of air pollution prevention

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Table 5. Robustness Test Results1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Radius matching			Nuclear matching			Nearest neighbor matching	
	cgdp	SO_2	water	cgdp	SO_2	water	cgdp	SO_2	water
DID	0.1404*** (0.0282)	−1.3103*** (0.2319)	−0.4372*** (0.0543)	0.1404*** (0.0282)	−1.2928*** (0.2318)	−0.4408*** (0.0544)	0.1404*** (0.0282)	−1.2928*** (0.2318)	−0.4408*** (0.0544)
Control	YES	YES	YES	YES	YES	YES	YES	YES	YES
R2	0.4081	0.189	0.0556	0.4086	0.1871	0.0563	0.4086	0.1871	0.0563
N	2784	2784	2784	2790	2790	2790	2790	2790	2790

Standard errors in parentheses.
***$p < 0.01$.

and control in each city as a key area based on a Logit regression. Then, kernel matching, radius matching, and the nearest neighbor matching methods are applied to match the samples (treatment groups) of air pollution control in the key areas with the control group, and the results show that there is no significant difference between the treatment group and the control group before the establishment of the key prevention and control area. Therefore, the DID method was used to identify the net impact of the division of key areas on city transformation of development. Because the propensity score can solve the deviation of the observable covariate to the greatest extent, and the difference-in-difference method can eliminate the effect of unobserved variables such as time invariance and time synchronous change, so the combination of the two methods can better Identify policy effects. The regression results are shown in Table 5. The estimation results are consistent with the benchmark regression, and the establishment of air pollution prevention and control in the key areas estimated in this paper is stable to promote the transformation of city development (Table 5).

Our second robustness check is to change sample period. The regression in this article is mainly based on the sample of tropical and subtropical cities from 2000 to 2017, and the policies for the prevention and control of atmospheric pollution in key regions occurred in 2012, so the period before the policy may be too long. Moreover, in order to avoid the impact of the 2008 financial crisis, we selected a new sampling period 2009 to 2017, that is, three years before and five years after the reform. As shown in columns (4)–(6) of Table 6, the empirical results are still consistent with the baseline regression.

The third is to adjust the sample size. In baseline regression, cities with good economic development in both treatment group and control group, such as cities in the Yangtze River Delta and the Pearl River Delta, have higher level of industrialization in the post-industrial period due to their rapid economic development. Many policies from central government would be tilted to them somehow, which could lead to biased results. So, we remove cities in the Yangtze River Delta and the Pearl River Delta, and run the DID estimation again. The regression results are shown in Table 6. Compared with the baseline regression, the results are still significant.

The last is to add lagged one period of control variables. Considering that there may be a reverse effect between the selected variables and the establishment of air pollution control areas in key areas, to identify such a potential endogenous problem, all control variables are lagged by one period. The empirical results are shown in columns (7), (8) and (9) in Table 6. Results still hold similar to the baseline regression results.

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Table 6. Robustness Test Results2.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		non-YRD&non-PRD			2009–2017 year			Lags Control variable	
	cgdp	SO_2	water	cgdp	SO_2	water	cgdp	SO_2	water
DID	0.0783*** (0.0145)	−0.8781*** (0.2775)	−0.2937*** (0.0460)	0.1169*** (0.0377)	−0.9381*** (0.2892)	−0.3256*** (0.0841)	0.1398*** (0.0282)	−1.3336*** (0.2325)	−0.4409*** (0.0552)
Control	YES	YES	YES	YES	YES	YES	YES	YES	YES
L.control									
R2	0.7153	0.1531	0.0834	0.1026	0.2602	0.0448	0.3954	0.201	0.0559
N	2124	2124	2124	1395	1395	1395	2635	2635	2635

Standard errors in parentheses.
***$p < 0.01$.

The Mechanism of Environmental Regulation Promoting City Transformation

To better implement the environmental regulation and test the impact of environmental regulation on the urban transformation, the implementation of environmental regulations mainly promotes the change of business and industrial. The strict environmental regulations promote City Transformation, which internalizes production cost, increases firm'' technology substitution to adjust to the implementation. Some firms increase technology investment and expand business, while other firms might not be able to afford the extra cost and choose to reduce production and even shut business. City transformation is a function of industrial restructuring, that is, as the implementation of environmental regulation, secondary industrial activities reduce, service activities increase. The manufacturing upgrading and service industries expansion are the result of emission limitation, then the declining of relative proportion of manufacture and the industrial structure has been improvement, which ultimately promotes the city transformation. By "manipulating" the data, we try to identify the intermediate mechanism and transmission process in which policies affect urban transformation.

The empirical results of the first step are shown in Table 7. Column (1) reports the policy effects in product market. The establishment of air pollution in key regions has increased the productivity. Column (5) shows that the implementation of key regions promotes the increase in the ratio of tertiary industry to secondary industry. In the second step, to explore whether the policy has indirectly promoted economic performance through the construction of the corresponding key areas, we refer to the intermediary effect test method proposed by Wen et al. (2004). On the basis of the first step of identifying policy effects, we construct an intermediary effect test model. The results show that it meets the expectations of the intermediary variables. Curitiba has proved to the world with its achievements, that is, economy and environment are not in conflict, and survival and life are not in conflict. 80% of the employed population in Curitiba is invested in the service industry, especially the pollution-free and technology-intensive information service industry. Curitiba has the highest human development index in Brazil and becomes one of the most livable cities in the world (Deng, 2015; Gustafsson & Kelly, 2012). Economic development and environmental governance are not contradictory, and they have even achieved rapid development because of environmental governance.

Discussion

In the context of increasing environmental pollution, traditional economic growth that relies on resource

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Table 7. Mechanism Validity Test.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Productivity	cgdp	SO_2	Water	Instr	cgdp	SO_2	Water
DID	0.0288** (0.0131)	0.1929*** (0.0263)	−2.1062*** (0.2188)	−0.4274*** (0.0491)	0.1249*** (0.0205)	0.1856*** (0.0264)	−1.9503*** (0.2184)	−0.4224*** (0.0494)
Productivity		0.1122*** (0.0390)	−1.1441*** (0.3248)	−0.1243* (0.0729)				
Instr						0.0840*** (0.0249)	−1.5126*** (0.2061)	−0.0694 (0.0466)
Control	YES	YES	YES	YES	YES	YES	YES	YES
R2	0.3939	0.3605	0.0998	0.0443	0.0454	0.3613	0.1137	0.044
N	2790	2790	2790	2790	2790	2790	2790	2790

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

consumption urgently needs transformation. As a carrier of economic growth and development, cities are the main areas under environmental prevention and control. City transformation is necessary to achieve "both green water and green mountains, but also the green economy development" in practice of Chinese president Xi's "Two Mountains theory". This article starts from the natural experiment on the division of key areas in the Twelfth Five-Year Plan for the Prevention and Control of Atmospheric Pollution in Key Areas to study the impact of environmental regulations on city transformation. Based on the panel data of 155 prefecture-level cities in China's tropical and subtropical cities from 2000 to 2017, empirical analyses were conducted. The following conclusions can be made according to the results:

1. The prevention and control of the division of key areas has a significant promotion effect on the development and transformation of tropical and subtropical cities, especially in promoting the reduction of sulfur dioxide and wastewater emissions and the increase in GDP per capita as well as promoting the city transformation.
2. The impact of environmental regulations on city transformation is more significant in areas with larger populations and more serious pollution, and the division of key areas for differentiated prevention and control has worked.
3. The further discussion of its mechanism finds that the division of key areas mainly increases the internal adjustment cost or compliance cost of firms. Some enterprises increase technology investment, expand production and ultimately increase market shares, but other firms cannot afford the rising cost and choose to reduce production or even get out of the market. It brings about a screening effects for firms, that is, the productions of firms adapting to environmental regulations have increased, and the absolute size of the manufacturing industry has expanded. On the other hand, with the expansion of the service industry, the relative proportion of manufacturing has declined, and the urban industrial structure has been upgraded.

Implications for Conservation

The practical reference value of this article lies as follows for sustainable conservation and city transformation, especially in emerging countries:

1. In the short term, environmental regulation may be difficult to achieve a win-win situation on "pollution reduction" and "increasing efficiency", but people often ignore the long-term benefits after "pollution

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reduction", the hidden short-term costs, and long-term opportunity costs due to the pollution intensification by environmental regulation. The "sub-optimal" choice of "speed adjustment and shift" also has an important effect on the development and transformation of cities.

2. Creating a good institutional environment is of great significance for amplifying the effects of environmental regulation, such as adjusting the investment structure, formulating policy incentives and guiding funds to flow to service industries and high-tech industries, in order to promote the transformation and upgrading of urban industrial structures. Simultaneously, it is important to integrate the effectiveness of sustainable conservation, city transformation and institutional innovation into the local government assessment system, highlighting the government's policy guidance and service functions, and enabling government policies to play their due role in industrial structure transformation.
3. The environmental regulation policies should consider the endowment of the city, like pollution status and population size. Moreover, environmental regulations should in accordance with local conditions and strive to achieve a win-win situation of urban economic development, industrial structure upgrade and ecological environment improvement. Of course, our article also has certain shortcomings, the effects of environmental regulations, urban development, and transformation take a long period of time to test. Further studies are needed in this area.

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Note

1. China's tropical and subtropical cities have annual temperatures greater than 10°C, with annual precipitation of more than 1000 mm, and the population of the jurisdiction area accounts for 34% of the total urban population, located in the Qinling Mountains, south of the Huaihe River, and north of the Leizhou Peninsula, including the Yangtze River Delta and Pearl River Delta urban agglomerations and major industrial areas, the total economic volume is large. Due of data limitation, this study focuses on cities in mainland China, excluding Hong Kong, Macau, and Taiwan.

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