Air pollutions and its control governance in Chinese provinces in post-COVID-19 era: panel estimations of provincial environmental Kuznets curves

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Air Pollutions and its Control Governance in Chinese Provinces in Post-COVID-19 Era: Panel Estimations of Provincial Environmental Kuznets Curves

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Abstract

China's rapid industrialization and urbanization in recent decades have deteriorated its air environmental quality. This study focuses on air pollutions in terms of CO, NO2, O3, PM2.5, PM10, and SO2 in Chinese provinces. Although the heterogeneity of environmental Kuznets curves (EKCs) from Chinese provinces has been studied, the positions of provincial EKCs (which reflect the province-specific pollution effects not affected by the provincial income levels) have not been investigated to date. Therefore, through a factor analysis of the heterogeneity of provincial pollutions under the EKC framework, we investigate how the governance shortage for pollution control contributes to the provincial pollution levels. We found that the governance shortage for pollution control accounted for about 50-70% of the province-specific air pollution levels. Our results indicate that China still has a much policy space to mitigate air pollutions. Particularly, in the Post-COVID-19 Era when industrial activities are recovered, pollution-control governance would be vital to make China's economic growth sustainable.

Keywords: air pollutions, pollution-control governance, Chinese provinces, environmental Kuznets curve
JEL Classification: Q53, Q58, O53

1. Introduction

China's growth has significantly improved the country's living standards since the implementation of the Open-door policy and the Reform Policy in 1978. The economic status of China was promoted from the low-income category to the lower-middle-income category in 1997, and to upper-middle-income category in 2010, based on the World Bank income classification[1]. However, this rapid economic development resulted in serious damages to its environment through industrialization and urbanization. The government has recognized the environmental challenges confronting the country, and over the past decade has established environmental authorities and introduced a comprehensive legal framework to protect the environment. It has also set the numerical targets to reduce main pollutants and invested considerable resources to achieve the targets. It is said that these efforts can claim some successes, but much remains to be done.

Air pollution is one of the vital issues that influences the survival of human beings and the development of socio-economic systems. Two forces are responsible for much of China's air pollution. The first is China's extreme dependence on coal. In 2023, coal satisfies 55 per cent of China's demand for energy[2], making China the world's largest coal consumer. The second factor is China's booming cities. Rising urbanization, accompanied by increased automobile use and largely untreated emissions of municipal waste, has increased the portion of the population exposed to the greater pollution found in urban areas. The World Bank (2022) demonstrated that 42 percent of China's population still lives in areas that do not meet the World Health Organization air quality guidelines, and almost all Chinese cities have particulate matter 2.5 (PM2.5) concentrations above the WHO recommended thresholds. It estimated the direct economic losses to amount to about 0.5 percent of Gross Domestic Product annually. According to the Environmental Performance Index[3], China remains in 168th place among 180 countries in terms of air quality.

In addition to the nation-wide issue of air pollution, another vital concern in China is the regional heterogeneity of the pollution levels and the factors influencing them. The air pollution levels largely differ by provinces, and the income levels and pollution-control governance that affects pollution levels vary by provinces, as shown in Table 1. The gaps in provincial pollution levels are observed as follows: 33.0 times between Guangdong (the lowest) and Qinghai (the highest) in carbon monoxide (CO), 25.5 times between Guangdong and Qinghai in nitrogen dioxide (NO2), 39.9 times between

[1] See the website: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519.
[2] See the website of National Bureau of Statistics of China: https://www.stats.gov.cn/english/.
[3] See the website: https://epi.yale.edu/.

Guangdong and Tibet in ozone (O3), 26.3 times between Guangdong and Qinghai in fine particulate matter (PM2.5), 29.4 times between Guangdong and Ningxia in particulate matter (PM10), and 42.6 times between Guangdong and Qinghai in Sulfur dioxide (SO2). The gaps in the factors affecting the pollution levels are also found: 4.5 times between Beijing (the highest) and Gansu (the lowest) in gross regional product (GRP) per capita (*ypc*), and 2.6 times between Shanghai and Tibet in provincial governance indicator (*gov*).

The reason for picking up the provincial governance indicator is that provincial pollution levels depend on local governments' capacities for implementing environmental regulations. MacBean (2007) argued that despite the mass of laws and policy tools in place in China and the wide spread of environmental officials throughout the country the compliance with regulations seems to be poor. It pointed out, as the main reasons, the higher value placed on conventionally measured economic growth and job maintenance or expansion by other departments in local governments. Thus, China's environmental prospects appear to depend highly on how each province addresses the problems of the implementation of environmental protection.

Environmental issues have often studied by the analytical framework of the environmental Kuznets curve (EKC), and China's cases are no exception. However, the existing EKC analyses have so far concentrated on the EKC modalities depending on pollutants and provinces, and there have been no empirical studies to explicitly uncover the nexus between provincial pollution levels and its pollution-control governance. The motivation of this study is to fill this missing gap in the research on EKC-governance link in Chinese provinces.

This study focuses on the air pollution measures that cover CO, NO2, O3, PM2.5, PM10, and SO2 in Chinese provinces, and aims to investigate the contributions of pollution-control governance shortage to provincial pollution levels, through a factor analysis that evaluates the heterogeneity of provincial pollution under the analytical framework of the EKC. This study takes the following steps: (1) the EKC is estimated econometrically from the provincial panel data using a fixed-effect model; (2) the province-specific pollution effect is extracted from the fixed effect, which is not affected by the provincial income level on the EKC; (3) the alternative EKC is re-estimated by replacing the fixed-effect model with the pollution-control governance; and (4) the contribution of the governance shortage to the province-specific pollution level is quantified through a factor analysis. The main finding of this study is that the governance shortage for pollution control accounts for about 50-70% of provincial air pollution levels. Therefore, China still has capacity to mitigate air pollution levels via improvements in policy-implementations. Particularly, in the Post-COVID-19 Era when industrial activities are recovered, pollution-control governance would be vital to make China's economic growth sustainable.

The remainder of the paper is structured as follows. Section 2 reviews the literature elated to the EKC issues, including air pollution in China, and clarifies this study's contributions. Section 3 shows the materials and methods for the empirical study. Section 4 presents the estimation results and the discussion. Section 5 summarizes and concludes this paper.

2. Literature Review and Contributions

This section reviews the literature related to the EKC issues including air pollution EKC in China and clarifies this study's contributions.

The EKC provides an analytical framework to examine how economies deal with environmental issues. It postulates an inverted-U-shaped relationship between pollution and economic development. Kuznets's name was apparently attached to the curve by Grossman and Krueger (1995), who noted its resemblance to Kuznets' inverted-U relationship between income inequality and development. Dasgupta et al. (2002) describes the EKC dynamic process as follows: In the first stage of industrialization, pollution worsens rapidly because people are more interested in jobs and income than in clean air and water, and environmental regulation is correspondingly weak. Along the curve, pollution reduces in wealthy societies, because leading industrial sectors become cleaner, people value the environment, and regulatory institutions become more effective.

Since the report of the World Bank (1992) initially discussed EKC issues, empirical tests and theoretical debates have intensified, supporting the applicability of EKC for some regions and environment problems (e.g., Selden and Song 1994, Lopez 1994, Grossman and Krueger 1995, Stokey 1998). At the initial stage until the 1990s, most of the empirical studies focused on validating the EKC hypothesis and its requirements using cross-sectional data. Since the late 1990s, however, the EKC studies have shifted from cross-sectional analyses to time-series analyses, and more importantly, have examined the heterogeneity of EKCs from individual economies, in terms of the curve's shapes and positions. In this context, Dasgupta et al. (2002) presented three different EKC scenarios from the conventional inverted-U EKC: Race to the Bottom (pessimistic, with a continuation of the highest level of pollution), New Toxics (pessimistic with a higher curve, owing to the newly emerging pollutants), and Revised EKC (optimistic with a lower and flatter curve, owing to a better management of pollution). These scenarios have been subjected to empirical tests (e.g., Dinda 2004, Mukhopadhyay and Chakraborty

2005, Taguchi and Murofushi 2010, Taguchi 2012). Sarkodie and Strezov (2019) comprehensively reviewed the heterogeneity of the EKC modalities in terms of the curve's shapes and positions.

There is a large body of literature on EKC studies for several countries and for several levels of environmental quality. However, studies on the EKC of China have increased since the 2000s. Therefore, there is a relatively limited number of EKC studies, particularly on air pollution in China, that cover total provinces or specific areas (Table 2). Their estimations show ambiguous and mixed outcomes: some studies identify the validity of the inverted-U-shaped EKC (e.g., Yan et al. 2023, Moriwaki and Shimizu 2023, Xu et al. 2021, Chang et al. 2021, Wang et al. 2016, Chen and Chen 2015, Jayanthakumaran and Liu 2012, Song et al. 2008), whereas the others demonstrate that the EKC modality is dependent on regions (e.g., Song et al. 2021, Song et al. 2013) and pollutants (e.g., Cui et al. 2021, Li et al. 2016, Brajer et al. 2011, Liu et al. 2007), and invalid (e.g., Shen 2006).

The contributions of this study to the literature are highlighted as follows. First, this study covers all of the air pollutants (CO, NO2, O3, PM2.5, PM10, and SO2) in Chinese provinces, whereas the previous studies target selected air pollutants. Thus, this study's outcomes are comprehensively generalized to the issue on air pollution in China. Second, more importantly, this study elucidates the nexus between provincial pollution levels and its pollution-control governance. The previous studies have so far concentrated on the EKC's "shapes" depending on pollutants and provinces. This study focuses on analyzing the heterogeneity of EKCs in different Chinese provinces in terms of their "positions" that reflect the province-specific pollution effects that are not affected by the provincial income levels, and investigates the contributions of pollution-control governance shortage to the province-specific pollution levels.

3. Empirical Analyses

This section conducts empirics consisting of the EKC econometric estimations using provincial panel data and a factor analysis of the heterogeneity of the province-specific air pollutions. The section starts with the description of methodology and data.

3.1 Methodology and Data

This study basically follows the original form of the EKC, i.e., the standard nonlinear model where air pollution per capita is regressed by income per capita and its square. The first specification in Equation (1) applies a fixed-effect model for provincial panel-data estimation in order to explicitly demonstrate the province-specific pollution effect, and also runs the alternative models in Equation (2) by replacing the fixed-effect with a pollution-control governance indicator to elucidate the contribution of the governance shortage to the province-specific pollution levels. The equations for the estimation are specified as follows.

$$\ln(aco_{it}, ano_{it}, ao3_{it}, ap1_{it}, ap2_{it}, aso_{it}) = \alpha_0 + \alpha_1 \ln ypc_{it} + \alpha_2 (\ln ypc_{it})^2 + f_i + f_t + \varepsilon_t \quad (1)$$

$$\ln(aco_{it}, ano_{it}, ao3_{it}, ap1_{it}, ap2_{it}, aso_{it}) = \beta_0 + \beta_1 \ln ypc_{it} + \beta_2 (\ln ypc_{it})^2 + \beta_3\, gov_{it} + f_t + \varepsilon_t \quad (2)$$

where the subscripts i and t denote sample 31 Chinese provinces and years for 2014-2019, respectively; *aco*, *ano*, *ao3*, *ap1*, *ap2*, and *aso* represent air pollutants: CO, NO2, O3, PM2.5, PM10, and SO2, expressed as per 100 million persons, respectively[4]; *ypc* shows gross regional product (GRP) per capita in terms of yuan at constant prices in 2010; *gov* denotes a governance indicator,; f_i and f_t show a time-invariant country-specific fixed effect and a country-invariant time-specific fixed effect, respectively; ε denotes a residual error term; $\alpha_{0...2}$, and $\beta_{0...3}$ represent estimated coefficients, respectively; and "ln" shows a logarithm form, which is set to avoid scaling issues for the air pollutants and GRP per capita. The explanatory variables in Equations (1) and (3), *ypc* and *gov* are lagged by one year. This helps avoid reverse causality in the model specifications, including the endogenous interaction between the dependent and independent variables.

Regarding the data sources, the data of air pollutants are retrieved from the National Climatic Data Center (NCDC)[5]; the one of GRP per capita is from the China Statistical Yearbook; and the governance indicator is from the index of "development of market intermediaries and legal environment" as one of five aspect indices of the provincial-level "Index of Marketization" developed by the National Economic Research Institute of China Reform Foundation (NERI)[6]. This index takes the number ranging from 0 (weak governance) to 10 (strong governance).

The study constructs a set of panel data of sample 31 provinces and period for 2014-

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[4] In case of CO, the value is processed by 10 times because the negative value should be avoided in the logarithm term.

[5] See the website of NCDC: https://www.cnemc.cn/sssj/.The air pollutant data are collected from 2,033 observation sites, and compiled by averaging the data in each province.

[6] See the website: https://cmi.ssap.com.cn/. The impacts of the index on economic growth and total factor productivity are analyzed by Fan et al. (2019).

2019.[7] The variable list and the descriptive statistics for the variable data are displayed in Table 3 and 4, respectively.

The notes on the specifications of the estimation models in (1) and (2) are required for an additional description as follows. Equation (1) applies a fixed-effect model, represented by f_i and f_t, for provincial panel-data estimation. The Hausman test is generally used for choosing between a fixed-effect model and a random effect model (Hausman 1978). This study, however, focuses on demonstrating province-specific pollution effects explicitly and time-specific factors such as economic fluctuations due to external shocks should be considered. In addition, adopting the fixed-effect model contributes to alleviating the endogeneity problem by absorbing the unobserved time-invariant heterogeneity among the sample provinces. The estimation sets Guangdong as the benchmark province for extracting the province-specific pollution effects, because Guangdong shows the best performance in air pollution (Table 1). The significantly positive coefficient of the province-specific fixed effect suggests that the air pollution in the particular province is more serious than that in Guangdong. The ordinary hypothesis of the EKC postulating the inverted-U-shaped path between air pollution and GRP per capita would be verified if α_1, $\beta_1 > 0$ and α_2, $\beta_2 < 0$ a are significant.

Equations (2) represents the alternative models, replacing the province-specific fixed effects with the pollution-control governance indicator. No multicollinearity problem exists in the regressors' combinations in Equations (2), namely, (ypc, gov). This is because the variance inflation factors (VIFs), reflecting the level of collinearity between the regressors, indicate a lower value than the criteria of collinearity (10 points): the VIF values of *ypc* and *gov* in Equation (2) are 2.427, according to the authors' estimation. The governance indicator (*gov*) is expected to impart a negative coefficient for air pollution because the higher governance enables the mitigation of pollution.

This study applies the Poisson pseudo maximum likelihood (PPML) estimator for the estimations. The PPML estimator was selected because the sample data with heterogeneity in the provincial properties would be plagued by heteroskedasticity and autocorrelation; in such cases, the ordinary least squares (OLS) estimator leads to bias and inconsistency in the estimates. The PPML estimator corrects for heteroscedastic error structure across panels and autocorrelation with panels, as Silva and Tenreyro (2006) and Kareem et al. (2016) suggest. We used EViews (version 12) (IHS Global Inc., CA, USA) for processing the data and estimations.

3.2 Panel Unit Root and Cointegration Tests

[7] This study excludes the year of 2020 when the COVID-19 seriously affected economic activities.

For the subsequent estimation, we investigated the stationary property of the panel data by utilizing panel unit root tests, and if necessary, a panel cointegration test for a set of variables' data. The panel unit root tests were first conducted on the null hypothesis such that a level and/or the first difference of the individual data have a unit root. In cases where the unit root tests reveal that each variable's data are not stationary in the level, but stationary in the first difference, a set of variables' data correspond to the case of $I(1)$; this can be further examined using a co-integration test for the "level" data. If a set of variables' data are identified to have a co-integration, the use of the "level" data is justified for model estimation.

For the panel unit root tests, this study applied the Levin, Lin, and Chu test (Levin et al. 2002) as a common unit root test, and the Im, Pesaran, and Shin test (Im et al. 2003) as individual unit root tests. The common unit root test assumes a common unit root process across cross-sections, and the individual unit root test allows for individual unit root processes that vary across cross sections. For a panel co-integration test, the study used the Pedroni residual co-integration test developed by Pedroni (2004). All of the test equations contained an individual intercept, with the lag length being an automatic selection.

Table 5 presents the test results: the common unit root test does not reject the null hypothesis a unit root on the majority of variables' data and the individual tests do not reject it on any of them in their levels. However, both tests reject it in their first differences at the conventional significant levels. Thus, the variables almost follow the case of $I(1)$. The panel co-integration test is conducted further on the combinations of variables in Equations (2). The Pedroni residual co-integration test suggests that the level series of a set of variables' data are cointegrated in the respective combinations. Thus, this study utilizes the level data for the estimations.

4. Results and Discussions

Tables 6a–6f present the estimation results in the form of a log link function for air pollutants: CO (*aco*), NO2 (*ano*), O3 (*ao3*), PM2.5 (*ap1*), PM10 (*ap2*), and SO2 (*aso*), respectively. Columns (i) displays the outcomes of the fixed-effect models, and columns (ii) presents the results of the alternative models containing the pollution-control governance indicator (*gov*), instead of the fixed effects. The findings from the estimation results are summarized as follows.

4.1 EKC Identification by Fixed-Effect Model

First, the EKC hypothesis, which assumes the inverted-U-shaped relationship between air pollution level and GRP per capita (where the coefficients of the GRP per capita were significantly positive, and those of its square were significantly negative), is confirmed in the limited cases: the estimation of columns (i) on O3, PM2.5, PM10, and SO2. The reason why the EKC is not necessarily identified in all the estimations seems to be that the sample period for 2014-2019 is too short to form a clearly inverted-U-shaped path. This does not lead to serious problem because the main research focus in this study is the provincial EKC positions rather than their shapes.

4.2 Extraction of Provincial-Specific Pollution Effect

Second, the fixed-effect models in columns (i) identified the positive coefficients as the province-specific fixed effects at conventional significant levels on all the pollutants (CO, NO2, O3, PM2.5, PM10, and SO2) in all the provinces except for O3 in Sichuan. The positive provincial fixed effects mean that the provincial EKCs are located above Guangdong, which is the benchmark, suggesting that the province-specific pollution effects (not affected by the provincial income level on the EKC) are larger than those in Guangdong. These results are in line with the simple observations on air pollution in all the provinces in Table 1. The degree of air pollution was indicated by the magnitude of the coefficients of provincial fixed effects: the CO in Beijing (column (i) in Table 6a), for instance, is exp. (1.752) = 6 times larger than that in Guangdong.

4.3 Re-Estimation Results of Alternative EKC Model

Third, in the alternative model containing the pollution-control governance indicator capacity (*gov*) in columns (ii), the coefficients of *gov* are significantly negative in all the pollutants in Tables 6a–6f. The negative coefficients of *gov* for all the pollutants suggest that the pollution-control governance had, indeed, affected the provincial pollution levels and that the heterogeneity of provincial pollution could be explained by the differences in the provincial pollution-control governance. The joint estimation outcomes of the province-specific pollution effects and the workability of pollution-control governance lead to a question regarding the quantitative contributions of provincial governance shortage to the provincial pollution levels.

4.4 Factor Analysis on Pollution-Control Governance

We quantified the contributions of the provincial pollution-control governance to the province-specific pollution effects. Tables 7a–7f present the analytical outcomes for CO, NO2, O3, PM2.5, PM10, and SO2, respectively. Columns (a) repeats the provincial fixed effects in Tables 6a–6f, representing the province-specific pollution effects, respectively; column (b) presents the period average of provincial pollution-control governance indicators (*gov*); column (c) computes the *gov* deviations from that of Guangdong (the benchmark)—we exclude the those in Beijing, Tianjin, Shanghai and Zhejiang whose governance indicators are higher than that of Guangdong; columns (d) indicates the *gov* contributions to the provincial-specific pollution effects, by multiplying the *gov* deviations with the estimated *gov* coefficients in Tables 6a–6f; and columns (e) demonstrates the *gov* contribution ratios to provincial-specific pollution effects by dividing column (d) by column (a).

The first rows in column (e) of Tables 7a–7f demonstrate that the average *gov* contribution ratios among the sample provinces are 0.724 for CO, 0.680 for NO2, 1.226 for O3, 0.560 for PM2.5, 0.669 for PM10, and 0.471 for SO2. Thus, the governance shortage for pollution control accounts for about 50-70% of the province-specific air pollution levels except for the O3 case.

4.5 Discussions

The factor analysis above could verify that the province-specific pollutions are largely affected by the provincial pollution-control governance. This finding on the nexus between provincial pollution levels and its pollution-control governance is in line with the previous policy studies for Chinese provincial environment performances such as Zheng et al. (2015) and Wu and Gao (2021). Zheng et al. (2015) found empirical support for the positive impacts of provincial energy saving regulations and environmental standards on the improvement of local air quality in China. Wu and Gao (2021) pointed out the provincial difference in the efficiency of air pollution control arising from the heterogeneity of environmental regulations in Chinese provinces. Unlike these previous policy studies, this study’s contribution is demonstrating explicitly the governance impacts on air pollution in a quantitative way.

5. Conclusions

This study focused on the air pollutions in terms of CO, NO2, O3, PM2.5, PM10, and SO2 in Chinese provinces, and investigated the contribution of pollution-control governance shortage to the provincial pollution levels, through a factor analysis that evaluates the heterogeneity of provincial pollutions under the EKC framework. The study's contribution to the literature lies in its framework of analyzing the heterogeneity of Chinese provinces' EKCs in terms of their positions (not their shapes) by using a fixed-effect model in the EKC panel estimation to extract the province-specific pollution effects, and conducting a factor analysis to uncover the contribution of provincial pollution-control governance to the provincial pollutions.

The main findings from the empirical estimations are summarized as follows. First, the fixed-effect models confirmed that all the provinces had more serious air pollutions than Guangdong as province-specific effects. Second, the alternative models revealed that the province-specific air pollutions were significantly affected by provincial pollution-control governance. Third, the factor analysis demonstrated that the governance shortage for pollution control accounted for about 50-70% of the province-specific air pollution levels.

The policy implication of this study's empirical results is that China still has much policy space and room to mitigate air pollutions by enhancing the governance for pollution control, for instance, through the development and training of human resources. Particularly, in the Post-COVID-19 Era when industrial activities are recovered, pollution-control governance would be vital to make China's economic growth sustainable.

The limitations of this study include the shortage of detailed research on individual provinces and regions. China has regional heterogeneity in terms of pollution levels and in the factors affecting them. Examining the complexity of pollution mechanisms and the policy performances of specific regions through detailed case studies would make it possible to develop firm region-specific recommendations and prescriptions for the management of air pollutions in China.

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Table 1 Air Pollution and its Influential Variables in Chinese Provinces in 2019

	CO	*NO2*	*O3*	*PM2.5*	*PM10*	*SO2*	*ypc*	*gov*
Beijing	3.2	161.8	316.4	189.4	305.3	20.2	127,816	13.149
Tianjin	7.0	303.8	537.2	373.0	579.7	79.1	79,377	13.019
Hebei	1.3	52.0	96.9	67.2	127.1	20.9	37,909	10.855
Shanxi	3.2	110.2	208.4	141.3	274.9	67.9	40,851	8.440
Inner Mongolia	3.4	123.0	287.4	129.9	291.7	70.3	56,765	5.289
Liaoning	2.1	67.4	165.0	94.7	166.6	42.8	46,399	10.178
Jilin	3.1	103.6	257.6	144.2	253.5	45.2	39,585	9.286
Heilongjiang	1.8	62.3	177.5	92.6	165.1	32.8	33,595	8.848
Shanghai	2.7	165.9	309.9	143.7	194.2	27.5	121,299	14.297
Jiangsu	0.9	41.8	89.0	51.2	86.1	10.5	93,882	13.424
Zhejiang	1.1	51.3	105.2	49.4	84.7	10.8	78,860	13.134
Anhui	1.2	53.2	123.9	75.4	122.3	16.0	49,455	11.515
Fujian	1.6	47.7	160.4	58.1	98.6	16.0	83,630	12.344
Jiangxi	1.8	51.5	144.8	75.8	128.3	27.4	44,234	10.927
Shandong	0.8	35.5	79.9	50.7	96.5	13.5	56,397	11.349
Henan	0.9	35.1	76.3	61.7	103.5	11.1	42,522	9.708
Hubei	1.5	51.3	118.6	76.3	122.5	15.6	56,788	10.842
Hunan	1.3	37.7	97.8	64.5	91.6	13.6	49,459	9.748
Guangdong	0.6	21.7	53.9	21.8	36.9	6.5	68,259	13.669
Guangxi	1.7	42.3	112.8	61.7	101.7	21.5	33,915	9.033
Hainan	5.6	114.2	668.9	158.5	302.3	45.6	41,565	6.475
Chongqing	2.7	122.2	154.5	118.5	184.1	23.5	62,176	12.586
Sichuan	0.9	34.6	66.1	45.3	69.3	10.7	45,290	11.041
Guizhou	1.6	48.2	154.7	63.0	103.1	28.4	36,729	8.981
Yunnan	1.5	41.4	139.4	46.8	81.9	19.5	40,611	8.685
Tibet	15.1	397.1	2,150.2	290.7	741.6	158.5	39,917	5.454
Shaanxi	2.1	95.3	144.2	124.7	221.3	24.9	51,742	10.398
Gansu	2.7	103.9	292.2	114.1	273.2	55.8	28,171	9.640
Qinghai	19.8	553.4	1,215.5	573.0	1,105.0	276.9	38,082	7.412
Ningxia	11.0	413.3	1,021.2	444.1	1,086.3	234.0	43,180	9.320
Xinjiang	3.6	138.3	253.1	163.2	302.1	28.4	41,769	7.830

Notes: For the variable descriptions, see Table 2.

Table 2 Literature Review of EKC on Water Pollution in China

	Sample Areas	Air Pollutants	Summary
Yan et al. (2023)	30 provinces	SO2, soot, dust	Inverted-U shaped EKC
Moriwaki & Shimizu (2023)	291 cities	SO2	Inverted-U shaped EKC
Xu et al. (2021)	30 provinces	NOX	Inverted-U shaped EKC
Cui et al. (2021)	31 provinces	SO2, CO2, NOX, dust	EKC validity depends on pollutants
Song et al. (2021)	74 cities	Quality including atmosphere index	EKC shape depends on cities
Chang et al. (2021)	284 cities	PM2.5	Inverted-U shaped EKC
Li et al. (2016)	30 provinces	CO2, SO2	EKC validity depends on pollutants
Wang et al. (2016)	31 provinces	SO2	Inverted-U shaped EKC
Chen & Chen (2015)	31 provinces	CO2	Inverted-U shaped EKC
Song et al. (2013)	31 provinces	Waste gas emission	EKC shape depends on provinces
Jayanthakumaran & Liu (2012)	30 provinces	SO2	Inverted-U shaped EKC
Brajer et al. (2011)	139 cities	Composite indices	EKC shape depends on pollutants
Song et al. (2008)	29 provinces	Waste gas emission	Inverted-U shaped EKC
Liu et al. (2007)	Shenzhen	TSP, SO2, NOX	EKC shape depends on pollutants
Shen (2006)	31 provinces	SO2, dust	No existance of Inverted-U shaped EKC

Notes:
WW: Waste water discharge
COD: Chemical Oxygen Demand
NH_3-N, NH_4-N: Ammonia Nitrogen
TPH: total petroleum hydrocarbon
Sources: Author's description

Table 3 List of Variables

Variables	Description
Dependent Variable	
aco	*Carbon monoxide (CO), mg/m^3, per 100 million persons, logarithm*
ano	*Nitrogen dioxide (NO2), µg/m^3, per 100 million persons, logarithm*
ao3	*Ozone (O3), µg/m^3, per 100 million persons, logarithm*
ap1	*Fine particulate matter (PM2.5), µg/m^3, per 100 million persons, logarithm*
ap2	*Particulate matter (PM10), µg/m^3, per 100 million persons, logarithm*
aso	*Sulfur dioxide (SO2), µg/m^3, per 100 million persons, logarithm*
Explanatory Variables	
ypc	*Gross regional product (GRP) per capita, 2010 prices, RMB, one-year lagged, logarithm*
gov	*Governance indicator, "Development of market intermediary organizations and legal environment" in the "China Marketization Index" by Fan, et al. (2019), one-year lagged*

Sources: Author's description

Table 4 Descriptive Statistics

Variables	Obs.	Median	Std. Dev.	Min.	Max
Dependent Variable					
aco	186	3.078	0.841	1.808	5.607
ano	186	4.297	0.809	3.079	6.574
ao3	186	5.203	0.860	3.980	8.080
ap1	186	4.717	0.776	3.080	6.871
ap2	186	5.214	0.854	3.607	7.641
aso	186	3.786	0.937	1.879	6.658
Explanatory Variables					
ypc	186	10.542	0.392	9.901	11.714
gov	186	7.309	3.210	0.460	14.132

Sources: Author's calculation

Table 5 Panel Unit Root and Cointegration Tests

	Unit Root Test	
	Level	1st difference
	Levin, Lin and Chu	
aco	2.557	-15.368 ***
ano	-7.891 ***	-16.179 ***
ao3	-11.509 ***	-15.468 ***
ap1	1.213	-23.166 ***
ap2	0.549	-23.428 ***
aso	2.505	-18.957 ***
ypc	3.835	-8.925 ***
gov	-9.423 ***	-36.717 ***
	Im, Pesaran and Shin	
aco	4.986	-6.198 ***
ano	-0.851	-5.683 ***
ao3	-0.772	-4.398 ***
ap1	4.420	-8.412 ***
ap2	4.214	-6.340 ***
aso	6.815	-5.350 ***
ypc	8.363	-1.327 *
gov	-0.667	-14.838 ***
	Panel Cointegration Test	
	Panal ADF	Panel PP
group of		
aco	-4.085 ***	-4.819 ***
ano	-3.481 ***	-4.307 ***
ao3	-1.796 **	-2.911 ***
ap1	-6.050 ***	-7.801 ***
ap2	-5.649 ***	-4.971 ***
aso	-3.268 ***	-2.621 ***

Note: ***, **, and * denote statistical significance at 99, 95 and 90 percent level, respectively.
Sources: Author’s estimation

Table 6a Estimation Results: CO (a*co*)

Estimation	(i)	(ii)
ypc	0.253	0.004
	(1.299)	(0.023)
ypc^2	-0.006	0.041 **
	(-0.018)	(2.397)
gov		-0.187 ***
		(-6.361)
Dummy for fixed effect		
Beijing	1.752 ***	
Tianjin	2.490 ***	
Hebei	0.954 ***	
Shanxi	1.855 ***	
Inner Mongolia	1.731 ***	
Liaoning	1.292 ***	
Jilin	1.658 ***	
Heilongjiang	1.161 ***	
Shanghai	1.384 ***	
Jiangsu	0.363 ***	
Zhejiang	0.581 ***	
Anhui	0.789 ***	
Fujian	0.891 ***	
Jiangxi	1.116 ***	
Shandong	0.410 ***	
Henan	0.652 ***	
Hubei	0.967 ***	
Hunan	0.833 ***	
Guangxi	1.103 ***	
Hainan	2.237 ***	
Chongqing	1.488 ***	
Sichuan	0.446 ***	
Guizhou	1.057 ***	
Yunnan	1.053 ***	
Tibet	3.414 ***	
Shaanxi	1.503 ***	
Gansu	1.726 ***	
Qinghai	3.523 ***	
Ningxia	2.928 ***	
Xinjiang	1.977 ***	
Cross-sections	31	31
Periods	2014-2019	2014-2019
Total observations	186	186

Note: ***, and ** denote statistical significance at 99, and 95 percent level, respectively.
Sources: Author’s estimation

Table 6b Estimation Results: NO2 (*ano*)

Estimation	(i)	(ii)
ypc	0.567 ***	0.030
	(2.726)	(0.177)
ypc^2	-0.024	0.048 ***
	(-1.275)	(2.761)
gov		-0.157 ***
		(-5.479)
Dummy for fixed effect		
Beijing	2.124 ***	
Tianjin	2.620 ***	
Hebei	0.957 ***	
Shanxi	1.520 ***	
Inner Mongolia	1.697 ***	
Liaoning	1.163 ***	
Jilin	1.659 ***	
Heilongjiang	1.174 ***	
Shanghai	1.993 ***	
Jiangsu	0.644 ***	
Zhejiang	0.899 ***	
Anhui	0.859 ***	
Fujian	0.850 ***	
Jiangxi	0.852 ***	
Shandong	0.494 ***	
Henan	0.561 ***	
Hubei	0.901 ***	
Hunan	0.549 ***	
Guangxi	0.707 ***	
Hainan	1.735 ***	
Chongqing	1.735 ***	
Sichuan	0.487 ***	
Guizhou	0.998 ***	
Yunnan	0.656 ***	
Tibet	3.078 ***	
Shaanxi	1.457 ***	
Gansu	1.626 ***	
Qinghai	3.245 ***	
Ningxia	2.894 ***	
Xinjiang	1.887 ***	
Cross-sections	31	31
Periods	2014-2019	2014-2019
Total observations	186	186

Note: *** denotes statistical significance at 99 percent level.
Sources: Author's estimation

Table 6c Estimation Results: O3 (*ao3*)

Estimation	(i)	(ii)
ypc	5.196 ***	0.238
	(3.373)	(1.287)
ypc^2	-0.255 ***	0.038 **
	(-3.539)	(2.048)
gov		-0.197 ***
		(-6.315)
Dummy for fixed effect		
Beijing	2.103 ***	
Tianjin	2.266 ***	
Hebei	0.427 ***	
Shanxi	1.105 ***	
Inner Mongolia	1.588 ***	
Liaoning	1.005 ***	
Jilin	1.441 ***	
Heilongjiang	0.976 ***	
Shanghai	2.060 ***	
Jiangsu	0.646 ***	
Zhejiang	0.803 ***	
Anhui	0.535 ***	
Fujian	1.094 ***	
Jiangxi	0.785 ***	
Shandong	0.325 ***	
Henan	0.169 *	
Hubei	0.679 ***	
Hunan	0.423 ***	
Guangxi	0.662 ***	
Hainan	2.252 ***	
Chongqing	1.028 ***	
Sichuan	0.142	
Guizhou	0.888 ***	
Yunnan	0.709 ***	
Tibet	3.560 ***	
Shaanxi	0.954 ***	
Gansu	1.504 ***	
Qinghai	2.855 ***	
Ningxia	2.787 ***	
Xinjiang	1.334 ***	
Cross-sections	31	31
Periods	2014-2019	2014-2019
Total observations	186	186

Note: ***, **, and * denote statistical significance at 99, 95, and 90 percent level, respectively.
Sources: Author’s estimation

Table 6d Estimation Results: PM2.5 (*ap1*)

Estimation	(i)	(ii)
ypc	0.967 ***	0.332 **
	(4.533)	(2.086)
ypc^2	-0.060 ***	0.021
	(-3.034)	(1.342)
gov		-0.141 ***
		(-5.100)
Dummy for fixed effect		
Beijing	2.566 ***	
Tianjin	2.890 ***	
Hebei	1.022 ***	
Shanxi	1.619 ***	
Inner Mongolia	1.681 ***	
Liaoning	1.279 ***	
Jilin	1.720 ***	
Heilongjiang	1.225 ***	
Shanghai	2.079 ***	
Jiangsu	0.938 ***	
Zhejiang	0.949 ***	
Anhui	1.079 ***	
Fujian	0.951 ***	
Jiangxi	1.066 ***	
Shandong	0.765 ***	
Henan	0.823 ***	
Hubei	1.207 ***	
Hunan	0.886 ***	
Guangxi	0.841 ***	
Hainan	1.796 ***	
Chongqing	1.663 ***	
Sichuan	0.589 ***	
Guizhou	0.983 ***	
Yunnan	0.500 ***	
Tibet	2.757 ***	
Shaanxi	1.563 ***	
Gansu	1.454 ***	
Qinghai	3.138 ***	
Ningxia	2.943 ***	
Xinjiang	1.896 ***	
Cross-sections	31	31
Periods	2014-2019	2014-2019
Total observations	186	186

Note: *** and ** denote statistical significance at 99 and 95 percent level, respectively.
Sources: Author’s estimation

Table 6e Estimation Results: PM10 (*ap2*)

Estimation	(i)	(ii)
ypc	1.181 ***	0.448 ***
	(6.867)	(2.597)
ypc^2	-0.076 ***	0.017
	(-4.761)	(1.004)
gov		-0.173 ***
		(-5.836)
Dummy for fixed effect		
Beijing	2.570 ***	
Tianjin	2.924 ***	
Hebei	1.084 ***	
Shanxi	1.714 ***	
Inner Mongolia	2.040 ***	
Liaoning	1.315 ***	
Jilin	1.719 ***	
Heilongjiang	1.178 ***	
Shanghai	2.038 ***	
Jiangsu	1.025 ***	
Zhejiang	0.974 ***	
Anhui	0.988 ***	
Fujian	1.055 ***	
Jiangxi	1.031 ***	
Shandong	0.903 ***	
Henan	0.839 ***	
Hubei	1.173 ***	
Hunan	0.799 ***	
Guangxi	0.740 ***	
Hainan	1.894 ***	
Chongqing	1.604 ***	
Sichuan	0.523 ***	
Guizhou	0.910 ***	
Yunnan	0.566 ***	
Tibet	3.138 ***	
Shaanxi	1.691 ***	
Gansu	1.775 ***	
Qinghai	3.337 ***	
Ningxia	3.291 ***	
Xinjiang	2.032 ***	
Cross-sections	31	31
Periods	2014-2019	2014-2019
Total observations	186	186

Note: *** denotes statistical significance at 99 percent level.
Sources: Author’s estimation

Table 6f Estimation Results: SO2 (*aso*)

Estimation	(i)	(ii)
ypc	0.967 ***	0.332 **
	(4.533)	(2.086)
ypc^2	-0.060 ***	0.021
	(-3.034)	(1.342)
gov		-0.141 ***
		(-5.100)
Dummy for fixed effect		
Beijing	2.566 ***	
Tianjin	2.890 ***	
Hebei	1.022 ***	
Shanxi	1.619 ***	
Inner Mongolia	1.681 ***	
Liaoning	1.279 ***	
Jilin	1.720 ***	
Heilongjiang	1.225 ***	
Shanghai	2.079 ***	
Jiangsu	0.938 ***	
Zhejiang	0.949 ***	
Anhui	1.079 ***	
Fujian	0.951 ***	
Jiangxi	1.066 ***	
Shandong	0.765 ***	
Henan	0.823 ***	
Hubei	1.207 ***	
Hunan	0.886 ***	
Guangxi	0.841 ***	
Hainan	1.796 ***	
Chongqing	1.663 ***	
Sichuan	0.589 ***	
Guizhou	0.983 ***	
Yunnan	0.500 ***	
Tibet	2.757 ***	
Shaanxi	1.563 ***	
Gansu	1.454 ***	
Qinghai	3.138 ***	
Ningxia	2.943 ***	
Xinjiang	1.896 ***	
Cross-sections	31	31
Periods	2014-2019	2014-2019
Total observations	186	186

Note: *** and ** denote statistical significance at 99 and 95 percent level, respectively.
Sources: Author's estimation

Table 7a Provincial Pollutions and Pollution-Control Governance (CO)

CO	fixed effect (a)	*govg* (b)	(b) - Benchmark (c)	(c) × -0.187 (d)	(d) / (a) (e) av. 0.724
Beijing	1.752	11.684	-	-	-
Tianjin	2.490	11.870	-	-	-
Hebei	0.954	6.418	-4.551	0.851	0.891
Shanxi	1.855	5.098	-5.871	1.098	0.592
Inner Mongolia	1.731	2.785	-8.183	1.530	0.884
Liaoning	1.292	7.355	-3.614	0.676	0.523
Jilin	1.658	6.811	-4.157	0.777	0.469
Heilongjiang	1.161	7.797	-3.171	0.593	0.511
Shanghai	1.384	13.073	-	-	-
Jiangsu	0.363	9.192	-1.777	0.332	0.915
Zhejiang	0.581	12.444	-	-	-
Anhui	0.789	8.159	-2.809	0.525	0.665
Fujian	0.891	9.891	-1.078	0.201	0.226
Jiangxi	1.116	6.784	-4.184	0.782	0.701
Shandong	0.410	8.683	-2.286	0.427	1.042
Henan	0.652	6.882	-4.086	0.764	1.172
Hubei	0.967	6.565	-4.404	0.823	0.852
Hunan	0.833	7.304	-3.665	0.685	0.823
Guangxi	1.103	5.416	-5.552	1.038	0.941
Hainan	2.237	3.490	-7.478	1.398	0.625
Chongqing	1.488	9.109	-1.860	0.348	0.234
Sichuan	0.446	8.431	-2.538	0.474	1.064
Guizhou	1.057	3.664	-7.304	1.365	1.292
Yunnan	1.053	2.755	-8.213	1.535	1.458
Tibet	3.414	1.541	-9.428	1.763	0.516
Shaanxi	1.503	8.715	-2.253	0.421	0.280
Gansu	1.726	5.241	-5.728	1.071	0.620
Qinghai	3.523	2.473	-8.496	1.588	0.451
Ningxia	2.928	4.833	-6.135	1.147	0.392
Xinjiang	1.977	3.600	-7.368	1.378	0.697

Sources: Author’s estimation

Table 7b Provincial Pollutions and Pollution-Control Governance (NO2)

NO2	fixed effect (a)	*govg* (b)	(b) - Benchmark (c)	(c) × -0.157 (d)	(d) / (a) (e) av. 0.680
Beijing	2.124	11.684	-	-	-
Tianjin	2.620	11.870	-	-	-
Hebei	0.957	6.418	-4.551	0.716	0.748
Shanxi	1.520	5.098	-5.871	0.923	0.608
Inner Mongolia	1.697	2.785	-8.183	1.287	0.758
Liaoning	1.163	7.355	-3.614	0.568	0.489
Jilin	1.659	6.811	-4.157	0.654	0.394
Heilongjiang	1.174	7.797	-3.171	0.499	0.425
Shanghai	1.993	13.073	-	-	-
Jiangsu	0.644	9.192	-1.777	0.279	0.434
Zhejiang	0.899	12.444	-	-	-
Anhui	0.859	8.159	-2.809	0.442	0.514
Fujian	0.850	9.891	-1.078	0.169	0.199
Jiangxi	0.852	6.784	-4.184	0.658	0.773
Shandong	0.494	8.683	-2.286	0.359	0.727
Henan	0.561	6.882	-4.086	0.643	1.146
Hubei	0.901	6.565	-4.404	0.693	0.768
Hunan	0.549	7.304	-3.665	0.576	1.050
Guangxi	0.707	5.416	-5.552	0.873	1.234
Hainan	1.735	3.490	-7.478	1.176	0.678
Chongqing	1.735	9.109	-1.860	0.292	0.169
Sichuan	0.487	8.431	-2.538	0.399	0.819
Guizhou	0.998	3.664	-7.304	1.149	1.151
Yunnan	0.656	2.755	-8.213	1.292	1.968
Tibet	3.078	1.541	-9.428	1.483	0.482
Shaanxi	1.457	8.715	-2.253	0.354	0.243
Gansu	1.626	5.241	-5.728	0.901	0.554
Qinghai	3.245	2.473	-8.496	1.336	0.412
Ningxia	2.894	4.833	-6.135	0.965	0.333
Xinjiang	1.887	3.600	-7.368	1.159	0.614

Sources: Author’s estimation

Table 7c Provincial Pollutions and Pollution-Control Governance (O3)

O3	fixed effect (a)	*govg* (b)	(b) - Benchmark (c)	(c) × -0.197 (d)	(d) / (a) (e) av. 1.226
Beijing	2.103	11.684	-	-	-
Tianjin	2.266	11.870	-	-	-
Hebei	0.427	6.418	-4.551	0.895	2.097
Shanxi	1.105	5.098	-5.871	1.154	1.044
Inner Mongolia	1.588	2.785	-8.183	1.609	1.013
Liaoning	1.005	7.355	-3.614	0.710	0.707
Jilin	1.441	6.811	-4.157	0.817	0.567
Heilongjiang	0.976	7.797	-3.171	0.623	0.639
Shanghai	2.060	13.073	-	-	-
Jiangsu	0.646	9.192	-1.777	0.349	0.541
Zhejiang	0.803	12.444	-	-	-
Anhui	0.535	8.159	-2.809	0.552	1.033
Fujian	1.094	9.891	-1.078	0.212	0.194
Jiangxi	0.785	6.784	-4.184	0.823	1.048
Shandong	0.325	8.683	-2.286	0.449	1.383
Henan	0.169	6.882	-4.086	0.803	4.740
Hubei	0.679	6.565	-4.404	0.866	1.274
Hunan	0.423	7.304	-3.665	0.720	1.704
Guangxi	0.662	5.416	-5.552	1.091	1.648
Hainan	2.252	3.490	-7.478	1.470	0.653
Chongqing	1.028	9.109	-1.860	0.366	0.356
Sichuan	0.142	8.431	-2.538	0.499	3.510
Guizhou	0.888	3.664	-7.304	1.436	1.617
Yunnan	0.709	2.755	-8.213	1.614	2.277
Tibet	3.560	1.541	-9.428	1.853	0.521
Shaanxi	0.954	8.715	-2.253	0.443	0.464
Gansu	1.504	5.241	-5.728	1.126	0.749
Qinghai	2.855	2.473	-8.496	1.670	0.585
Ningxia	2.787	4.833	-6.135	1.206	0.433
Xinjiang	1.334	3.600	-7.368	1.448	1.086

Sources: Author’s estimation

Table 7d Provincial Pollutions and Pollution-Control Governance (PM2.5)

PM2.5	fixed effect (a)	*govg* (b)	(b) - Benchmark (c)	(c) × -0.141 (d)	(d) / (a) (e) av. 0.560
Beijing	2.566	11.684	-	-	-
Tianjin	2.890	11.870	-	-	-
Hebei	1.022	6.418	-4.551	0.639	0.626
Shanxi	1.619	5.098	-5.871	0.825	0.510
Inner Mongolia	1.681	2.785	-8.183	1.150	0.684
Liaoning	1.279	7.355	-3.614	0.508	0.397
Jilin	1.720	6.811	-4.157	0.584	0.340
Heilongjiang	1.225	7.797	-3.171	0.446	0.364
Shanghai	2.079	13.073	-	-	-
Jiangsu	0.938	9.192	-1.777	0.250	0.266
Zhejiang	0.949	12.444	-	-	-
Anhui	1.079	8.159	-2.809	0.395	0.366
Fujian	0.951	9.891	-1.078	0.151	0.159
Jiangxi	1.066	6.784	-4.184	0.588	0.551
Shandong	0.765	8.683	-2.286	0.321	0.420
Henan	0.823	6.882	-4.086	0.574	0.697
Hubei	1.207	6.565	-4.404	0.619	0.513
Hunan	0.886	7.304	-3.665	0.515	0.581
Guangxi	0.841	5.416	-5.552	0.780	0.927
Hainan	1.796	3.490	-7.478	1.051	0.585
Chongqing	1.663	9.109	-1.860	0.261	0.157
Sichuan	0.589	8.431	-2.538	0.357	0.606
Guizhou	0.983	3.664	-7.304	1.026	1.044
Yunnan	0.500	2.755	-8.213	1.154	2.307
Tibet	2.757	1.541	-9.428	1.325	0.481
Shaanxi	1.563	8.715	-2.253	0.317	0.203
Gansu	1.454	5.241	-5.728	0.805	0.553
Qinghai	3.138	2.473	-8.496	1.194	0.380
Ningxia	2.943	4.833	-6.135	0.862	0.293
Xinjiang	1.896	3.600	-7.368	1.035	0.546

Sources: Author’s estimation

Table 7e Provincial Pollutions and Pollution-Control Governance (PM10)

PM10	fixed effect (a)	*govg* (b)	(b) - Benchmark (c)	(c) × -0.173 (d)	(d) / (a) (e) av. 0.669
Beijing	2.570	11.684	-	-	-
Tianjin	2.924	11.870	-	-	-
Hebei	1.084	6.418	-4.551	0.788	0.727
Shanxi	1.714	5.098	-5.871	1.016	0.593
Inner Mongolia	2.040	2.785	-8.183	1.417	0.694
Liaoning	1.315	7.355	-3.614	0.626	0.476
Jilin	1.719	6.811	-4.157	0.720	0.419
Heilongjiang	1.178	7.797	-3.171	0.549	0.466
Shanghai	2.038	13.073	-	-	-
Jiangsu	1.025	9.192	-1.777	0.308	0.300
Zhejiang	0.974	12.444	-	-	-
Anhui	0.988	8.159	-2.809	0.486	0.492
Fujian	1.055	9.891	-1.078	0.187	0.177
Jiangxi	1.031	6.784	-4.184	0.724	0.703
Shandong	0.903	8.683	-2.286	0.396	0.438
Henan	0.839	6.882	-4.086	0.707	0.843
Hubei	1.173	6.565	-4.404	0.762	0.650
Hunan	0.799	7.304	-3.665	0.634	0.794
Guangxi	0.740	5.416	-5.552	0.961	1.299
Hainan	1.894	3.490	-7.478	1.295	0.684
Chongqing	1.604	9.109	-1.860	0.322	0.201
Sichuan	0.523	8.431	-2.538	0.439	0.840
Guizhou	0.910	3.664	-7.304	1.264	1.389
Yunnan	0.566	2.755	-8.213	1.422	2.510
Tibet	3.138	1.541	-9.428	1.632	0.520
Shaanxi	1.691	8.715	-2.253	0.390	0.231
Gansu	1.775	5.241	-5.728	0.992	0.559
Qinghai	3.337	2.473	-8.496	1.471	0.441
Ningxia	3.291	4.833	-6.135	1.062	0.323
Xinjiang	2.032	3.600	-7.368	1.276	0.628

Sources: Author’s estimation

Table 7f Provincial Pollutions and Pollution-Control Governance (SO2)

SO2	fixed effect (a)	*govg* (b)	(b) - Benchmark (c)	(c) × -0.160 (d)	(d) / (a) (e) av. 0.471
Beijing	1.404	11.684	-	-	-
Tianjin	2.617	11.870	-	-	-
Hebei	1.491	6.418	-4.551	0.728	0.488
Shanxi	2.712	5.098	-5.871	0.939	0.346
Inner Mongolia	2.393	2.785	-8.183	1.309	0.547
Liaoning	1.982	7.355	-3.614	0.578	0.292
Jilin	2.167	6.811	-4.157	0.665	0.307
Heilongjiang	1.794	7.797	-3.171	0.507	0.283
Shanghai	1.690	13.073	-	-	-
Jiangsu	0.739	9.192	-1.777	0.284	0.384
Zhejiang	0.692	12.444	-	-	-
Anhui	1.111	8.159	-2.809	0.449	0.404
Fujian	0.826	9.891	-1.078	0.172	0.209
Jiangxi	1.647	6.784	-4.184	0.669	0.406
Shandong	1.029	8.683	-2.286	0.366	0.355
Henan	0.989	6.882	-4.086	0.654	0.661
Hubei	1.007	6.565	-4.404	0.705	0.699
Hunan	0.986	7.304	-3.665	0.586	0.594
Guangxi	1.320	5.416	-5.552	0.888	0.673
Hainan	1.747	3.490	-7.478	1.196	0.685
Chongqing	1.391	9.109	-1.860	0.298	0.214
Sichuan	0.696	8.431	-2.538	0.406	0.583
Guizhou	1.633	3.664	-7.304	1.169	0.716
Yunnan	1.280	2.755	-8.213	1.314	1.027
Tibet	3.298	1.541	-9.428	1.508	0.457
Shaanxi	1.514	8.715	-2.253	0.361	0.238
Gansu	2.439	5.241	-5.728	0.916	0.376
Qinghai	3.838	2.473	-8.496	1.359	0.354
Ningxia	3.969	4.833	-6.135	0.982	0.247
Xinjiang	1.659	3.600	-7.368	1.179	0.710

Sources: Author’s estimation