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Factors Influencing Air Quality in Chengdu: A Multiple Linear Regression Analysis

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Abstract

Fine particulate matter ($PM_{2.5}$), a key pollutant under priority control in Chengdu, has significant adverse effects on public health and urban visibility. Constrained by the special topography of the Sichuan Basin, Chengdu has weak atmospheric dispersion conditions and faces considerable pressure on its living environment amid industrialization and urbanization. To investigate how gaseous pollutants affect $PM_{2.5}$ concentrations, this paper uses monthly air quality monitoring data from January 2018 to December 2023 released by the Chengdu Ecological and Environmental Bureau and employs Stata to construct a multiple linear regression model. With monthly average $PM_{2.5}$ concentration as the dependent variable, the study focuses on the marginal effects of ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) concentrations, and introduces monthly dummy variables to control for seasonal meteorological interference. The empirical results show that O_3 has a significant positive effect on $PM_{2.5}$, suggesting that ozone, as a strong oxidant, may promote the secondary formation of $PM_{2.5}$. The coefficients of CO and NO_2 are both significantly positive, indicating that vehicle exhaust and the incomplete combustion of fossil fuels remain important drivers of $PM_{2.5}$ in Chengdu. SO_2 does not pass the significance test, which is consistent with the fact that SO_2 concentrations in Chengdu have dropped to very low levels in recent years, implying that its marginal effect is limited. Based on these empirical findings, the paper also puts forward relevant recommendations.

Keywords

$PM_{2.5}$; Gaseous Pollutants; Multiple Linear Regression; Chengdu; Air Quality

1. Introduction

Ecological civilization construction is a fundamental task concerning the sustainable development of the Chinese nation, and the development philosophy that “lucid waters and lush mountains are invaluable assets” profoundly reveals the dialectical relationship between economic development and environmental protection. However, in the process of advancing modernization, air pollution has always been an unavoidable global challenge. Looking back at history, the 19th-century Industrial Revolution in Britain greatly raised productivity levels while also

imposing heavy environmental costs. London was known as the "City of Fog" due to severe coal-smoke pollution, and its pungent yellow smog triggered a serious public health crisis. This historical lesson shows that extensive economic growth is inevitably accompanied by a deterioration in environmental quality.

As the capital of Sichuan Province and an important manufacturing base and comprehensive transportation hub in western China, Chengdu has seen accelerating urbanization and industrialization in recent years. However, constrained by the special topography of the Sichuan Basin and meteorological conditions characterized by low wind speed and scarce precipitation, the local capacity for pollutant dispersion is weak, and air pollution problems have become increasingly prominent. Declining air quality not only reduces urban visibility and affects residents' daily travel but also directly induces various respiratory and cardiovascular diseases, posing a serious threat to public health.

To curb the deterioration of air quality, Chengdu has in recent years formulated and implemented a series of policy documents, including the Chengdu 2023 Air Pollution Prevention and Control Action Plan, which set clear air quality improvement targets and vigorously promoted clean energy substitution, an increased share of electricity consumption, and the spread of new energy vehicles and related infrastructure. Against this background, empirically identifying the main drivers of air quality in Chengdu can not only provide data support for the effectiveness of current environmental policies but also have important practical significance for achieving targeted policy measures and long-term improvement of the urban living environment in the future.

Based on the above background, the purpose of this paper is to empirically examine the specific effects of atmospheric gaseous pollutants on $PM_{2.5}$ concentrations using monthly air quality data from Chengdu from January 2018 to December 2023. The research content mainly includes the following: First, it reviews the sources and formation mechanisms of major pollutants such as $PM_{2.5}$, O_3, CO, and NO_2. Second, with monthly average $PM_{2.5}$ concentration as the dependent variable and O_3, CO, NO_2, and SO_2 concentrations as core explanatory variables, it constructs a multiple linear regression model while introducing monthly dummy variables to control for seasonal meteorological factors. Third, based on the empirical results, it identifies the key drivers affecting $PM_{2.5}$ concentrations in Chengdu. Fourth, combined with the topographic characteristics of the Chengdu Basin and pollution sources, it proposes targeted recommendations for improving air quality.

1.1. Literature Review

To date, domestic and international scholars have conducted extensive empirical research on the factors influencing urban air quality. In terms of indicator selection, early studies mostly used the Air Quality Index (AQI) or single pollutants such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) as evaluation criteria. With the intensification of complex atmospheric pollution, $PM_{2.5}$ and ozone (O_3) have

gradually become core indicators in this field.

In terms of research methods, multiple linear regression models have been widely applied in empirical analyses of urban air quality because of their strong explanatory power and intuitive results. Xu et al. (2024), based on air quality monitoring data from Dongguan from 2013 to 2019, used a multiple linear regression model for empirical testing and found that the key pollutants under priority control in Dongguan were $PM_{2.5}$, O_3, and NO_2, on which basis they proposed recommendations for improving the ecological environment [3]. Wang (2021) focused on the accuracy of monitoring data and used multiple stepwise regression and partial least squares regression models to calibrate data from self-built monitoring stations, thereby improving data reliability [1]. In addition, some scholars have focused on governance policies and natural factors. For example, Wang (2024) reviewed air pollution prevention and control measures from the perspectives of domestic, industrial, and transportation pollution sources [2], while Liu et al. (2025) assessed the health risks of pollution in Anyang based on the Air Quality Health Index (AQHI) and found a significant trend of superimposed particulate matter and ozone pollution in spring [4].

Overall, existing studies provide a solid theoretical and methodological foundation for this paper, but the following gaps remain. First, existing empirical studies mostly focus on plain or coastal cities such as those in the Beijing–Tianjin–Hebei region and the Pearl River Delta, while dedicated studies on cities under the special topography of the Sichuan Basin, such as Chengdu, are relatively scarce. Second, most studies directly use AQI as the dependent variable without fully considering the mathematical nesting relationship between AQI and its component pollutants, making it difficult to precisely identify the marginal effects of individual pollutants, such as the effects of gaseous pollutants on $PM_{2.5}$. Therefore, this paper takes Chengdu as the research object, focuses the dependent variable on monthly average $PM_{2.5}$ concentration, and examines in particular the effects of gaseous pollutants such as O_3, CO, and NO_2 on it, in order to provide more targeted empirical evidence for the governance of complex atmospheric pollution in basin cities.

2. Key Concepts

The mainstream domestic and international literature on air pollutants mainly involves the following pollutants:

(1) Fine particulate matter ($PM_{2.5}$): refers to particulate matter with a diameter of 2.5 micrometers or less, which can penetrate the respiratory tract and enter the alveoli and is one of the pollutants most harmful to public health. Its sources include primary emissions such as industrial coal combustion, vehicle exhaust, and road dust, as well as secondary particulate matter formed from gaseous pollutants through photochemical reactions. This paper uses it as the dependent variable.

(2) Inhalable particulate matter (PM_{10}): refers to particulate matter with a particle

size of 10 micrometers or less. Its sources partially overlap with those of $PM_{2.5}$ but are more strongly affected by road dust and construction dust. Because PM_{10} includes $PM_{2.5}$ in terms of particle size range and the two are highly correlated, including both in the model simultaneously would easily produce severe multicollinearity. Therefore, this paper introduces it in the conceptual section but retains only $PM_{2.5}$ as the particulate matter indicator in the empirical model.

(3) Ozone (O_3): a typical secondary pollutant, mainly generated by the reaction of nitrogen oxides (NO_2) and volatile organic compounds under sunlight. O_3 is not only the primary exceeding-standard factor in summer but, as a strong oxidant, can also participate in the secondary formation of $PM_{2.5}$. It is therefore included in the model to examine its effect on particulate matter.

(4) Nitrogen dioxide (NO_2): mainly originates from vehicle exhaust and industrial combustion and is a typical indicator of traffic sources and combustion sources. NO_2 is both a precursor of O_3 and shares the same origin as primary $PM_{2.5}$ emissions, making it an important intermediate variable linking gaseous pollutants and particulate matter.

(5) Carbon monoxide (CO): mainly comes from the incomplete combustion of fossil fuels and biomass, with emissions particularly prominent under vehicle idling and congested driving conditions. Changes in CO concentration can reflect the intensity of combustion sources and traffic sources and serve as an important accompanying indicator of primary $PM_{2.5}$ emissions.

(6) Sulfur dioxide (SO_2): mainly originates from the combustion of sulfur-containing coal and industrial coal burning and is a typical indicator of coal-burning sources. In recent years, SO_2 concentrations in Chengdu have dropped to relatively low levels, with limited monthly fluctuation.

3. Model Specification and Empirical Analysis

3.1. Variables and Data

This paper selects monthly air quality data for Chengdu from January 2018 to December 2023 as the research sample. The data are sourced from the Chengdu Ecological and Environmental Bureau, yielding a total of 72 observations. Regarding the dependent variable, since the Air Quality Index (AQI) is synthesized from six sub-indices, directly regressing it on individual pollutants can easily produce spurious correlation due to mathematical nesting. Therefore, this paper selects the monthly average concentration of fine particulate matter ($PM_{2.5}$), the primary pollutant in Chengdu, as the dependent variable.

For the core explanatory variables, this paper selects the monthly average concentrations of ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) to focus on the marginal effects of gaseous pollutants and secondary photochemical pollution on $PM_{2.5}$ concentrations. During the preliminary variable screening, inhalable particulate matter (PM_{10}) was excluded from the final

model because its particle size range includes $PM_{2.5}$, resulting in severe multicollinearity. In addition, given the significant seasonal characteristics of air pollution, monthly dummy variables are introduced as control variables to isolate the interference of meteorological cycles such as temperature and precipitation. Regarding units of measurement, the concentrations of $PM_{2.5}$, NO_2, O_3, and SO_2 are measured in μg/m^3, while CO is measured in mg/m^3.

3.2. Model Specification

Based on the above variable settings, this paper establishes the following multiple linear regression equation to quantitatively measure the effects of O_3, CO, NO_2, and SO_2 on $PM_{2.5}$ concentrations in Chengdu:

$$PM_{2.5,t} = \alpha + \beta_1 O_{3,t} + \beta_2 CO_t + \beta_3 NO_{2,t} + \beta_4 SO_{2,t} + \gamma_m Month_m + \mu_t \quad (1)$$

α is the intercept, β_1 to β_4 are the core parameters to be estimated, and μ_t is the random error term.

3.3. Descriptive Statistics

Table 1 reports the descriptive statistics of the variables, with a sample size of 72 observations. The average concentration of $PM_{2.5}$ is 42.14 μg/m^3 with a standard deviation of 18.42, and the maximum value reaches 86 μg/m^3, indicating that $PM_{2.5}$ concentrations in Chengdu were at a relatively high level during the sample period with significant monthly fluctuations. The mean concentration of O_3 reaches 133.86 μg/m^3, with a maximum value of 229 μg/m^3, suggesting that ozone pollution has become a non-negligible environmental issue in Chengdu. The mean of CO is 0.97 mg/m^3 with a small standard deviation of 0.22, indicating that its monthly concentration is relatively stable. The mean concentration of SO_2 is only 5.90 μg/m^3, remaining at a low level. Overall, the data of all variables are reasonably distributed without obvious outliers, meeting the basic requirements for subsequent regression analysis.

Table 1. Descriptive Statistics of Variables

Variable	Obs	Mean	Std. dev	Min	Max
PM2.5	72	42.13889	18.42098	18	86
O3	72	133.8611	50.73663	52	229
CO	72	0.970833	0.222937	0.7	1.5
NO2	72	36.52778	10.54964	17	62
SO2	72	5.902778	2.182902	3	12

3.4. Multicollinearity Test

To test whether severe multicollinearity exists among the explanatory variables, this paper calculates the Variance Inflation Factor (VIF) for the final regression model. As shown in Table 2, the VIF values for the core explanatory variables O_3, CO, NO_2, and

SO_2 are 9.79, 7.84, 9.61, and 4.18, respectively, all of which are below the commonly used threshold of 10. The mean VIF of the model is 5.25. In addition, the monthly dummy variables included in the model also have VIF values within a reasonable range. This indicates that there is no severe multicollinearity among the explanatory variables, and the model estimation results are reliable.

Table 2. Multicollinearity Test Results (VIF)

Variable	VIF	1/VIF
O_3	9.79	0.1022
CO	7.84	0.1275
NO_2	9.61	0.1041
SO_2	4.18	0.2393
Average VIF	5.25	—

3.5. Regression Analysis

The parameters of the above equation were estimated using Ordinary Least Squares (OLS) in Stata software, and the regression results are reported in Table 3.:

Table 3. Regression Analysis Results

Variable	$PM_{2.5}$
O_3	0.131 ***
	(0.031)
CO	14.262**
	(6.305)
NO_2	0.346**
	(0.147)
SO_2	-0.125
	(0.0165)
Constant	31.841***
	(5.538)
Month FE	YES
Observations	72
R2	0.958

Note. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 3 reports the multiple linear regression results for the factors influencing $PM_{2.5}$ concentrations in Chengdu. Overall, the R-squared (R^2) is 0.958, indicating a good model fit; the core explanatory variables and monthly dummy variables can explain the vast majority of the variation in $PM_{2.5}$ concentrations.

Regarding the core explanatory variables:

First, O_3 has a significant positive effect on $PM_{2.5}$. The regression coefficient of O_3 is 0.131 and is significant at the 1% level, indicating that, holding other conditions constant, a 1 $\mu g/m^3$ increase in O_3 concentration is associated with an average increase of 0.131 $\mu g/m^3$ in $PM_{2.5}$ concentration. This indirectly corroborates the characteristics of complex atmospheric pollution: as a strong oxidant, O_3 can alter atmospheric oxidizing capacity and accelerate the conversion of gaseous pollutants into secondary particulate matter. The frequently superimposed ozone and particulate matter pollution in Chengdu during summer is closely related to this

mechanism.

Second, CO and NO_2 also have significant positive effects on $PM_{2.5}$ concentrations. The coefficients of CO and NO_2 are 14.262 and 0.346, respectively, both of which are significantly positive at the 5% level. CO and NO_2 are typical indicators of incomplete fossil fuel combustion and motor vehicle exhaust emissions. The significant positive effects of these two variables directly indicate that traffic and industrial combustion sources remain important drivers of $PM_{2.5}$ in Chengdu.

Third, the marginal effect of SO_2 is not significant. The coefficient of SO_2 is -0.125 with a p-value of 0.791, failing to pass the significance test. This is highly consistent with the current governance situation in Chengdu in recent years: with the advancement of clean energy substitution and industrial desulfurization, SO_2 concentrations have dropped to a very low level (with a sample-period mean of only 5.90 $\mu g/m^3$) and exhibit minimal monthly fluctuations, thus showing weak independent explanatory power for $PM_{2.5}$. This also suggests that the current focus of $PM_{2.5}$ governance in Chengdu has shifted from traditional coal-fired sulfide control to the coordinated control of vehicle exhaust and secondary conversion.

3.6. Robustness Check

Considering the potential skewed distribution of pollutant concentration data and to test the sensitivity of the regression results to the functional form of the dependent variable, this paper further replaces the dependent variable $PM_{2.5}$ with its natural logarithm ($lnPM_{2.5}$) and re-estimates the regression while keeping the core explanatory variables and control variables unchanged. The results are reported in Table 4.

As shown in Table 4, the coefficient of O_3 is 0.0036, significantly positive at the 1% level; the coefficient of NO_2 is 0.0106, significantly positive at the 1% level; and the coefficient of SO_2 is -0.005, which does not pass the significance test. The signs and significance levels of these three variables are consistent with the baseline regression. The coefficient of CO is 0.221, maintaining a positive sign but failing to pass the significance test ($p = 0.117$). This is mainly because CO and NO_2 are highly homologous, both originating from vehicle exhaust and fossil fuel combustion, with a correlation coefficient of 0.84 between them. After the logarithmic transformation, NO_2 absorbs part of the explanatory power of CO, leading to a decrease in the estimation precision of CO. Overall, the directions of the core explanatory variables are not reversed, and the main conclusions of the model remain valid, indicating that the empirical results of this paper have good robustness.

Table 4. Robustness Check Results

Variable	$lnPM_{2.5}$
O_3	0.0036***
	(0.0007)
CO	0.211

	(0.139)
NO_2	0.0106***
	(0.0032)
SO_2	-0.005
	(0.010)
Constant	3.293***
	(0.122)
Month FE	YES
Observations	72
R2	0.963

Note. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

4. Conclusions and Recommendations

4.1. Conclusions

Based on the monthly air quality data of Chengdu from January 2018 to December 2023, taking the monthly average concentration of $PM_{2.5}$ as the dependent variable, and the concentrations of O_3, CO, NO_2, and SO_2 as explanatory variables, while introducing monthly dummy variables to control for seasonal meteorological factors, this paper constructs a multiple linear regression model to empirically examine the impact of gaseous pollutants on $PM_{2.5}$ concentrations in Chengdu. The main conclusions are as follows:

First, O_3 has a significant positive effect on $PM_{2.5}$. The regression results show that the coefficient of O_3 is significantly positive at the 1% level, indicating that an increase in ozone concentration will push up $PM_{2.5}$ concentration. This result is consistent with the formation mechanism of complex atmospheric pollution: as a strong oxidant, O_3 can alter atmospheric oxidizing capacity and accelerate the conversion of gaseous pollutants into secondary particulate matter. The frequently superimposed ozone and particulate matter pollution in Chengdu during summer is precisely a manifestation of this mechanism.

Second, CO and NO_2 are important driving factors for $PM_{2.5}$. The coefficients of CO and NO_2 are both significantly positive at the 5% level. They mainly originate from motor vehicle exhaust emissions and the incomplete combustion of fossil fuels, indicating that traffic sources and combustion sources remain important sources of $PM_{2.5}$ pollution in Chengdu.

Third, the marginal effect of SO_2 on $PM_{2.5}$ is not significant. SO_2 fails to pass the significance test, which is consistent with the reality that SO_2 concentrations in Chengdu have dropped to a very low level in recent years (with a sample-period mean of only 5.90 $\mu g/m^3$). This result indirectly corroborates that Chengdu's clean energy substitution and industrial desulfurization policies have achieved remarkable results. The current focus of $PM_{2.5}$ governance should shift from traditional coal-fired sulfide control to the coordinated control of vehicle exhaust and secondary conversion.

4.2. Recommendations

Based on the above empirical conclusions and taking into account the special topography of the Sichuan Basin and the characteristics of complex atmospheric pollution in Chengdu, this paper puts forward the following recommendations:

(1) Strengthen the control of motor vehicle exhaust and industrial combustion emissions. The regression results show that CO and NO_2 have significant positive effects on $PM_{2.5}$. They mainly come from motor vehicle exhaust and the combustion of fossil fuels such as coal, making them key targets for $PM_{2.5}$ governance in Chengdu. It is recommended to rationally plan traffic routes to reduce exhaust emissions caused by long-term vehicle idling during congested periods; accelerate the promotion of new energy vehicles and encourage citizens to use public transportation more frequently; at the same time, promote clean energy substitution for industrial coal-fired boilers and scattered coal use to reduce CO and NO_2 emissions at the source.

(2) Pay attention to the superimposed pollution of ozone and particulate matter in summer and strengthen the joint control of the two pollutants. The regression results show that O_3 has a significant positive effect on $PM_{2.5}$, indicating that ozone is not only a major exceeding-standard factor in summer but also pushes up particulate matter concentrations through atmospheric chemical reactions. It is recommended to strengthen emission management in key industries that emit volatile organic compounds, such as chemical, coating, and printing industries, during high-temperature periods in summer. At the same time, strengthen the control of nitrogen oxides in motor vehicle exhaust to reduce the raw materials needed for ozone generation at the source, achieving joint improvement of ozone and particulate matter.

(3) Arrange prevention and control priorities by season and time period according to the seasonal pattern of "high in winter and low in summer." $PM_{2.5}$ pollution in Chengdu has obvious seasonal characteristics, and it is recommended to adjust the governance focus in different seasons. In winter, there are more calm wind days and pollutants are not easily dispersed. Therefore, the control of particulate matter and coal-burning emissions should be strengthened. During heavily polluted weather, emergency measures such as staggered production for industrial enterprises and traffic restrictions on motor vehicles should be implemented. In summer, with high temperatures and strong sunlight, ozone problems are prominent. The governance focus should shift to controlling the volatile organic compounds and nitrogen oxides required for ozone generation, forming a seasonal governance pattern of "targeting particulate matter in winter and ozone in summer."

(4) Consolidate the achievements of SO_2 emission reduction and gradually shift the governance focus to the joint control of multiple pollutants. The insignificant result of SO_2 indicates that Chengdu's sulfide emission reduction policy has achieved remarkable results. In the future, while maintaining the current intensity of

desulfurization supervision, the focus of air governance should gradually shift from single coal-fired sulfide control to the joint governance of multiple pollutants generated by vehicle exhaust, industrial combustion, and photochemical reactions. This will promote the transformation of air quality improvement from "meeting a single indicator standard" to "joint control of multiple pollutants."

References

[1] Wang, J. (2021). Air quality monitoring data calibration model based on partial least squares regression model. Science and Technology Bulletin, 37(10), 31-37. DOI: 10.13774/j.cnki.kjtb.2021.10.006. (in Chinese)

[2] Wang, H. (2024). Research on urban air pollution control measures. Leather Manufacture and Environmental Technology, 5(21), 122-124. DOI: 10.20025/j.cnki.CN10-1679.2024-21-42. (in Chinese)

[3] Xu, Z., Fang, J., & Chen, Y. (2024). Study on air quality index in Dongguan based on multiple linear regression model. Environmental Protection and Technology, 30(02), 40-44. (in Chinese)

[4] Liu, J., Wang, B., He, W., et al. (2025). Assessment of the changing trend of air quality health index in Anyang City in the past five years. Journal of Environmental Engineering Technology. (in Chinese)