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Original Research

Local Fiscal Imbalances and Pollution Emissions: Assessing the Vice Role of Local Government Debt in China

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Abstract

Local government debt (LGD) has a crucial impact on the development of the economy. However, the vice effects of local government debt bonds have also garnered attention in recent years. Local governments lead the improvement and governance of regional pollution emissions. Therefore, understanding the influencing mechanism of local government debt on the regional environment can help us better comprehend the role of local government bonds. Using panel data on corporate pollution emissions and local government debt in China from 2006 to 2013, we investigate the relationship between local government debt and pollution emissions from enterprises. Our research suggests that local government bonds have a U-shaped effect on firms' pollution emissions. (2) The level of local debt can impact the fiscal spending capacity of local governments, which in turn affects local pollution emissions. (3) Local government debt impacts the environmental governance of non-state-owned or financially constrained firms. This demonstrates that local government bonds can affect the government's fiscal capacity. (4) Local government debt can impact the governance of local governments, potentially leading to relaxed regulations on corporate pollution emissions when faced with debt pressure.

Keywords: local government debt, government governance, enterprise pollution mechanism, vice effect

Introduction

Since the 1990s, industrial globalization has accelerated global economic development, but has also led to serious global pollution problems. In recent decades, China has experienced rapid economic growth and gained world-renowned achievements, but it has also faced serious environmental pollution issues. Based on published data from the World Bank, China is currently the largest carbon-emitting country in the world. This has led to serious environmental problems that affect the quality of life of its residents. In response, the Chinese government has made significant efforts towards a low-carbon environment, energy conservation, and emission reduction in recent years. However, despite a decreasing rate of growth in carbon emissions and intensity, there is still much work to be done. To fulfill its environmental commitments under the 2016 Paris Climate Agreement, China has implemented energy-saving and emission-reduction policies and laws [1]. One such policy is the white paper titled 'China's Policies and Actions to Address Climate Change.' As the specific executor

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of environmental policy, local governments' choices on the environment are crucial in this vast improvement project.

Local government debt is a significant source of funding for policy objectives. In China, positive fiscal and loose monetary policies promoted the development and environment improvement of the region through issuing local government debt, which sharply increased the government debt ratios [2, 3]. Based on the published data from the Ministry of Finance, local government debt had increased to 35 trillion in 2022, and the amount of debt increased by 15.3% annually, which surpassed the growth rate of GDP. The climbing debt ratio has led to the accumulation of debt risks, rising local government debt issuance costs, and strong pressure on the repayment of the original debt [4]. The default risk of local government debt will ascend the systemic risk, which affects the government maturity structure [5].

However, the implementation of environmental improvement and pollution control may face obstacles due to the regional economic situation. Due to the imbalance of the economic situation, the regional conflicts and wars in the oil-producing regions, which deteriorate the global economic position, result in different levels of shock on the local government. Those local governments have fiscal dilemmas and have to face a difficult trade-off between economic development and environmental protection [6]. High levels of public debt and prices have increased fiscal pressures on governments, slowing the push for environmental governance [7]. While economic growth is a top priority for local governments, they will decrease the expense of environmental improvement projects and pollution control measures for businesses [8]. Therefore, it is of great practical significance to discuss how the total amount of local government debt affects the local environment and pollution emissions.

Previous studies have extensively studied the impact of local government debt on the governance of governments. To achieve government policy goals, local governments often resort to expanding their debt [9, 10]. Zhao et al. (2019) found a nonlinear relationship between local government debt and regional economic development [11]. Zhu et al. (2022) go further by taking firms' total factor productivity (TFP) as the subject of their study, constructing a nonlinear causal relationship between firms' TFP and local debt, and arguing that economic development needs to improve debt efficiency [12]. The impact of government investment guided by the issuance of government public debt on GDP growth exists somewhere between a positive and negative threshold. Yared [13] argued that fiscal rules are needed to constrain policymakers and dampen the long-term trend of debt growth through flexible rules so that the government does not over-issue debt in the face of shocks. Therefore, it is important to consider government debt sustainability as a crucial factor in shaping local government behavior and environmental governance. Zhou et al. (2023) [14] provide linear evidence about the environmental side effects of infrastructure development from the local government. Cuestas and Regis (2018) [15] caution against investing in local government bonds in China due to a significant downward trend in debt sustainability since 2014. Gao et al. (2021) [16] also found that when local governments encounter default problems, banks with weaker political rights are more likely to default.

Our study contributes to the literature in several ways. First, our study is about investigating the growing situation of public debt and its effect on the regions. We present new evidence about local government debt having a vice effect on firms' pollution emissions. Previous research about public debt mainly concentrates on the economic effect of the rapidly growing issue of growing debt, whereas ours probes into regional climate change [11]. Secondly, different from the previous research, we explore the nonlinear relationship of the vice effect from the local government debt to the environmental situation. Just as the economic effect of local government debt, we consider it to have a similar situation to the vice effect on the environment. Additionally, it provides a mechanistic study of the impact of government debt on the government's environmental governance using firms' pollution emissions data. We examine the relationship between the government's fiscal expenditure capacity and firms' pollution governance. Finally, the paper reveals the two-sided nature of local government debt. This can improve their investment and governance capacity to carry out pollution management. Enterprises can cooperate with local governments to achieve environmental governance goals by obtaining subsidies and other means. When the debt stock exceeds a great amount, local government debt weakens the investment and governance capacity of local governments. What's more, it also affects the liquidity of the regional financial market, which leads to difficulty in financing energy-saving and emission-reduction projects.

The remaining parts of the paper are as follows: The second part provides a brief literature review and the hypothesis we put forward; the third part displays data variables and models; the fourth part introduces empirical results and conducts homogeneity and robustness tests; and the fifth part verifies the mechanism and analyzes heterogeneity. The sixth part is the conclusion.

Theoretical Analysis and Research Hypothesis

We already know that the government promotes economic growth by increasing leverage [17]. Local government debt has a nonlinear effect on the economic development of the region. Appropriate government debt is positive for the development of the regional economy. However, once the issuance of local government debt exceeds a certain point, it will instead inhibit the development of the regional economy [18]. While promoting regional development, regional debt can

have negative effects on the environment as well as the economy. This paper argues that local government debt has a nonlinear effect on the regional environment. In China, local governments are primarily responsible for improving the regional environment, so their behaviors and abilities have a significant impact on the condition of the environment [19]. Therefore, we hypothesize:

H1: Local government debt has a non-linear effect on pollution emissions.

Providing financial subsidies to enterprises is often an effective method for the government to improve the regional environment [20-22]. By subsidizing polluting enterprises and supporting them with emission reduction projects, they can effectively reduce pollution emissions. When local government debt is lower, the cost of issuing local debt capital is also lower. This allows for more funds to be allocated towards environmental subsidies, which can help reduce pollution emissions from regional enterprises. When the local government issues government debt beyond the equilibrium point, the negative impact on its finances outweighs the positive effect of issuance. Except for higher financing costs, this brings greater pressure to repay the debt [23]. If the local government faces severe financial obligations, it may consider reducing expenditures, including subsidies for environmental governance [24].

H2: Local government debt can impact pollution emissions by affecting the financial ability of local governments.

Local government debt can affect the government's ability to govern [25]. When local government debt is small, it benefits to strengthen the capability of government governance. Governments with sufficient financial resources have more ability to pay attention to regional pollution problems. However, when local government debt extends too fast, the local government faces increased repayment pressure, which weakens its governance [26]. The local government will need to consider more from the local economic development to increase revenues, thereby maintaining adequate governance. As objective politicians, local officials will focus on developing the regional economy. This may lead the government to support high-yield polluting enterprises and prioritize economic growth over environmental concerns. Additionally, local governments may be incentivized to cover up pollution problems of key enterprises by lowering the threshold of environmental governance [14].

H3: The governance capacity of local governments and corporate pollution emissions are affected by local government debt.

From an enterprise perspective, they may have less incentive to reduce emissions because the more they produce, the more pollution they emit [1]. This is because emissions are directly proportional to production [27]. The government's concern for environmental improvement and corporate pollution emissions is expected to drive regional investment, making financial firms more willing to invest in emission-reduction projects for enterprises. With enough financial liquidity, enterprises will strive to reduce pollution to comply with government requirements [28, 29]. However, strong financing constraints can still hinder an enterprise's investment in energy-saving and emission-reduction projects, thereby weakening its ability to reduce emissions [30]. Only enterprises with stronger financial strength will be able to invest in such projects, as well as prefer to devote themselves to the regional environment [31]. Moreover, a larger stock of local debt can crowd out capital liquidity and increase pressure on non-performing assets for local financial institutions. This, in turn, drives up interest rates and raises the cost of enterprise financing [17, 32]. As a result, it becomes more challenging for enterprises to obtain funds from local banks, further weakening their ability to invest in emissions reduction projects. We have also hypothesized:

H4: Local government debt may hinder firms with limited financing options from reducing pollution emissions.

H5: Local government debt reduces financial liquidity, which in turn limits firms' ability to invest in emission reduction programs.

Experimental Procedures

Data

To explore the vice effect of local government debt on pollution emissions of corporations, we collected data about corporate emissions from the China Environmental Statistics Database (CESD), which records the annual emissions of pollutants from enterprises (such as wastewater, nitrogen oxides, SO_2, and COD). The economic information we need is collected from the China Industrial Enterprise Database (CIED), which is collected from industrial enterprises with sales of more than 5 million yuan (more than 20 million yuan since 2011). Local government debt, matched to the city level as a proxy variable was collected from the WIND database. In addition, we collected statistical yearbooks from various cities as a supplementary source of data for macroeconomic control variables. Due to data availability reasons, this article limits the study sample time to 2006-2013.

According to the research needs, the sample data were processed as follows: Firstly, the data of Chinese industrial enterprises and the China Environmental Statistics Database were organized into panel data and matched. Secondly, local government debt data is based on the city and year in which the enterprise is located. Once again, samples that do not conform to logic will be removed, and tail reduction will be performed on all continuous variables at the 1% level above and below. In the end, a total of 69492 valid samples were obtained.

Definition of Variables

The Pollution of Enterprises

China's pollutant emissions have far exceeded environmental capacity limits [33]. The reason is that China's energy consumption heavily relies on fossil fuels such as coal and oil, which has also led to nitrogen oxides (NO_x) becoming the fastest-growing and most important atmospheric pollutant [34]. Nitrogen oxides not only cause direct damage to the human respiratory system but also trigger catastrophic climates such as the greenhouse effect, acid rain, photochemical smog, and haze. Through photochemical reactions, various secondary pollutants are produced, which in turn trigger climate change and threaten natural ecology and public health. Therefore, this article chooses the total amount of nitrogen oxide emissions from enterprises to measure their pollution emissions. In the following text, the total amount of sulfur dioxide and COD emitted by enterprises is also used for robustness testing.

Local Government Debt (LGD)

The reform of China's tax-sharing system is an important turning point in local governments' fiscal policy. After the change of policy, mismatched powers and a huge funding gap bring the dilemma of fiscal expenditure to the local government. In this situation, local governments have established many state-owned investment companies, commonly referred to as local government financing platforms (LGFVs) [35]. These entities represent local governments in infrastructure investment and have the ability to issue bonds or obtain loans from banks to raise funds. Huang et al. (2020) introduced us to a more precise and standardized method for collecting data on local government debt in China [36]. Their measure of local government debt is the volume of loans and bonds issued by these LGFVs. Therefore, the crux explanatory variable we used is the proportion of local financing platform interest-bearing debt to GDP at the city level, denoted as LGD.

Control Variables (Controls)

According to the work of Zhou et al. (2023), our research adds in the control variables include enterprise size (Size), enterprise age (Age), return on assets (Roa), financial leverage (Lev), capital intensity (Ci), GDP per capita (GDPPC), the urban GDP growth rate (GR), the proportion of secondary industry output value to GDP (I2), the proportion of the output value of the tertiary industry to GDP (I3), the ratio of the loan balance of financial institutions to GDP (Loan), population size (POP), education level (Edu), and the science and

Table 1. Definition of the variables.

Variable	Explanation	Definition
NO_x	Enterprise pollution emissions	Total NO_x emissions from enterprises are taken as logarithmic
LGD	Local government debt	The balance of interest-bearing debt of LGFVs divided by GDP at the prefecture-city level
LGD^2	The quadratic of local government debt	Local government debt multiplied by local government debt
Size	Enterprise size	The natural logarithm of the total assets
Age	Firm age	Expressed as the natural logarithm of the difference between the year of observation and the year the firm went public
Roa	Total return on assets	Net profit divided by total assets
Lev	Leverage ratio	The aggregate of short-term liabilities and long-term liabilities divided by the total assets
Ci	Capital intensity	Total assets divided by operating revenues
GDPPC	GDP per capita	GDP per capita taken as a logarithm
GR	GDP growth rate (%)	City GDP growth rate
I2	Share of secondary sector (%)	Secondary sector output as a proportion of GDP
I3	Share of tertiary sector (%)	Tertiary sector output as a proportion of GDP
Loan	Loan balances of financial institutions	The balance of loans to financial institutions divided by GDP
POP	Population size	Average annual population taken in logarithms
Edu	Educational level	The sum of the number of schools in a region taken as logarithmic
Scie	Technological level	Regional science expenditures are taken as logarithmic

Notes: This table shows the variable definitions in this paper.

technology level (Scie). All the variables we use in our article are provided in Table 1.

Model Design and Descriptive Statistics

Model Design

To reveal the impact of local government debt on corporate pollution, this article establishes the following econometric model for identification:

$$Pollution_{i,t} = \beta_0 + \beta_1 LGD_{c,t} + \beta_2 LGD^2_{c,t} + \gamma X_{i,t} + \mu_t + \theta_t + \varepsilon_{i,t} \quad (1)$$

Among them, the subscripts i and t represent the enterprise and year, respectively. $Pollution_{i,t}$ refer to the pollution of the enterprise, $LGD_{c,t}$, which is the independent variable, represents the government debt in city c and year t, and $LGD^2_{c,t}$ is the square term of the debt. In addition, we add the control variable $X_{i,t}$, incorporating firm fixed effects μ_i and fixed effect θ_t and error term $\varepsilon_{i,t}$ into the model. This article mainly concentrates on the results of β_1 and β_2, which indicate the net effect of local government debt on pollution emissions from enterprises.

Summary Statistics

In Table 2, we describe the statistics of the main variables we mentioned. From the perspective of pollution emissions from enterprises, the total amount of NO_x emissions from enterprises remains at 8.95, with a standard deviation of 2.056, a minimum value of 3.932, and a maximum value of 14.68, indicating a significant difference in pollution emissions among enterprises. The mean value of the local government debt is 0.072, with a minimum value of 0 and a maximum value of 0.646. Due to tail reduction, no outliers were found in other control variables, and we will not elaborate on them here.

Results

Baseline Regression

Table 3 reports the estimated environmental effects of local government debt using corporate pollution emissions as the dependent variable. The first column shows the univariate test results of local government debt on corporate nitrogen oxide emissions. The coefficient of the primary term of the core explanatory variable (LGD) is significantly negative, while the coefficient of the secondary term is significantly positive. Secondly, we used a stepwise regression method for testing, and the results in columns (2) and (3) showed that the results remained consistent even after gradually adding control variables. This indicates a non-linear U-shaped structure between local government debt and corporate pollution emissions. The pollution emissions of enterprises decrease with the increase of local government debt.

Table 2. Summary statistics of the main variables.

Variable	N	Mean	Std	Min	Median	Max
NO_X	69492	8.950	2.056	3.932	8.896	14.680
LGD	69492	0.122	0.177	0.000	0.054	0.928
LGD^2	69492	0.046	0.131	0.000	0.003	0.862
Size	69492	18.180	1.585	15.040	18.050	22.520
Age	69492	2.296	0.623	0.693	2.303	3.761
Roa	69492	0.115	0.198	-0.174	0.050	0.977
Lev	69492	0.569	0.270	0.032	0.577	1.333
Ci	69492	0.387	0.214	0.032	0.360	0.916
GDPPC	69492	10.490	0.629	8.925	10.510	11.720
GR	69492	12.570	2.666	4.940	12.900	17.910
I2	69492	51.800	6.941	33.890	52.340	66.830
I3	69492	38.540	7.096	23.710	37.970	62.240
Loan	69492	0.926	0.474	0.322	0.775	2.340
POP	69492	6.218	0.478	4.658	6.332	7.085
Edu	69492	6.783	0.631	5.242	6.763	8.416
Scie	69492	10.310	1.469	6.785	10.410	14.100

Notes: Variable definitions are provided in Table 1.

Table 3. The impact of local government debt on corporate pollution emissions.

Variables	(1)	(2)	(3)
	NO_X	NO_X	NO_X
LGD	-0.484***	-0.421***	-0.328**
	(-3.37)	(-2.93)	(-2.23)
LGD^2	0.400***	0.351**	0.408***
	(2.81)	(2.46)	(2.77)
Size		0.101***	0.099***
		(9.75)	(9.45)
Age		0.082***	0.083***
		(4.61)	(4.66)
Roa		0.019	0.009
		(0.61)	(0.30)
Lev		-0.014	-0.012
		(-0.52)	(-0.45)
Ci		-0.059*	-0.063**
		(-1.91)	(-2.07)
GDPPC			0.109*
			(1.83)
GR			-0.004
			(-1.58)
I2			-0.017***
			(-3.57)
I3			-0.024***
			(-4.51)
Loan			-0.285***
			(-6.12)
POP			-0.658***
			(-6.94)
Edu			0.034
			(0.81)
Scie			-0.018
			(-1.46)
Constant	8.992***	6.983***	12.013***
	(719.25)	(35.90)	(13.07)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	69,492	69,492	69,492
R-squared	0.89	0.89	0.89

Notes: Robust standard errors are clustered at the firm level, and t-statistics are provided in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

When reaching a certain critical value, the pollution emissions of enterprises increase with the increase of local government debt. The hypothesis has been validated.

Endogenous Test

To address the estimation bias caused by endogeneity issues, this study employed instrumental variable regression. Referring to the research method of Demirci et al. (2019), this article selects healthcare expenditure in public finance expenditure as the instrumental variable (IV). From the correlation of instrumental variables, healthcare expenditure is related to the revenue and expenditure of public finance, and thus it influences the debt that local government issues. From the perspective of the homogeneity of instrumental variables, this study suggests that is relatively exogenous in government fiscal expenditure. As a fundamental livelihood program that the government needs to expand, it has a weak correlation with short-term economic fluctuations that affect corporate pollution emissions, making it less susceptible to external factors.

The first and second columns of Table 4 show the regression results of the instrumental variables in the first stage, respectively. The results show that the correlation coefficients between the healthcare expenditure and the explanatory variable LGD are significantly positive for both the one-time and quadratic terms. The F-statistics are 452.199 and 581.092, respectively, excluding the issue of weak instrumental variables. The third column shows the regression results of the second stage, where the coefficient of the LGD first-order term is significantly negative and the coefficient of the second-order term is significantly positive. This indicates a non-linear U-shaped structure between local government debt and corporate pollution emissions. This result is consistent with the main regression.

Robustness Test

U-Shaped Relationship Test

Table 5 shows the results of the U-shaped relationship test. Haans et al. (2016) pointed out that a significant quadratic coefficient cannot certainly confirm the existence of the (inverted) U-shaped relationship, so it is necessary to test the (inverted) U-shaped relationship; thus, this article examines the relationship between local government debt and corporate pollution emissions [37]. The results show that the range of the local government debt scale is (0.000, 0.928), with a slope of -0.328 on the left and significant at the 5% level, and a slope of 2.672 on the right and significant at the 1% level. This result indicates a U-shaped relationship between local government debt and corporate pollution emissions, further supporting the hypothesis. Calculate the inflection point of the U-shaped curve based on the coefficient of local government debt and its square term. Calculating the regression coefficients of column (3) in the benchmark regression yields a turning point of approximately 0.401. This means that when the proportion of debt issued by local governments to GDP is less than 40%, the impact of local government debt on

Table 4. Instrumental Variable Test.

Variables	(1)	(2)	(3)
	LGD		NO_X
IV	3.760***	1.607***	
	(10.32)	(5.83)	
LGD			-17.447***
			(-2.75)
LGD^2			19.322***
			(2.68)
Size	-0.002***	-0.000	0.136***
	(-3.71)	(-1.18)	(8.75)
Age	0.001	-0.000	0.097***
	(1.03)	(-0.56)	(4.02)
Roa	-0.002	-0.002**	0.241***
	(-1.22)	(-2.32)	(5.76)
Lev	-0.002*	-0.001	0.067*
	(-1.65)	(-1.34)	(1.93)
Ci	-0.004***	-0.002**	0.007
	(-3.07)	(-2.54)	(0.18)
GDPPC	0.023***	0.041***	0.238
	(9.97)	(23.69)	(1.32)
GR	0.004***	0.003***	0.027***
	(37.87)	(37.49)	(5.36)
I2	-0.002***	-0.002***	-0.036***
	(-9.49)	(-12.04)	(-5.89)
I3	-0.002***	-0.002***	-0.044***
	(-11.40)	(-13.03)	(-6.25)
Loan	0.110***	0.096***	-0.301***
	(62.35)	(72.56)	(-4.80)
POP	0.021***	0.035***	-1.315***
	(5.88)	(12.80)	(-7.76)
Edu	0.049***	0.046***	0.108*
	(29.95)	(37.36)	(1.87)
Scie	0.004***	0.001	-0.074**
	(6.94)	(1.20)	(-2.14)
Constant	-0.618***	-0.903***	1.923***
	(-17.66)	(-34.14)	(5.52)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	69,492	69,492	69,492
R-squared	0.950	0.907	-0.050
F	452.199***	581.092***	39.323***

Notes: Robust standard errors are clustered at the firm level, and t-statistics are provided in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 5. The U-shaped Relationship Test.

	Lower bound	Upper bound
Interval	0.000	0.928
Slope	-0.328	0.431
t-value	-2.231	2.672
P>|t|	0.013	0.004

corporate pollution emissions is in the downward phase on the left side of the U-shaped curve. At this time, the increase in local government debt will reduce corporate pollution emissions. When the proportion of debt issued by local governments to GDP exceeds 40%, the impact of local government debt on corporate pollution emissions is in the upward phase on the right side of the U-shaped curve. At this time, the increase in local government debt will lead to an increase in corporate pollution emissions.

Replacing the Dependent Variable

Table 6 shows the robustness test after replacing the dependent variable. This article uses the total amount of sulfur dioxide emissions (SO_2) from enterprises to represent their pollution emissions. The use of this measurement method is mainly due to two reasons. Firstly, China is the world's largest producer and consumer of coal and also the country with the highest sulfur dioxide emissions in the world. Industrial sulfur dioxide has always been considered the most destructive pollutant produced by Chinese industrial enterprises and is widely used to measure the environmental quality and pollution emission levels of regions and enterprises. Secondly, sulfur dioxide is one of the main factors causing acid rain and sulfur mist, and it has been identified as the main pollutant for emission reduction in different environmental regulatory policies. In addition, Chemical Oxygen Demand (COD) is the most comprehensive and commonly used indicator for measuring water pollution levels in environmental chemistry and is a key focus of environmental monitoring, governance, and law enforcement in China. Therefore, this article selects the chemical oxygen demand emissions of enterprises for further robustness testing.

Modifying the Model Settings

Table 7 shows the regression results after replacing the fixed effects model. We replaced companies, years, cities, and industries in our regression model. The first column is the regression result of LGD on corporate NO_x emissions after adding urban fixed effects based on the benchmark model. The second column shows the regression results of LGD on NO_x emissions after adding urban fixed effects and industry fixed effects based on

Table 6. Replacing the Dependent Variable.

Variables	(1)	(2)	(3)	(4)
	SO_2	SO_2	COD	COD
LGD	-0.850***	-0.766***	-1.552***	-1.078***
	(-3.65)	(-3.27)	(-5.27)	(-3.64)
LGD^2	0.868***	1.120***	1.127***	0.800**
	(2.86)	(3.59)	(2.94)	(2.03)
Size		0.099***		0.155***
		(9.41)		(11.75)
Age		0.083***		0.080***
		(4.70)		(3.56)
Roa		0.009		0.225***
		(0.30)		(5.63)
Lev		-0.011		0.076**
		(-0.43)		(2.27)
Ci		-0.064**		0.024
		(-2.09)		(0.62)
GDPPC		0.106*		0.628***
		(1.78)		(8.36)
GR		-0.004		0.015***
		(-1.49)		(4.61)
I2		-0.017***		-0.034***
		(-3.67)		(-5.70)
I3		-0.024***		-0.037***
		(-4.65)		(-5.65)
Loan		-0.290***		-0.343***
		(-6.10)		(-5.71)
POP		-0.661***		-1.011***
		(-6.99)		(-8.47)
Edu		0.037		0.143***
		(0.86)		(2.68)
Scie		-0.018		-0.160***
		(-1.39)		(-10.00)
Constant	8.996***	12.106***	8.748***	9.313***
	(721.11)	(13.14)	(553.74)	(8.01)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	69,492	69,492	69,492	69,492
R-squared	0.89	0.89	0.87	0.87

Notes: Robust standard errors are clustered at the firm level, and t-statistics are provided in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

the benchmark model. The third column shows the regression results of LGD on corporate SO_2 emissions after adding urban fixed effects to the benchmark model. The fourth column shows the regression results of LGD on SO_2 emissions after adding urban fixed effects and industry fixed effects based on the benchmark model. The fifth column shows the regression results of LGD on corporate COD emissions after adding urban fixed effects to the benchmark model. The sixth column shows the regression results of LGD on COD emissions after adding urban fixed effects and industry fixed effects based on the benchmark model. The regression results are consistent with the benchmark regression results. Therefore, the research conclusion of this article still holds.

Using Original Data

In our baseline regression, we follow the standard approach found in contemporary literature by applying winsorization to extreme values. This entails capping and flooring all continuous variables at the 1st and 99th percentiles, respectively, mitigating the influence of outliers. However, recognizing that extreme values might offer valuable insights, we refrain from winsorization in this particular section and utilize the original dataset instead. The empirical findings are presented in Table 8.

Further Analysis

Mechanism Analysis

Table 9 shows the mechanism verification results. Through theoretical analysis, it can be concluded that local government debt will ultimately affect corporate pollution emissions in a way that changes the government's investment and regulatory efforts in the environment. Therefore, this section will verify the mechanism of the effect of local government debt on corporate pollution emissions by studying the impact of local government debt on environmental investment and regulation.

Firstly, conduct inspections at the government level. This article uses the domestic sewage treatment rate (DSTR), the harmless treatment rate of domestic waste (HT), and the industrial smoke and dust removal amount (ISD) as indicators to measure the government's environmental supervision efforts. The larger the values of these three indicators, the stronger the urban environmental supervision. In columns (1) to (3), the variable of local government debt remains significantly positive, while its square term remains significantly negative. This result indicates that urban environmental investment and regulation exhibit an inverted U-shaped trend of first increasing (strict) and then decreasing (relaxed) with the increase of local government debt. This indicates that before the debt reaches the turning point, local governments can make up for the lack of fiscal funds through debt issuance, strengthening

Table 7. Modifying the Model.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	NO_X	NO_X	SO_2	SO_2	COD	COD
LGD	-0.338**	-0.345**	-0.777***	-0.792***	-1.081***	-1.099***
	(-2.30)	(-2.35)	(-3.30)	(-3.37)	(-3.64)	(-3.70)
LGD^2	0.426***	0.431***	1.160***	1.182***	0.814**	0.832**
	(2.89)	(2.92)	(3.71)	(3.78)	(2.06)	(2.11)
Size	0.099***	0.099***	0.099***	0.099***	0.156***	0.154***
	(9.47)	(9.44)	(9.44)	(9.40)	(11.76)	(11.62)
Age	0.084***	0.084***	0.084***	0.085***	0.078***	0.081***
	(4.72)	(4.75)	(4.75)	(4.78)	(3.50)	(3.60)
Roa	0.009	0.010	0.010	0.010	0.225***	0.224***
	(0.30)	(0.32)	(0.30)	(0.32)	(5.63)	(5.61)
Lev	-0.012	-0.011	-0.011	-0.010	0.077**	0.080**
	(-0.45)	(-0.41)	(-0.43)	(-0.39)	(2.29)	(2.38)
Ci	-0.062**	-0.062**	-0.063**	-0.062**	0.026	0.027
	(-2.03)	(-2.02)	(-2.05)	(-2.04)	(0.67)	(0.69)
GDPPC	0.091	0.088	0.087	0.084	0.623***	0.623***
	(1.52)	(1.46)	(1.46)	(1.40)	(8.24)	(8.23)
GR	-0.004	-0.004	-0.004	-0.004	0.015***	0.016***
	(-1.59)	(-1.54)	(-1.52)	(-1.46)	(4.60)	(4.65)
I2	-0.018***	-0.018***	-0.018***	-0.018***	-0.034***	-0.034***
	(-3.73)	(-3.75)	(-3.84)	(-3.85)	(-5.72)	(-5.78)
I3	-0.025***	-0.026***	-0.026***	-0.026***	-0.038***	-0.038***
	(-4.76)	(-4.85)	(-4.90)	(-4.99)	(-5.65)	(-5.75)
Loan	-0.300***	-0.298***	-0.307***	-0.305***	-0.348***	-0.342***
	(-6.40)	(-6.34)	(-6.41)	(-6.35)	(-5.75)	(-5.65)
POP	-0.687***	-0.691***	-0.690***	-0.695***	-1.037***	-1.029***
	(-7.19)	(-7.22)	(-7.24)	(-7.28)	(-8.62)	(-8.54)
Edu	0.030	0.031	0.032	0.033	0.135**	0.130**
	(0.71)	(0.73)	(0.75)	(0.77)	(2.52)	(2.43)
Scie	-0.019	-0.019	-0.019	-0.019	-0.160***	-0.160***
	(-1.53)	(-1.54)	(-1.47)	(-1.48)	(-10.04)	(-10.04)
Constant	12.528***	12.606***	12.641***	12.730***	9.623***	9.672***
	(13.34)	(13.40)	(13.43)	(13.49)	(8.10)	(8.12)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	Yes	No	Yes	No	Yes
Observations	69,492	69,492	69,492	69,492	69,492	69,492
R-squared	0.89	0.89	0.89	0.89	0.87	0.87

Notes: Robust standard errors are clustered at the firm level, and t-statistics are provided in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 8. Using Original Data.

Variables	(1)	(2)	(3)
	NO_X	NO_X	NO_X
LGD	-0.812***	-0.728***	-0.666***
	(-3.35)	(-3.01)	(-2.72)
LGD^2	0.944***	0.858***	1.067***
	(3.13)	(2.85)	(3.44)
Size		0.108***	0.105***
		(9.88)	(9.54)
Age		0.084***	0.084***
		(4.72)	(4.72)
Roa		0.037	0.031
		(1.63)	(1.35)
Lev		-0.037**	-0.037**
		(-2.10)	(-2.08)
Ci		-0.046	-0.051
		(-1.46)	(-1.62)
GDPPC			0.105*
			(1.66)
GR			-0.003
			(-1.25)
I2			-0.018***
			(-3.51)
I3			-0.026***
			(-4.36)
Loan			-0.254***
			(-5.25)
POP			-0.550***
			(-5.48)
Edu			0.076*
			(1.68)
Scie			-0.013
			(-0.93)
Constant	8.989***	6.867***	11.056***
	(682.89)	(33.92)	(11.20)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	69,492	69,492	69,492
R-squared	0.89	0.89	0.89

Notes: Robust standard errors are clustered at the firm level, and t-statistics are provided in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

environmental investment, and supervision. However, once the debt exceeds the turning point, the issuance of debt will lead to increased financial pressure on the government, thereby reducing and relaxing environmental investment and regulation.

Secondly, conduct inspections at the enterprise level. This article refers to the approach of He et al. (2020) and uses the operating cost of wastewater treatment facilities (WTF), industrial wastewater treatment capacity (IWTV), and industrial dust removal capacity (IDRA) as indicators to measure the environmental governance investment of enterprises. The operating cost of enterprise wastewater treatment facilities represents the investment of enterprises in environmental governance, while IWTV and IDRA reflect the effectiveness of enterprise environmental governance. In columns (4) to (6), the coefficient of the local government debt variable remains significantly positive, while its square term remains significantly negative. This result indicates that the investment in corporate environmental governance shows an inverted U-shaped trend of first increasing (strict) and then decreasing (relaxed) with the increase of local government debt. This indicates that before the debt reached a turning point, local governments had relatively strict environmental supervision over enterprises, which prompted them to strengthen their investment in environmental pollution and research and development. However, once the debt exceeds the turning point, the increasing financial pressure on the government will lead to a reduction in regulatory investment in corporate environmental governance, thereby increasing the pollution emissions of enterprises.

Heterogeneity Analysis

Table 10 presents the analysis results of heterogeneity. The difference in ownership of enterprises means that there are differences in production and operation goals and different ways of allocating factors, which in turn can affect the environmental performance of enterprises. This article divides enterprises into state-owned enterprises and non-state-owned enterprises based on registration types and analyzes the impact of local government debt on pollution emissions of enterprises with different ownership systems. Due to the need for state-owned enterprises to balance the maintenance of government and public interests in their operations, they may consciously adhere to higher-level emission reduction targets. In columns (1) and (2) of Table 10, the pollution emissions of private enterprises show a trend of first decreasing and then increasing, which changes with the expansion of local government debt. On the contrary, the pollution emissions of state-owned enterprises are not affected. This indicates that state-owned enterprises seem to comply with higher levels of environmental standards and are relatively more conscious of reducing emissions.

There are differences in the pollution generation and financial strength of enterprises of different scales, which

Table 9. Mechanism Analysis.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	DSTR	HT	ISD	WTF	IWTV	IDRA
LGD	0.297***	0.394***	0.030*	0.433*	0.800**	8.014***
	(2.73)	(3.91)	(1.74)	(1.65)	(2.28)	(4.18)
LGD^2	-0.437***	-0.424***	-0.044***	-0.551**	-1.032**	-9.906***
	(-3.35)	(-3.16)	(-6.92)	(-2.00)	(-2.43)	(-4.27)
Size	0.017**	0.004	-0.020*	0.049***	0.195***	0.117
	(2.46)	(0.99)	(-1.88)	(2.69)	(8.40)	(1.24)
Age	0.007	0.032***	-0.004	0.101*	0.128***	0.139
	(0.77)	(4.17)	(-0.27)	(1.70)	(3.35)	(1.18)
Roa	-0.008	0.009	0.008	0.075	0.251***	-0.146
	(-0.40)	(0.67)	(0.24)	(1.57)	(3.50)	(-0.51)
Lev	0.015	0.025**	0.005	0.046	0.053	0.348*
	(0.97)	(2.23)	(0.21)	(1.02)	(0.91)	(1.68)
Ci	-0.005	0.028**	0.057*	0.079	0.015	0.023
	(-0.24)	(2.10)	(1.95)	(1.62)	(0.22)	(0.09)
GDPPC	-0.045	-0.164***	-1.324***	-0.474***	0.671***	2.247***
	(-1.07)	(-6.40)	(-19.95)	(-2.78)	(5.35)	(3.40)
GR	-0.005***	-0.003***	-0.010***	0.015***	0.029***	-0.090***
	(-2.81)	(-2.62)	(-3.78)	(3.56)	(4.97)	(-4.02)
I2	-0.009***	0.034***	0.056***	0.013	0.006	-0.001
	(-2.70)	(17.06)	(10.92)	(1.16)	(0.60)	(-0.03)
I3	-0.026***	0.018***	-0.004	-0.013	-0.006	-0.035
	(-7.33)	(8.19)	(-0.72)	(-1.07)	(-0.49)	(-0.75)
Loan	-0.010	-0.399***	-0.699***	0.206*	-0.623***	0.478
	(-0.37)	(-19.50)	(-17.56)	(1.73)	(-6.10)	(1.05)
POP	0.072	0.351***	0.895***	0.210	1.308***	-4.386**
	(0.57)	(8.63)	(4.53)	(0.48)	(6.81)	(-2.10)
Edu	0.182***	-0.506***	0.862***	-0.160**	0.319***	-0.378
	(5.21)	(-27.78)	(15.87)	(-2.08)	(3.40)	(-0.77)
Scie	-0.143***	-0.146***	0.073***	-0.016	-0.396***	-0.429***
	(-22.85)	(-26.80)	(7.42)	(-0.59)	(-14.45)	(-4.61)
Constant	5.442***	6.586***	13.194***	6.407*	-6.080***	15.988
	(6.34)	(16.62)	(9.83)	(1.82)	(-3.11)	(1.19)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,426	69,492	35,003	21,432	53,603	6,548
R-squared	0.81	0.70	0.93	0.94	0.81	0.96

Notes: Robust standard errors are clustered at the firm level, and t-statistics are provided in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 10. Heterogeneity Analysis.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	property		size		Financing constraint	
	SOEs	No-SOEs	Big-size	Small-size	Low-Fc	High-Fc
LGD	-0.118	-0.759***	0.024	-0.598***	0.123	-0.661***
	(-0.27)	(-4.14)	(0.11)	(-2.84)	(0.53)	(-3.25)
LGD^2	0.160	0.856***	0.100	0.757***	-0.002	0.813***
	(0.39)	(4.56)	(0.45)	(3.54)	(-0.01)	(3.94)
Size	0.153***	0.119***	0.157***	0.068***	0.147***	0.066***
	(3.83)	(9.56)	(7.66)	(4.26)	(6.91)	(4.24)
Age	0.033	0.051**	0.109***	0.060**	0.103***	0.061**
	(0.67)	(2.29)	(3.86)	(2.44)	(3.20)	(2.46)
Roa	0.154	0.048	0.050	0.030	0.082	0.022
	(1.18)	(1.34)	(0.72)	(0.81)	(1.17)	(0.59)
Lev	-0.160*	0.027	-0.111**	0.018	-0.059	0.014
	(-1.88)	(0.83)	(-2.33)	(0.54)	(-1.22)	(0.40)
Ci	-0.055	-0.032	0.012	-0.068*	-0.031	-0.059
	(-0.54)	(-0.89)	(0.21)	(-1.68)	(-0.57)	(-1.49)
GDPPC	-0.107	0.209***	0.001	0.129	0.011	0.151*
	(-0.51)	(2.83)	(0.01)	(1.54)	(0.12)	(1.87)
GR	0.015**	-0.007**	-0.009**	-0.001	-0.012***	0.001
	(1.98)	(-2.24)	(-2.29)	(-0.17)	(-2.86)	(0.33)
I2	0.005	-0.014**	-0.005	-0.019***	-0.001	-0.021***
	(0.38)	(-2.38)	(-0.66)	(-2.87)	(-0.16)	(-3.30)
I3	0.002	-0.024***	-0.019**	-0.022***	-0.014	-0.025***
	(0.13)	(-3.73)	(-2.31)	(-2.92)	(-1.60)	(-3.53)
Loan	-0.279**	-0.344***	-0.161**	-0.383***	-0.180**	-0.412***
	(-2.02)	(-5.98)	(-2.29)	(-5.75)	(-2.47)	(-6.42)
POP	-0.356	-1.686***	-0.133	-1.529***	-0.118	-1.466***
	(-1.28)	(-9.33)	(-1.11)	(-8.98)	(-0.93)	(-9.13)
Edu	-0.110	0.094*	0.044	0.049	0.059	0.044
	(-0.84)	(1.80)	(0.63)	(0.84)	(0.82)	(0.79)
Scie	-0.008	-0.032**	-0.021	-0.021	-0.007	-0.028*
	(-0.20)	(-2.07)	(-1.01)	(-1.26)	(-0.33)	(-1.73)
Constant	10.925***	16.645***	8.318***	17.355***	7.745***	17.148***
	(3.66)	(11.73)	(5.99)	(12.30)	(5.37)	(12.64)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,366	45,790	32,600	36,892	30,623	38,869
R-squared	0.92	0.88	0.91	0.87	0.91	0.87

Notes: Robust standard errors are clustered at the firm level, and t-statistics are provided in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

will directly affect the emission reduction decisions of operators. According to the median of the total assets of each enterprise calculated during the sample period, enterprises are divided into large-scale enterprises and small-scale enterprises. Chinese large enterprises are usually the key regulatory targets of local environmental protection departments, and compared to small and micro enterprises, large enterprises usually demonstrate a higher sense of social responsibility. Therefore, it is reasonable to believe that small-scale enterprises have a relatively large space and willingness to increase their pollution emissions. In columns (3) and (4) of Table 10, we report the impact of local government debt on pollution emissions from enterprises of different scales. The results showed that the coefficients of the first-order and squared terms of local government debt were only significant in smaller enterprises, and this effect did not exist in larger enterprises, consistent with the expected analysis. This indicates that local government debt has a significant impact on the pollution emissions of smaller enterprises, while the impact on larger enterprises is relatively small.

Enterprises with different financial constraints perform differently in production, operation, and investment. Because enterprise pollution control requires equipment updates and environmental investment, which generally have the characteristics of long cycles, low initial returns, and high risks, internal financing alone may generate significant cash flow pressure and operational risks. Therefore, external financial constraints of enterprises have an impact on pollution reduction. When enterprises face financial constraints, the cost and risk of environmental investment cannot be shared through external financing, making it difficult to fully realize the incentives for environmental investment and pollution control. Therefore, we have reason to speculate that local government debt brings a more vice effect on the pollution emissions of enterprises with higher financial constraints. This article refers to the SA financing constraint index constructed by Hadlock and Pierce (2010) and divides enterprises into low-financing constraint groups and high-financing constraint groups. In columns (5) and (6) of Table 10, the impact of local government debt on pollution emissions of enterprises under different financial constraints is reported. The results showed that the coefficients of the first-order and squared terms of local government debt were only significant in enterprises with high financial constraints, while this effect did not exist in enterprises with low financial constraints, consistent with the expected analysis.

Conclusions

Despite the ongoing economic recovery from COVID-19, environmental governance remains a crucial factor for sustainable economic growth and global development. This research analyzes the vice impact of local government debt on corporate pollution emissions and explores potential operation mechanisms, using a significant amount of government and corporate data from China. The study reveals a U-shaped relationship between local government debt and pollution emissions from enterprises. Specifically, when the debt stock is reasonable, issuing local government debt leads to a decrease in corporate pollution emissions. However, when the debt stock is overbalanced, an increase in the local government debt results in a rise in corporate pollution emissions. We also test the reliability of this non-linear relationship while controlling for the endogeneity through the instrumental variable of healthcare expenditure, which is the necessary expenditure in public finance. The robustness of the quadratic relationship is tested through U-shaped relationship testing as well by replacing the dependent variable, replacing fixed effects, and using raw data. All of the robustness tests support the conclusion of the U-shaped vice effect of the local government debt on corporate pollution emissions. In the heterogeneity analysis, we conducted sample-wise regression using three methods: enterprise ownership, enterprise size, and financial constraints. The data suggests that pollution emissions from enterprises with higher financing constraints, such as private companies, initially decrease, then increase after local government debt surpasses a certain threshold. In contrast, state-owned and larger enterprises, as well as those with low financial constraints, appear to be unaffected by this factor.

We examine the mechanism from two perspectives: government environmental regulation and corporate environmental financing cost. The findings indicate that urban environmental expenditure and regulation exhibit an inverted U-shaped trend regarding local government debt, initially increasing (strict) and then decreasing (relaxed). Before reaching the sustainable point, an abundant fiscal level strengthens the governance capacity of local governments; the government increases fiscal support for the investment in environmental protection programs of enterprises. However, when the amount of debt surpasses the regional capacity, issuing more debt will increase the government's financial burden and reduce the government's willingness to take initiative in environmental governance. This, in turn, leads to a relaxation of environmental regulations. From an environmental perspective, the input of environmental behaviors of corporations follows an inverted U-shaped trend with an increase in local government debt. Initially, there is a strict increase, followed by a relaxation decrease. It is evident that prior to reaching the inflection point of debt, enterprises have more initiative to control their pollution emissions due to the benefit of obtaining subsidies or financing from financial institutions, which encouraged them to invest in the program of development anti-pollution measures. However, when the government's debt exceeds a certain point, the influence of environmental regulation

on the enterprises' pollution will decrease. This leads to the weakening of the incentives of enterprises to reduce pollution emissions.

From the research we did before, this article suggests that the government should maintain correct fiscal discipline: it is necessary to establish a comprehensive evaluation system based on actual situations to measure its debt-bearing capacity. The central government must implement environmental governance policies with caution, taking into account the basic needs of local economic development and environmental issues. It is important to seek policies that are in line with local conditions and to curb excessive issuance of debt by local governments. In analyzing heterogeneity, it is recommended that local governments pay closer attention to pollution emissions from private enterprises, small and micro enterprises, and enterprises with high financial constraints in order to evaluate their debt stock. The government should develop environmental protection policies based on the pollution emissions of private enterprises, small and medium-sized enterprises, and financially constrained enterprises.

Based on empirical evidence from mechanism analysis, it is challenging for local governments to maintain a healthy debt stock in practical operations. However, it is crucial to consider the bidirectional effect of local government debt on corporate pollution emissions. Therefore, the central government should have a flexible mindset when assessing local governments. Pursuing sustained rapid economic growth and rapid environmental improvement simultaneously is not practical. The governance of the environment should be aligned with economic development, and the development of regions that comply with laws is a reasonable process. After all, environmental protection is a sustainable process.

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Conflict of Interest

The authors declare no conflict of interest.

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