How does Haze Pollution Affect Enterprise Markup?

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Abstract. Continuously improving the markup of firms is an important measure to enhance the superior growth of China's international commerce and promote enterprises to the middle and high end of the global value chain. The results show that haze pollution significantly inhibit the increase of firms' markup, which is still robust when considering the endogeneity problem and the policy changes. Heterogeneity analysis shows that the inhibitory effect of haze pollution on the markup is more pronounced in the samples of non-state-owned enterprises, labor-intensive and technology-intensive enterprises. Haze pollution inhibits the markup through two transmission channels: technological innovation effect and green total factor productivity (GTFP) improvement effect. Futhermore, urban environmental legislation could weaken the inhibitory effect of haze pollution on markup, and the moderating effect of environmental legislation is more significant with the increase of urban environmental legislation intensity.

Keywords: Haze pollution; Enterprise markup; Technological innovation effect; Green total factor productivity improvement effect

1 Introduction

In recent years, the scale of China's trade has been expanding, however, manufacturing industry in China still confronts low-end lock-in, which seriously affects the high-quality development of the Chinese economy. Amidst major modifications of the global industrial chain, achieving the "quality improvement and increment" of enterprises' export is undoubtedly a crucial impetus for enhancing the quality of China's international circulation. The enterprise markup can better measure the international competitiveness of enterprises (Edmond et al., 2015) [1]. In-depth exploration of the key factors affecting the markup is not only favorable to the enhancement of China's international trade in both "quantity" and "quality", but also helps to promote enterprises to ascend to the intermediate and upper echelons of the worldwide value chain.

Improving the ecological quality plays an important role in achieving high-level opening-up. The extensive economic growth model driven by large-scale factor input for a long time has led to the increasingly serious environmental pollution problems in China, especially the decline of air quality and frequent occurrence of smog. Haze pollution not only poses a threat to people's health (Schlenker and Walker, 2016) [2], but also has a significant adverse impact on economic operation. Therefore, based on this target choice, clarifying the internal logic between environmental pollution and the markup of enterprises is the key to find a way that is not only conducive to the construction of ecological civilization, but also promotes the transformation of economic growth model to intensive efficiency.

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Different from the previous studies, the innovation of this paper lies in the following aspects: first, by integrating haze pollution and enterprise markup into a unified analysis framework, this paper reveals the transmission channel of haze pollution reducing the markup through technological innovation effect and GTFP improvement effect. Second, based on the *simhash* algorithm of text quantitative analysis, this paper quantifies the legal texts of urban environmental legislation, and further uses the entropy method to construct the differentiation index of environmental legislation intensity, so as to verify the moderating effect of urban environmental legislation on the impact of haze pollution on enterprise markup.

2 Literature Review

This paper primarily pertains to the following two categories of literature. The first is the research on the adverse external effects of air pollution. Haze pollution not only seriously threatens the physical and psychological well-being of the inhabitants (Deryugina et al., 2019) [3], but also has a strong effect on the stable operation of the macro economy (Fu et al., 2021) [4]. Some scholars further explored the impact of haze pollution on the the innovation performance (Evans et al., 1988) and brain drain (Xue et al., 2021) [5-6].

Another branch of literature mainly emphasizes the influencing factors of enterprise markup. De Loecker and Warzynski (2012) found that compared with non-exporting firms [7], exporting firms tend to have higher markup. Melitz and Ottaviano (2008) demonstrated the positive relationship between firm productivity and markup by introducing quasi-linear utility functions into the study [8]. In addition, product quality (Kugler and Verhoogen,2012) and digital technology (Cette et al., 2022) are all important factors affecting firms' markup [9-10].

Through the review of the existing literature, it can be found that there are abundant studies on the negative externalities of haze pollution and the influencing factors of enterprise markup. However, there are still some shortcomings: First, few studies have incorporated haze pollution and enterprise markup into a unified analysis framework, and clarified the internal affecting channels. Second, relevant studies have not examined the moderating role of urban environmental legislation in the process of haze pollution affecting enterprise markup.

3 Theoretical Analysis and Research Hypotheses

Haze pollution will have a negative impact on the operating cost and production efficiency of enterprises, and will also have an inhibitory effect on the markup of enterprises. From the perspective of labor force, firstly, air pollution can cause individuals to have negative emotions, reduce cognitive ability and damage physical health, which indirectly has a negative impact on corporate innovation. Secondly, there is an increasing focus on environmental condition amidst the populace. With the aim of mitigate the outflow of talent, enterprises in high-pollution areas need to pay higher wages to high-skilled employees and provide more favorable welfare benefits (Akpalu and Ametefee, 2017) [11]. The rising environmental costs will crowd out their R&D investment funds, which is not favorable to the increase of enterprise productivity, thus reducing the enterprise markup. Based on this, this paper puts forward the following hypothesis:

Hypothesis 1: Haze pollution will inhibit the increase of export firms' markup.

Viewing through the lens of the technological innovation effect, the increasingly serious haze pollution will squeeze out research and development funds, thus reducing regional innovation capacity and inhibiting the increase of firms' markup. First of all, in the process of technology production, haze pollution will trigger negative emotions of relevant technical personnel and weaken the enthusiasm of R&D personnel, so it will reduce innovation performance. Secondly, governments in areas with severe haze pollution often issue stricter environmental regulations. Therefore, the previously reserved R&D innovation funds will be crowded out, which will have a crowding-out effect on innovation resources. From the perspective of GTFP improvement effect, haze pollution may reduce the efficiency of resource allocation, resulting in the mismatch between labor and human capital. Meanwhile, when faced with increasing environmental governance costs, in order to realize the production principle of cost minimization, enterprises will choose to transfer to the region with more relaxed environmental regulations, which will indirectly disrupt the integrity of the industrial chain

Hypothesis 2: Haze pollution can inhibit the increase of firms' markup through technological innovation effect and GTFP improvement effect.

4 Model Construction, Variable Selection and Data Processing

4.1 Econometric Model Construction

Based on the above theoretical analysis framework, this paper explores the impact of haze pollution on markup by constructing Formula (1) econometric model:

$$markup_{it} = \alpha_0 + \alpha_1 PM_{2.5it} + \alpha_2 X_{it} + \eta_i + \varphi_t + \varepsilon_{it} \quad (1)$$

Where, $markup_{it}$ represents the markup level of enterprise i in year t, and PM2.5 is the variable of haze pollution. X_{it} is the control variable. η_i and φ_t denote individual-level and year-level fixed effects, respectively. εi_t is the random disturbance term.

4.2 Variable Selection and Calculation

Core explained variable: enterprise markup. This article uses the production function method proposed by De Loecker and Warzynski (2012) to calculate the markup of enterprises. To be specific, under the production principle of cost minimization, the firm's markup can be calculated by the output flexibility of variable input factors and the proportion of factor input costs to total sales revenue. Where, this paper uses the ACF two-step method to estimate the output elasticity of variable input factors.

Core explanatory variable: haze pollution (PM2.5). This study chooses the mean yearly PM2.5 levels as the key indicator for assessing air pollution levels. Based on the method of Ma et al. (2016) [12], this paper incorporates satellite and ground monitoring data into a two-stage spatial statistical model for calculation, and then uses ArcGIS software to match the raw-grid data with China's administrative vector areas to obtain the PM2.5 concentration data.

Selection of control variables. Firm size (*size*), which is symbolized by the logarithmic value of annual sales revenue of firm products; firm age (*age*) is represented by the logarithmic value of the year in which the company is located subtracts by the year of established plus l; corporate debt ratio (*debt*) is measured by the proportion between a company's overall liabilities and its

aggregate assets. The Herfindahl-Hirschman index is used to reflect the extent of industry rivalry(*hhi*). The city-level control variables: total amount of foreign investment utilized by cities(*fdi*); urban economic growth level (*pgdp*), which is expressed by GDP per person.

4.3 Data Sources and Statistical Analysis

This paper's sampling period is from 2001 to 2013, mainly involving the following databases: the database of China Industrial Enterprise, China Customs, and China City Statistical Yearbook. According to the firm name, establishment year, and postal code, the databases are gradually matched and merged. The descriptive statistical of variables are displayed in Table 1.

Table 1. Descriptive statistics of variables.

Variable names	Obs.	Mean	St Dev.	Min.	Max.
Enterprise markup (*markup*)	364477	0.5614	1.1237	-10.9265	12.7082
Haze pollution (*PM2.5*)	364635	3.8035	0.3132	1.1415	4.7016
Enterprise size (*size*)	364635	16.9714	2.6078	5.0173	26.1568
Enterprise age (*age*)	364635	2.0764	0.6676	0	4.1589
Corporate debt ratio (*debt*)	364602	0.3324	0.3486	-4.5643	20.1371
Degree of industry competition (*hhi*)	364635	0.0556	0.0842	0.0016	1
Foreign direct investment (*fdi*)	364635	2.3844	1.5042	-8.1117	5.1257
Urban economic development (*pgdp*)	364635	10.5480	0.6842	7.3852	12.1640

5 Analysis of Empirical Results

5.1 Benchmark Regression Results

Table 2 indicates the benchmark regression results of haze pollution affecting the markup of enterprises, Columns (1)-(7) indicates that the estimated coefficient of PM2.5 is significantly negative when all control variables such as enterprise size are gradually included and the fixed effects of enterprise and year are controlled. The benchmark regression results indicate that the increase of haze pollution will significantly inhibit the increase of markup.

Table 2. Benchmark regression results.

Explained variable	*markup*						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
PM2.5	-0.244***	-0.219***	-0.219***	-0.222***	-0.221***	-0.228***	-0.210***
	(0.020)	(0.019)	(0.019)	(0.019)	(0.019)	(0.020)	(0.020)
size		-0.171***	-0.179***	-0.181***	-0.181***	-0.180***	-0.177***
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
age			0.096***	0.097***	0.097***	0.096***	0.098***
			(0.009)	(0.009)	(0.009)	(0.009)	(0.0092
debt				-0.136***	-0.135***	-0.136***	-0.135***
				(0.013)	(0.013)	(0.013)	(0.013)
hhi					-0.084**	-0.083**	-0.078**
					(0.034)	(0.034)	(0.034)
fdi						-0.035***	-0.023***
						(0.005)	(0.005)
pgdp							-0.180**

							(0.016)
_cons	1.480***	4.296***	4.228***	4.310***	4.315***	4.413***	6.163***
	(0.076)	(0.103)	(0.103)	(0.103)	(0.103)	(0.104)	(0.192)
Individual FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
N	331426	331426	331426	331403	331403	330960	330960
R^2	0.674	0.679	0.679	0.679	0.679	0.679	0.680

Notes: Standard errors clustered at the urban level are in parentheses. *, **, and *** respectively significant at 10%, 5%, and 1%. The following empirical tables include all control variables and fixed effects.

5.2 Robustness Test

Endogeneity test. This paper takes urban wind speed (*WS*) and terrain relief (*HIGH*) as the instrumental variables of air pollution, respectively, and uses the two-stage least square method for regression estimation. On the one hand, wind speed possesses a direct effect on the spread of atmospheric air pollutants, air pollution is closely related to the degree of population density, both aligning with the hypothesis of effective instrumental variables' correlation. On the other hand, the wind speed and terrain relief is determined by the external geographical conditions, and has nothing to do with the enterprise markup, which better meets the exogeneity assumption of effective instrumental variables. The results are displayed in columns (1)-(4) of Table 3. It can be found that the *PM2.5* is still significantly negative, that is, pollution is not conducive to enterprises to improve the markup, and the baseline regression conclusion is robust.

Table 3. Robustness test.

Explained variable	*PM2.5* (1)	*markup* (2)	*PM2.5* (3)	*markup* (4)	*markup*	*markup*
PM2.5		-0.3833**		-0.7999**	-0.1480*	-0.2148***
		(0.2051)		(0.3126)	(0.0828)	(0.0770)
WS	-0.0327***					
	(0.0011)					
HIGH			-0.0318***			
			(0.0050)			
N	330762	330762	330064	330064	330960	330960
R^2		0.246		0.243	0.680	0.680

Control other policy interference. In 2007, the *Circular of The State Council on the Issuance of the 11th Five-Year Plan for National Environmental Protection* identified 113 cities as the key cities for comprehensive prevention and control of air contamination. The establishment of the National High-tech Development zone is conducive to fostering comprehensive collaboration between businesses and scientific research entities, thereby enhancing the overall enterprise markup. To sum up, this paper incorporates the above policy dummy variables into the benchmark regression equation, and the empirical results are shown in columns (5)- (6) of Table 3. They indicate that after controlling the interference of the above related policies, the estimated coefficients of PM2.5 are uniformly and significantly negative.

Heterogeneity analysis. This study segments the research sample into private firms, state enterprises and foreign-funded enterprises to test the heterogeneous impact of haze pollution on the markup of firms. The estimated results are indicated in Columns (1)-(3) of Table 4. It can be seen that haze pollution will significantly reduce the markup of private enterprises and foreign enterprises, but has no marked effect on the markup of state enterprises. The possible

reason is that the implementation and supervision of environmental pollution control policies may be unbalanced, resulting in relatively little pressure on state enterprises.

In addition, this study classifies the research samples into labor-intensive, capital-intensive and technology-intensive industries. The regression results in columns (4) - (6) of Table 4 indicate that haze pollution has a marked impact on the markup of labor-intensive and technology-intensive enterprises, but not on capital-intensive industries. This is mainly because labor-intensive industries are usually occupying a low value-added position in the industrial chain, and have no great decision on product innovation and pricing, so they have low profits. However, capital-intensive industries are in a higher position in the industrial chain, with higher technical content and added value. Therefore, the impact of haze pollution on them is not significant.

Table 4. Heterogeneity analysis.

Explained variable	*markup*					
	(1)	(2)	(3)	(4)	(5)	(6)
PM2.5	-0.2140***	0.1029	-0.1645*	-0.2538***	-0.0902	-0.1645*
	(0.0714)	(0.1857)	(0.0856)	(0.0860)	(0.0860)	(0.0856)
N	156595	5471	165394	111849	78734	137456
R^2	0.717	0.712	0.659	0.659	0.682	0.659

Mechanism test. In terms of selecting the index of enterprise creative level, this paper uses the ratio of the resultant value from novel products to total industrial production value to measure it. Enterprise GTFP is calculated by using the DSBM (Dynamic Slacks Based Measure) model, which is based on the matching Chinese enterprise pollution database and Chinese Industrial Enterprise Database. In the DSBM model, the economic production activities of a single enterprise cover a variety of input and output factors, including the intertemporal correlation of input factors spanning from the preceding to the present or possibly the subsequent period. Table 5 indicates the test consequences of the mechanism of haze pollution affecting the markup of export enterprises. Column (l) indicates that the estimated coefficient of PM2.5 is markedly negative. This means that haze pollution is not conducive to promoting corporate innovation. It can be seen from Column (2) that the estimated coefficient of *innov* is markedly positive, which shows that corporate innovation will help promote the increase of corporate markup. The estimation results in columns (3)-(4) show that haze pollution will inhibit the increase of firms markup by decreasing enterprises GTFP.

Table 5. Mechanism test.

Explained variable	*innov*	*markup*	*gtfp*	*markup*
	(1)	(2)	(3)	(4)
PM2.5	-0.0498**		-0.0128***	
	(0.0201)		(0.0043)	
innov		0.0695**		
		(0.0295)		
gtfp				14.51311***
				(0.0841)
N	236792	236643	331106	330960
R^2	0.428	0.682	0.854	0.891

6 Extended Analysis

Urban environmental legislation, as the legal guarantee of local governments' territorial ecological and environmental governance, plays a vital role in promoting high-quality development, ecological priority, green and low-carbon road. Therefore, this study further examines the moderating effect of environmental legislation on the impact of haze pollution on firm markup. Among them, the regional environmental legislation variables are obtained by manually collecting the policy and regulation information published on the website of each city's environmental protection bureau and further collating it. Meanwhile, this part uses Python to quantitatively analyze the environmental legislation texts and constructs the indicator of urban environmental legislation intensity, Firstly, *simhash* algorithm was used to de-duplicate the legal texts. Secondly, Python was used to automatically calculate the word frequency of 19 keywords reflecting the strength of legislation. Finally, entropy method was used to objectively weight each keyword, and the differentiation index of urban environmental legislation intensity was constructed. Table 6 displays the outcomes of the moderating influence. Observing columns (1) – (2), it can be seen that the estimated coefficients of the moderating variable *law*PM2.5* and *lawqd*PM2.5* are significantly positive, which means that the implementation of environmental legislation in cities significantly weakens the negative effect of haze pollution on the corporate markup. And with the increases of the intensity of urban environmental legislation, the reducing effect becomes greater.The reasonable explanation is that under the high intensity of environmental regulation, the extent to which businesses absorb environmental costs will be significantly increased, which may further inspire companies to enhance their production technology and efficiency to offset the pressure of environmental cost (Lanoie et al., 2008) [13], thus increasing the markup of enterprises.

Table 6. Test of moderating effect.

Explained variable	*Markup*	
	(1)	(2)
PM2.5	-0.2031***	-0.2161***
	(0.0200)	(0.0200)
*law*PM2.5*	0.0490***	
	(0.0028)	
*lawqd*PM2.5*		0.0848***
		(0.0102)
N	330960	330960
R^2	0.680	0.680

7 Conclusions and Implications

Continuously increasing the corporate markup is not only the practice of high-quality development concepts such as "green" and "open", but also a powerful way to promote China to achieve high-level opening-up. The findings suggest that haze pollution will dramatically reduce the firms' markup during the sample period, which is still robust when considering the endogeneity problem and the interference of control policies Heterogeneity analysis shows that the inhibitory effect of haze pollution on markup is more significant in non-state-owned firms, labor-intensive and technology-intensive firms. Technological innovation effect and GTFP

improvement effect are the key transmission channels for haze pollution to inhibit the increase of firms' markup. Further extensive analysis shows that urban environmental legislation weakens the inhibitory effect of haze pollution on markup, and with the increase of urban environmental legislation intensity, the reducing effect becomes greater.

The above conclusions have important policy implications for persisting in environmental governance, continuously improving the markup of export enterprises, and realizing the high-quality development of economy. First, we should maximize the influence of technological innovation in pollution prevention and control and improving the markup of enterprises. Government departments should encourage research and development of innovative technologies and initiate dedicated financial resources to bolster scientific inquiry and technological advancements in the field of green development. Second, the government should use a variety of scientific policy tools to implement differentiated environmental regulations in light of local conditions. In addition, the environmental regulation policy system and incentive mechanism should be further improved to force enterprises to upgrade their industrial structure to increase the markup and climb to the middle and high end of the global value chain.

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