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Does air pollution matter in a supplier's trade credit strategy? Evidence from an emerging market[☆]

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Abstract

This study analyzes the impact of air pollution on the city in which customers are located on the trade credit strategy of their suppliers. Following the framework of environmental stress theory, we hypothesize that suppliers change their trade credit strategy to grant less trade credit to their customers located in cities with severe air pollution. Our findings are consistent with our hypothesis. We find that the adverse effects of air pollution occur through financial constraints, operating risk, and customers' default risk, corroborating the underlying logic of our proposed hypothesis. Additional analyses suggest that changes in a supplier's trade credit are more pronounced when a customer is in a polluting industry, has low total factor productivity, receives fewer government subsidies, has fewer bank loans, is far from its suppliers, and has poor inventory management.

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Keywords: Air pollution; Environmental stress theory; Trade credit strategy

1. Introduction

The literature on air pollution mostly focuses on its impact on the environment, economy, or human health, but the firm-

level effects of air pollution are underexplored. Hence, it is not clear whether air pollution has an adverse impact on firm decisions and, thereby, on shareholder value. In this study, we focus primarily on trade credit because it plays an important role in economic activities, especially in emerging markets (Ayyagari, Demirgüç-Kunt, Maksimovic, 2010).

Trade credit refers to the funds owed to suppliers for goods sold to customers, and it is a source of informal and supply chain financing. In emerging markets, formal financing, such as bank loans, is not readily available to firms because of capital market impediments (Allen, Qian, Qian, 2005; Ayyagari et al., 2010). Prior studies on trade credit focused on firm-level determinants, such as creditworthiness (Ng, Smith, Smith, 1999); macroeconomic determinants; and informal institutional determinants, such as social trust and religiosity (Cao, Chan, Hou, Jia, 2019; Wu, Firth, Rui, 2014). However, the impact of air pollution on a firm's trade credit has

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been underexplored. Given the importance of trade credit in the economic development of a country (Allen et al., 2005), it is imperative to examine its contributing factors. Few studies, however, have explored an environmental driver of local air pollution. Our study fills this gap.

The purpose of this study is to examine the impact of air pollution in the city in which customers are located on the trade credit strategy of their suppliers. Our study is supported by the fact that air pollution has a material impact on people's emotions and decision-making beyond its adverse effects on their physical health. Specifically, air pollution can lead investors to be excessively pessimistic about stock prices (Huang, Xu, Yu, 2020), causing analysts to lower their optimistic earnings forecasts (Dong, Fisman, Wang, Xu, 2021) and prompting managers to expand their engagement in corporate social responsibility (Tan, Tan, Chan, 2021). Following Tan et al. (2021), we observe that, like other people, firm managers are subject to cognitive impairment. In addition, we observe that the operating costs incurred by customers in highly polluted cities are also higher because of the poor physical health of their employees compared to customers located in cities with less air pollution; customers in cities with a significantly higher air pollution also suffer from greater financial constraints, higher operating risk, and higher default risk, resulting from managers' suboptimal business decisions. *Ceteris paribus*, we hypothesize that suppliers extend less trade credit to customers with poor credit quality.

Our findings are consistent with our hypothesis and are robust to alternative metrics of trade credit and air pollution, using a difference-in-differences (DID) research design, and the instrumental variables method. Additional analyses suggest that the financial constraints, operating risk, and default risk of a customer are the mediating factors in a supplier's change in trade credit strategy due to air pollution. Further, we document that the decrease in trade credit is more salient when a customer is in a polluting industry, has low total factor productivity, receives fewer government subsidies, has fewer bank loans, is far from its suppliers, and has poor inventory management. Finally, we find that customers in cities with higher air pollution offer more trade credit to their own customers, reflecting the challenges in their operation. Our findings are consistent with the notion that increased air pollution adds stress to the managers at customer firms, thereby making their firms less creditworthy.

Our study makes three contributions. First, we document that, in addition to the formal and informal factors, air pollution is a determinant of trade credit. Second, we complement the literature on the financial impact of air pollution. In addition to stock returns, analyst earnings' forecasts, and corporate social responsibilities, currently addressed in the literature, we show that air pollution affects suppliers' trade credit strategy. Our findings suggest that it is important to manage air pollution to ensure the sustainable operation of

firms, in addition to the prevention of risks associated with public health. Third, our mediating factor analyses suggest that a supplier's changes in trade credit strategy due to local air pollution take effect through financial constraints, operating risk, and default risk. Thus, it is beneficial for customers to manage these risks in order to mitigate the adverse impact of air pollution.

2. Literature review and hypothesis development

The existing literature documents several adverse effects of air pollution on people. First, it negatively affects their physical health. For instance, air pollution damages cardiac and respiratory functioning, leading to an increase in death rates (Franklin, Brook, Arden, 2015). Second, severe air pollution adversely affects the quality of life, making people unhappy (Zhang, Zhang, Chen, 2017), anxious, frustrated (Evans, Colome, Shearer, 1988), and even suicidal (Bakian, Huber, Coon, Gray, Wilson, McMahon, Renshaw, 2015). Third, air pollution adversely affects the quality of decision-making, which leads people to make cognitive errors. For instance, Ackert, Church, Deaves (2003) suggest that air pollution weakens people's ability to process information. Consequently, on days with more air pollution, investors are pessimistic about future stock performance (Huang et al., 2020), and securities analysts are more pessimistic in their earnings forecasts (Dong et al., 2021). Overall, air pollution adversely affects people's physical health, emotions, and decision-making ability. Specifically, as supported by Tan et al. (2021), managers are susceptible to the adverse effects of air pollution. Therefore, air pollution induces physical and mental stress for managers and, most importantly, impairs their ability to make decisions, consistent with the environmental stress theory (Skrzypek, Zejda, Kowalska, Czech, 2013). Furthermore, customer firms located in cities with severe air pollution are compelled to spend resources on compliance with local environmental regulations. Accordingly, we expect these firms to have worse performance than equivalent firms located in cities with good air quality (Wang et al., 2020).

The main determinants of unsecured trade credit are the creditworthiness of the customer (Petersen & Rajan, 1997) and information asymmetry between a customer and a supplier (Lin & Chou, 2015). These determinants are captured primarily by firm size, cash holdings, leverage, earning power, firm age (Petersen & Rajan, 1997), reputation (Ng et al., 1999), and ethical practices (Cowton & San-Jose, 2017). From the perspective of a supplier's trade credit strategy, we argue that the most important consideration is the repayment ability of customers. A high sales level is useless if the accounts receivable are not collectible. Hence, we expect suppliers to pay particular attention to the creditworthiness of customers before granting them trade credit. Therefore, we expect firm-level determinants to continue to be important.

Air pollution is a factor in climate risk. The severity of air pollution poses a threat to the health of managers and operations of a firm. For instance, if managers face a high health risk, the human capital of their firms deteriorates, leading to poor business decisions. Similarly, when a city has severe air pollution, a firm unavoidably diverts its resources to manage pollution, ultimately affecting its profitability. These inferences are consistent with human capital and resource dependence theories. Therefore, we expect customer firms in cities with severe air pollution to perform poorly compared with those in cities with good air quality. Hence, we test the following core hypothesis:

Hypothesis 1. *Ceteris paribus*, a supplier provides less trade credit to a customer that is located in a city with severe air pollution than to those in a city with good air quality.

3. Sample selection and methodology

3.1. Data and sample selection

We test H1 using all the A-share firms on the Shanghai and Shenzhen Stock Exchanges during the period 2013–2019. We obtain firm-level accounting and financial information from the China Stock Market and Accounting Research database. We start at the beginning of 2013 because that is when the city-level air quality index (AQI) was first publicly disclosed. A high AQI means severe air pollution.¹ We exclude 932 firm-years located in cities that did not disclose their AQI in 2013. The final sample has 12,444 firm-year observations. We winsorize the data at the 1% and 99% levels.

3.2. Methods

To test H1, we use the following multiple regression model:

$$TRADECREDIT_{i,t} = \alpha + \beta_1 POLLUTE_{i,t} + CONTROL + INDUSTRY + YEAR + CITY + \varepsilon_{i,t} \quad (1)$$

where *TRADECREDIT* denotes the trade credit of firm *i* at time *t*. For robustness, we use three metrics to proxy for trade credit: the ratio of accounts payable to the cost of goods sold (*AP_CS*), the ratio of accounts payable to total assets (*AP_AT*), and the ratio of accounts payable to total liabilities (*AP_LT*). *POLLUTE* is the logarithm of the daily average AQI of the city in which the firm is located. We include the following set of control variables in Equation (1): firm size (*SIZE*), return on assets (*ROA*), firm age (*AGE*), financial leverage (*LEVERAGE*), market-to-book ratio (*MTB*), liquidation cost (*LIQUID_COST*), industry market share (*MKTSHARE*), non-cash current asset level (*CA*), non-

accounts payable current liability level (*CL_XTRADE*), tangible assets (*TANGIBILITY*), board size (*BSIZE*), and board independence (*INDEPT*). These variables account for firm operating, repayment ability, liquidity, and governance characteristics that affect a firm's creditworthiness. The detailed definitions are presented in [Appendix Table A1](#). We control for industry-, year-, and city-fixed effects in Equation (1). The standard errors of coefficients are clustered at the industry and city levels. If H1 is valid, we expect β_1 to be negative.

4. Results

4.1. Summary statistics

We present the summary statistics of the data in [Table 1](#). The means of *AP_CS*, *AP_AT*, and *AP_LT* are 0.264, 0.123, and 0.321, respectively, suggesting that firms have moderate reliance on trade credit for their operation. In terms of air pollution, the mean of *POLLUTE* is 4.380, which is approximately equivalent to an AQI level of 80.

4.2. Baseline findings

We present the baseline findings for Equation (1) in [Table 2](#). Across the three columns, the coefficients of *POLLUTE* are consistently negative and significant at the 1 percent or 5 percent levels, suggesting that when a firm is located in a city with severe air pollution, the firm, on average, receives less trade credit. The coefficients of control variables, if significant, carry the expected signs. For instance, the coefficients of *SIZE* and *CA* are consistently positive and significant at the 1 percent level. That is, when a firm is bigger or has a large amount of current assets, it is a less risky credit proposition. Then, suppliers extend more trade credit.

To compare the relative importance of firm-level determinants and air pollution on trade credit, we present standardized coefficients on the baseline findings in [Table 2](#). Standardized coefficients allow us to compare the magnitude of estimated coefficients by standardizing the measurement unit of each variable. For instance, in column (2), the standardized coefficients of *POLLUTE*, *SIZE*, and *ROA* are -0.0298 , 0.1054 , and -0.0180 , respectively, suggesting that air pollution reduces trade credit by 2.98 percent, firm size raises trade credit by 10.54 percent, and profitability reduces trade credit by 1.8 percent. Then, a comparison of all three coefficients shows that firm size has the most important impact on trade credit whereas air pollution is more important than profitability in lowering trade credit. Although air pollution is not the most important determinant of trade credit, its effect is comparable to that of the current asset level, the liquidation cost, and the market-to-book ratio.

4.3. Robustness checks

For robustness, we conduct several checks. First, instead of AQI, we use PM2.5 to proxy for the severity of air pollution

¹ AQI measures the degree of air pollution. It captures the extent of sulfur dioxide, nitrogen dioxide, PM10, PM2.5, carbon monoxide, and ozone in the atmosphere.

Table 1
Descriptive statistics.

Variables	N	mean	std	min	p25	p50	p75	max
<i>AP_CS</i>	12,444	0.264	0.207	0.000	0.115	0.212	0.354	1.104
<i>AP_AT</i>	12,444	0.123	0.098	0.000	0.049	0.099	0.172	0.444
<i>AP_LT</i>	12,444	0.321	0.212	0.000	0.148	0.290	0.464	0.844
<i>POLLUTE</i>	12,444	4.380	0.259	3.776	4.197	4.415	4.556	4.861
<i>SIZE</i>	12,444	22.19	1.435	19.515	21.212	22.003	22.924	27.304
<i>ROA</i>	12,444	0.058	0.069	-0.233	0.027	0.0548	0.091	0.256
<i>AGE</i>	12,444	2.917	0.290	2.079	2.773	2.944	3.135	3.555
<i>LEVERAGE</i>	12,444	0.424	0.214	0.059	0.252	0.405	0.578	0.941
<i>MTB</i>	12,444	2.459	2.416	0.000	0.871	1.745	3.223	13.585
<i>LIQUID_COST</i>	12,444	-0.134	0.128	-0.679	-0.172	-0.105	-0.051	0.000
<i>MKTSHARE</i>	12,444	0.022	0.046	0.001	0.002	0.005	0.018	0.290
<i>CA</i>	12,444	0.390	0.195	0.000	0.253	0.389	0.526	0.839
<i>CL_XTRADE</i>	12,444	0.330	0.182	0.000	0.191	0.311	0.448	0.834
<i>TANGIBILITY</i>	12,444	0.046	0.051	0.000	0.016	0.033	0.056	0.326
<i>BSIZE</i>	12,444	2.233	0.185	1.792	2.079	2.303	2.303	2.773
<i>INDEPT</i>	12,444	0.377	0.054	0.333	0.333	0.364	0.429	0.571

Variables are defined in Appendix Table A1.

Table 2
The impact of air pollution on trade credit.

Variables	<i>AP_CS</i>	Std. Coeff.	<i>AP_AT</i>	Std. Coeff.	<i>AP_LT</i>	Std. Coeff.
	(1)	(2)	(3)	(4)	(5)	(6)
<i>POLLUTE</i>	-0.0238*** (-3.765)	-0.0298	-0.0049** (-1.991)	-0.0130	-0.0177*** (-2.814)	-0.0216
<i>SIZE</i>	0.0152*** (7.424)	0.1054	0.0036*** (4.901)	0.0527	-0.0047*** (-2.624)	-0.0318
<i>ROA</i>	-0.0540** (-2.157)	-0.0180	0.0063 (0.609)	0.0044	-0.0005 (-0.019)	-0.0002
<i>AGE</i>	-0.0389*** (-6.744)	-0.0532	-0.0268*** (-11.613)	-0.0793	-0.0621*** (-10.769)	-0.0849
<i>LEVERAGE</i>	0.1182*** (6.054)	0.1222	0.0654*** (3.052)	0.1428	0.0854*** (4.653)	0.0862
<i>MTB</i>	-0.0028*** (-3.354)	-0.0327	-0.0031*** (-9.654)	-0.0764	-0.0067*** (-6.432)	-0.0764
<i>LIQUID_COST</i>	0.0581*** (2.728)	0.0359	0.1155*** (14.621)	0.1509	0.2394*** (12.142)	0.1445
<i>MKTSHARE</i>	-0.6802*** (-13.029)	-0.1512	-0.0779*** (-5.009)	-0.0366	-0.0905** (-2.332)	-0.0196
<i>CA</i>	0.0402*** (3.310)	0.0379	0.1396*** (29.522)	0.2778	0.3690*** (31.258)	0.3394
<i>CL_XTRADE</i>	0.1893*** (9.164)	0.1664	0.3716*** (56.958)	0.6901	0.4442*** (27.278)	0.3813
<i>TANGIBILITY</i>	-0.1743*** (-4.997)	-0.0429	-0.0349*** (-2.641)	-0.0182	-0.1533*** (-4.651)	-0.0369
<i>BSIZE</i>	-0.0016 (-0.146)	-0.0014	0.0202*** (4.383)	0.0378	0.0762*** (6.624)	0.0665
<i>INDEPT</i>	0.0040 (0.114)	0.0010	-0.0002 (-0.012)	-0.0001	0.0506 (1.368)	0.0129
Constant	-0.3329*** (-5.269)		-0.0409* (-1.814)		-0.3812*** (-6.770)	
N	12,444		12,444		12,444	
Adjusted <i>R</i> ²	0.344		0.463		0.289	
<i>F</i>	67.52		167.58		98.32	

This table presents the impact of air pollution in a city in which a customer is located on its supplier's trade credit strategy using ordinary least squares. Columns (2), (4), and (6) present the standardized coefficients of columns (1), (3), and (5), respectively. We control for year-, industry-, and firm-fixed effects. Variables are defined in Appendix Table A1. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.

Table 3
Robustness checks.

Panel A: Alternative metric of air pollution				
Variables	<i>AP_CS</i>	<i>AP_AT</i>	<i>AP_LT</i>	
	(1)	(2)	(3)	
<i>PM2.5</i>	−0.0177*** (−3.555)	−0.0047*** (−2.698)	−0.0113** (−2.392)	
Controls	YES	YES	YES	
N	12,444	12,444	12,444	
Adjusted <i>R</i> ²	0.344	0.568	0.434	
<i>F</i>	67.45	94.43	98.12	
Panel B: Difference-in-differences analysis				
<i>RANKED</i>	0.0257*** (5.462)	0.0053*** (2.945)	0.0087* (1.943)	
Controls	YES	YES	YES	
N	12,444	12,444	12,444	
Adjusted <i>R</i> ²	0.345	0.569	0.434	
<i>F</i>	67.72	167.83	98.08	
Panel C: Instrumental variables				
Variables	<i>POLLUTE</i>	<i>AP_CS</i>	<i>AP_AT</i>	<i>AP_LT</i>
	(1)	(2)	(3)	(4)
<i>BAN_COAL</i>	−0.1876*** (−6.889)			
<i>PRED_POLLUTE</i>		−0.0350*** (−5.275)	−0.0049* (−1.950)	−0.0164*** (−2.795)
Controls	YES	YES	YES	YES
N	12,444	12,444	12,444	12,444
Adjusted <i>R</i> ²	0.302	0.179	0.463	0.289
<i>F</i>	55.66	195.44	766.13	362.04

This table presents several robustness checks for the impact of air pollution in a city in which a customer is located on its supplier's trade credit strategy using ordinary least squares. Panel A uses an alternative metric for air pollution by replacing the AQI level with the PM2.5 level. Panel B uses a difference-in-differences research design. *RANKED* = 1 if a firm is located in a city that participates in air quality ranking and 0 otherwise. Panel C uses an instrumental variable (IV) approach. The IV is *BAN_COAL*, which is 1 if a firm is located in a city that bans the use of coal and 0 otherwise. We control for year-, industry-, and firm-fixed effects. Variables are defined in Appendix Table A1. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.

and reexamine Equation (1). For the sake of brevity, we do not report the coefficients of control variables from this point on. The results in Panel A in Table 3 show that the coefficients of *POLLUTE* continue to be negative and significant at the 1 percent or 5 percent levels.

Second, we leverage the fact that China publicly announced the AQI rankings for some cities in 2013–2015. We expect that government officials in these ranked cities took particular care and spent additional resources on managing their air quality. Thus, air quality is better in these cities. To alleviate endogeneity concerns in Equation (1), we employ a DID research design using a *RANKED* dummy variable with a value of 1 if the firm is located in a ranked city and 0 otherwise in 2013–2015. Then, we replace *POLLUTE* with *RANKED* in Equation (1). We expect the coefficient of *RANKED* to be positive with the DID research design. The findings in Panel B in Table 3 indicate that the coefficients of *RANKED*, as expected, are positive and significant at the 1 percent or 10 percent levels.

Third, we use the instrumental variable (IV) method to mitigate potential endogeneity between *POLLUTE* and various trade credit metrics in Equation (1). We leverage the fact that several Chinese cities in our sample ban the use of coal. Hence, we define *BAN_COAL* as a dummy variable with a value of 1 if the firm is located in a city that bans the use of coal and use it as the IV for *POLLUTE*. *BAN_COAL* helps achieve less air pollution, but it does not directly affect a firm's trade credit. We present the findings in Panel C in Table 3. In column (1), as expected, the coefficient of *BAN_COAL* is negative and significant in predicting *POLLUTE*. We then obtain the predicted value of *POLLUTE* (*PRED_POLLUTE*) and replace *POLLUTE* with it in Equation (1). The results in columns (2)–(4) in Panel C show that the coefficients of *PRED_POLLUTE* are negative and significant at the 1 percent or 10 percent levels. Collectively, the findings in Table 3 are robust to the use of an alternative measurement of air pollution and after accounting for endogeneity.

4.4. Transmission channels

To examine the logic behind H1, we examine the mediating effect of financial constraints (*KZ*), operating risk (*RISK*), and the default risk (*ZSCORE*) of customers in the impact of air pollution on trade credit strategy of suppliers. For *KZ*, we use the *KZ* index, which is $-1.002 \cdot \text{cashflow} + 0.2838 \cdot \text{Tobin's } Q + 3.139 \cdot \text{leverage} - 39.368 \cdot \text{dividends} - 1.3158 \cdot \text{cash}$. *KZ* means a firm has tight financial constraints. For *RISK*, we use a firm's standard deviation of the return on assets in the previous three years. *ZSCORE* is the Altman's Z-score, which is $6.56 \cdot (\text{working capital}/\text{total assets}) + 3.26 \cdot (\text{retained earnings}/\text{total assets}) + 6.72 \cdot (\text{earnings before interests and taxes}/\text{total assets}) + 1.05 \cdot (\text{market value of equity}/\text{market value of total liabilities})$. A high *ZSCORE* means a firm has low default risk.

We follow Barron and Kinney (1986) in conducting the mediating tests using *KZ*, *RISK*, and *ZSCORE*. The findings are presented in Panels A–C in Table 4. In column (1) in all panels, we use *KZ*, *RISK*, and *ZSCORE* as dependent variables and *POLLUTE* as the key explanatory variable. The coefficients of *POLLUTE* are significant at the 5 percent or 10 percent level with the expected signs. That is, when the firm is located in a city with severe air pollution, its financial constraints are higher (*KZ* is low), operating risk is higher (*RISK* is high), and default risk is higher (*ZSCORE* is low). In columns (2)–(4) in all panels, we use the three trade credit metrics as dependent variables and both *POLLUTE* and a mediating variable (*KZ*, *RISK*, or *ZSCORE*). The findings in these columns show that the coefficients of *KZ*, *RISK*, or *ZSCORE* are significant at the 1 percent or 10 percent level with the expected signs. Thus, the transmission channels for changes in trade credit strategy toward suppliers are financial constraints, operating risk, and the default risk of a customer.

4.5. Additional analysis

Air pollution results from many factors. Hence, we expect to see many moderating factors in the impact of air pollution

Table 4
Mediating effects.

Panel A: Financial constraints				
Variables	<u>KZ</u>	<u>AP_CS</u>	<u>AP_AT</u>	<u>AP_LT</u>
	(1)	(2)	(3)	(4)
<i>POLLUTE</i>	0.1663** (2.458)	-0.0201*** (-3.243)	-0.0034* (-1.701)	-0.0144** (-2.394)
<i>KZ</i>		-0.0003* (-1.684)	-0.0005*** (-6.001)	-0.0014*** (-6.901)
Controls	YES	YES	YES	YES
N	12,444	12,444	12,444	12,444
Adjusted R ²	0.173	0.344	0.570	0.436
F	31.43	66.81	166.83	97.98
Panel B: Operating risk				
Variables	<u>RISK</u>	<u>AP_CS</u>	<u>AP_AT</u>	<u>AP_LT</u>
	(1)	(2)	(3)	(4)
<i>POLLUTE</i>	0.0182* (1.725)	-0.0155*** (-2.739)	-0.0029* (-1.792)	-0.0120* (-1.906)
<i>RISK</i>		-0.0650*** (-9.684)	-0.0268*** (-9.710)	-0.0547*** (-8.538)
Controls	YES	YES	YES	YES
N	12,444	12,444	12,444	12,444
Adjusted R ²	0.035	0.350	0.466	0.436
F	12.75	68.66	719.0	97.99
Panel C: Z-Score				
Variables	<u>Z_SCORE</u>	<u>AP_CS</u>	<u>AP_AT</u>	<u>AP_LT</u>
	(1)	(2)	(3)	(4)
<i>POLLUTE</i>	-0.0272* (-1.891)	-0.0132** (-2.372)	-0.0048* (-1.909)	-0.0135** (-2.193)
<i>Z_SCORE</i>		0.0620*** (7.397)	0.0404*** (11.637)	0.1020*** (12.854)
Controls	YES	YES	YES	YES
N	12,444	12,444	12,444	12,444
Adjusted R ²	0.094	0.347	0.468	0.442
F	24.54	67.64	131.83	96.16

This table presents the mediating effects of financial constraints, operating risk, and default risk for the impact of air pollution in a city in which a customer is located on its supplier's trade credit strategy using ordinary least squares. Panel A uses the *KZ* index to measure a customer's financial constraints. Panel B uses the standard deviation of the return on assets for three years up to the current year as operating risk. Panel C uses Altman's Z-score as the default risk metric. We control for year-, industry-, and firm-fixed effects. Variables are defined in Appendix Table A1. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.

on a supplier's trade credit strategy. We discuss the results below.

4.5.1. Industry and firm characteristics

First, for industry, we consider whether a firm is in a polluting industry. According to the classifications by the Ministry of Environmental Protection and Ecology, China has a total of 16 polluting industries (thermal power, steel, cement, electrolytic aluminum, coal, metallurgy, chemicals, petrochemicals, building materials, papermaking, brewing, pharmaceuticals, fermentation, textiles, tanning, and mining). Then, we examine Equation (1) in terms of subsamples of polluting and nonpolluting industries. Second, we examine a firm's total factor productivity (TFP). Some studies suggest

that pollution and pollution regulations affect firm TFP (Ai, Hu, Li, Shao, 2020; Tian, Tian, Chen, Shao, 2020). To gauge the moderating effect of TFP, we estimate a Cobb-Douglas production function for each industry in each year as:

$$INCOME_{i,t} = \delta_0 + \delta_1 ASSET_{i,t} + \delta_2 LABOR_{i,t} + \delta_3 COST_{i,t} + \mu_{i,t}, \quad (2)$$

where *INCOME* is the logarithm of the total revenue of a firm; *ASSET* is the logarithm of a firm's total assets; *LABOR* is the logarithmic value of the total number of employees; and *COST* is the logarithmic value of the cost of goods sold. The residual of Equation (2) is the TFP for each firm. Using the median of the residual, we divide the full sample into subsamples with high and low TFP.

We present the findings in Panels A and B in Table 4. Across all columns in both panels, the coefficients of *POLLUTE* are consistently negative and significant at the 1 percent, 5 percent, or 10 percent level for the subsamples of firms that are in polluting industries or have low TFP. The findings are consistent with the notion that when firms are susceptible to disproportionate impacts of air pollution, such as those that are in a polluting industry or have low TFP, the adverse effect on trade credit is more salient. That is, in the presence of air pollution, suppliers pay particular attention to the status of customers' industries and TFP when setting their trade credit strategy.

4.5.2. External financing

In addition to trade credit, firms can use government subsidies and bank loans to meet their financing needs. To examine the mediating effect of these factors, we divide the full sample into subsamples with high and low government subsidies and bank loan subsamples, using the respective medians. We present the findings in Panels A and B in Table 6. In both panels, the coefficients of *POLLUTE* consistently continue to be negative and significant at the 1 percent, 5 percent, or 10 percent level for the low-government-subsidy and bank loan subsamples, whereas those of the other subsamples are not significant. The findings indicate that when firms have little funding (low government subsidies and bank loans), the effect of air pollution on their trade credit is binding. That is, with respect to their customers in cities with severe air pollution, suppliers consider the customers' level of government subsidy and bank loans in shaping their trade credit strategy.

4.5.3. Supply chain

The shaping of a supplier's trade credit strategy depends, in part, on supply chain factors. We expect these factors to moderate the impact of air pollution on a supplier's trade credit strategy. Specifically, we consider the proximity between a supplier and its customer, because a more distant supplier incurs higher costs in obtaining goods, making trade credit more important to the customer than to a closer supplier with lower costs. Given that Chinese firms are required to disclose their top five suppliers, we hand-collected those suppliers'

Table 5
Cross-sectional analysis.

Panel A: Polluting industry						
Variables	<i>AP_CS</i>		<i>AP_AT</i>		<i>AP_LT</i>	
	Yes	No	Yes	No	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
<i>POLLUTE</i>	-0.0353*** (-4.305)	-0.0084 (-0.872)	-0.0145* (-1.930)	-0.0027 (-0.891)	-0.0174* (-1.715)	-0.0020 (-0.517)
Controls	YES	YES	YES	YES	YES	YES
N	4149	8296	4149	8296	4149	8296
Adjusted <i>R</i> ²	0.341	0.318	0.461	0.583	0.376	0.550
<i>F</i>	45.86	26.15	75.24	122.24	33.53	67.11
Panel B: Firm-level productivity						
Variables	<i>AP_CS</i>		<i>AP_AT</i>		<i>AP_LT</i>	
	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)
<i>POLLUTE</i>	-0.0114 (-1.577)	-0.0395*** (-3.945)	0.0039 (1.196)	-0.0067* (-1.959)	0.0101 (1.495)	-0.0175** (-2.005)
Controls	YES	YES	YES	YES	YES	YES
N	6347	6097	6347	6097	6347	6097
Adjusted <i>R</i> ²	0.342	0.376	0.571	0.606	0.496	0.430
<i>F</i>	35.88	41.70	90.76	104.35	67.13	51.91

This table presents the moderating effects of polluting industry and firm-level productivity for the impact of air pollution in a city in which a customer is located on its supplier's trade credit strategy using ordinary least squares. Panel A divides the sample into subsamples of "yes" and "no" based on whether a customer is in a polluting industry. Panel B uses a Cobb-Douglas production function to calculate total factor productivity for each firm and uses the median in each industry to divide customers into groups for high and low total factor productivity. We control for year-, industry-, and firm-fixed effects. Variables are defined in Appendix Table A1. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.

locations and calculated the average distance from warehouses to the focal customer firm. Based on the median, we divide the sample into more distant (far) and less distant (nearby) suppliers. Alternatively, we consider the inventory turnover of a customer. A high inventory turnover ratio means that the

customer firm is managing its inventory efficiently. Based on the median value, we divide the sample into subsamples with high and low efficiency.

We present the findings in Panels A and B in Table 7. In both panels, the coefficients of *POLLUTE* continue to be

Table 6
External support.

Panel A: Government subsidies						
Variables	<i>AP_CS</i>		<i>AP_AT</i>		<i>AP_LT</i>	
	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)
<i>POLLUTE</i>	0.0130 (1.466)	-0.0333*** (-3.526)	-0.0033 (-1.063)	-0.0092** (-2.443)	-0.0001 (-0.011)	-0.0321*** (-3.654)
Controls	YES	YES	YES	YES	YES	YES
N	6212	6232	6212	6232	6212	6232
Adjusted <i>R</i> ²	0.332	0.366	0.545	0.589	0.410	0.462
<i>F</i>	33.41	37.98	79.23	92.60	46.38	55.97
Panel B: Bank loans						
<i>POLLUTE</i>	-0.0105 (-1.141)	-0.0398*** (-4.603)	0.0045 (1.334)	-0.0176* (-1.867)	-0.0018 (-0.518)	-0.0155** (-2.073)
Controls	YES	YES	YES	YES	YES	YES
N	6428	6016	6428	6016	6428	6016
Adjusted <i>R</i> ²	0.380	0.346	0.628	0.369	0.510	0.522
<i>F</i>	42.78	35.99	116.15	39.60	69.60	75.27

This table presents the moderating effects of government subsidies and bank loans for the impact of air pollution on a city in which a customer is located on its supplier's trade credit strategy using ordinary least squares. We use the medians of the sample to divide customers into groups for high and low government subsidies and bank loan levels. We control for year-, industry-, and firm-fixed effects. Variables are defined in Appendix Table A1. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.

Table 7
Additional analysis.

Panel A: Supply chain distance						
Variables	AP_CS		AP_AT		AP_LT	
	Far	Near	Far	Near	Far	Near
	(1)	(2)	(3)	(4)	(5)	(6)
POLLUTE	-0.0391*** (-4.056)	-0.0078 (-1.055)	-0.0067* (-1.906)	0.0013 (0.389)	-0.0252*** (-2.966)	-0.0127 (-1.531)
Controls	YES	YES	YES	YES	YES	YES
N	6281	6163	6281	6163	6281	6163
Adjusted R ²	0.383	0.285	0.571	0.610	0.464	0.457
F	44.40	26.66	86.70	110.46	56.69	59.80
Panel B: Inventory turnover						
Variables	AP_CS		AP_AT		AP_LT	
	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)
POLLUTE	0.0003 (0.043)	-0.0329*** (-3.400)	-0.0014 (-0.437)	-0.0093*** (-2.735)	0.0045 (0.542)	-0.0314*** (-3.780)
Controls	YES	YES	YES	YES	YES	YES
N	6522	5922	6522	5922	6522	5922
Adjusted R ²	0.330	0.376	0.570	0.617	0.434	0.494
F	34.23	41.54	90.19	109.87	52.50	66.83
Panel C: A customer firm's own trade credit extension						
Variables	AR/CS		AR/AT		AR/LT	
	(1)	(2)	(1)	(2)	(1)	(2)
POLLUTE		0.0388*** (2.974)		0.0087** (2.100)		0.0683*** (3.693)
Controls		YES		YES		YES
N		12,444		12,444		12,444
Adjusted R ²		0.458		0.618		0.571
F		107.84		206.03		169.75

This table presents several additional analyses. Panel A uses the distance between suppliers and customers and divides the full sample into far and near subsamples using the median. Panel B uses the inventory turnover ratio to divide the full sample into high and low inventory management subsamples. Panel C shows the impact of air pollution in a city in which a customer is located on its own trade credit to its customers. We control for year-, industry-, and firm-fixed effects. Variables are defined in Appendix Table A1. ***, **, and * indicate 1%, 5%, and 10% significance, respectively.

negative and significant at the 1 percent or 10 percent level in the subsamples for more distant supplier-customer relationships and low inventory management efficiency, while those of the other subsamples are not significant. Therefore, the effect of air pollution on shaping a supplier's trade credit strategy is more salient for customers with more distant suppliers or poor inventory management, which is consistent with the intuition that a supplier's trade credit strategy is critically important in these scenarios.

4.5.4. Supply of trade credit

Our analysis focuses on the trade credit strategy of a supplier for its customers located in cities with more air pollution compared to those with less air pollution. We aim to determine whether these firms extend more trade credit to their own customers when air pollution is severe. We argue that because firms in cities with severe air pollution have poor performance and are less creditworthy, they need to be more aggressive in their own trade credit strategy in order to sustain their

businesses. To confirm this conjecture, we replace accounts payable in Equation (1) with accounts receivable. We present the findings in Panel C in Table 7. The coefficients of POLLUTE are positive and significant at the 1 percent or 5 percent level, which is consistent with our expectation.

5. Summary and discussions

In this study, we investigate whether air pollution affects the trade credit strategy of a supplier toward its customers in a city with severe air pollution. Based on environmental stress, human capital, and resource dependence theories, we predict that a supplier changes its trade credit strategy to grant less trade credit to a customer located in a city with severe air pollution. This inference is based on the fact that severe air pollution has an adverse effect on the emotions and human capital of managers, such that some resources need to be diverted to managing air pollution. Consequently, air pollution adversely affects manager decisions and business

performance. With all else remaining the same, customers in cities with severe air pollution are less creditworthy than those in cities with good air quality.

Our findings are consistent with the hypothesis and are robust to alternative measurements of trade credit and air pollution. We conduct mediating effect analyses that reveal that a customer's financial constraints, operating risk, and default risk are the transmission channels for the adverse effects of air pollution on lowering trade credit, thereby corroborating the underlying logic of the hypothesis. We find that the change in a supplier's strategy in terms of extending less trade credit is more pronounced when a customer is in a polluting industry, has low TFP, has lower government subsidies, has fewer bank loans, is far away from suppliers, and has poorer inventory management. Finally, we find that customer firms in cities with more air pollution offer more trade credit to their own customer firms.

Our theoretical contribution is in finding that the adverse impact of air pollution on trade credit is consistent with the theories on environmental stress, human capital, and resource dependence. Our managerial contribution comes from our finding that if a firm is located in a city with severe air pollution, it receives less trade credit from suppliers; therefore, it needs to address this deterioration in trade credit by signaling its creditworthiness. For instance, it might want to maintain higher current assets in order to obtain other types of financing (e.g., bank loans). So, firms need to recognize not only the adverse impact of air pollution on the environment but its detrimental effects on trade credit financing. To firms can benefit from working with green technology, promoting environmentally friendly policies, and engaging internal and external stakeholders to reduce air pollution. Therefore, in the long run, as cities improve their environmental sustainability, firms can increase their trade credit.

Our findings have two implications. First, reducing air pollution is good for the environment and people as well as for firms in terms of trade credit. This message needs to be communicated by national governments, to reverse the mistaken view that improving air quality is always costly for firms. Second, trade credit depends on many firm-level factors. However, air pollution leads to lower trade credit, thus firms help themselves by driving policies that reduce air pollution. Overall, efficient management of air pollution not only improves physical health but also enhances customer trade credit financing, which leads to sustainable economic growth. Although we conduct our analysis on Chinese firms, our findings apply equally to other emerging markets. Future studies can examine other countries and over a longer period to further validate our findings.

Declaration of competing interest

We do not have any conflict of interests.

Appendix Table A1. Definition of variables

Trade credit	
<i>AP_CS</i>	The ratio of accounts payable to the cost of goods sold.
<i>AP_AT</i>	The ratio of accounts payable to total assets.
<i>AP_LT</i>	The ratio of accounts payable to total liabilities.
Variable	
<i>POLLUTE</i>	Natural logarithm of the daily average of the air quality index of the city where the firm is located.
Control variables	
<i>SIZE</i>	The natural logarithm of total assets.
<i>ROA</i>	The return on assets, calculated as the ratio of net income over total assets.
<i>AGE</i>	The natural logarithm of firm age plus 1.
<i>LEVERAGE</i>	The ratio of long-term debt and debt in current liabilities to total assets.
<i>MTB</i>	The ratio of the market value of equity to total assets.
<i>LIQUID_COST</i>	The liquidation costs calculated as the ratio of raw materials to total assets and multiplied by (−1).
<i>MKTSHARE</i>	A firm's market share calculated as the ratio of the firm's sales over total industry sales, where industry classification is based on SIC two-digit codes.
<i>CA</i>	The ratio of noncash current assets to total assets.
<i>CL_XTRADE</i>	The ratio of current liabilities excluding accounts payable to total assets.
<i>TANGIBILITY</i>	The ratio of net property, plant, and equipment to total assets.
<i>BFSIZE</i>	The natural logarithm of firm board of directors plus 1.
<i>INDEPT</i>	The ratio of independent director to board of directors.
<i>RANKED</i>	A dummy variable with a value of 1 if a firm is located in a province that is included in the ranking at <i>t</i> and afterward, and zero otherwise; it is always zero for firms located in provinces that are never included in the ranking.
<i>KZ</i>	$-1.002 * \text{Cash_flow} + 0.2838 \text{ Tobin's Q} + 3.139 * \text{Leverage} - 39.368 * \text{Dividends} - 1.3158 * \text{Cash_Holdings}$.
<i>RISK</i>	Standard deviation of return on assets in the previous three years.
<i>Z_SCORE</i>	$6.56 * (\text{working capital} / \text{total assets}) + 3.26 * (\text{retained earnings} / \text{total assets}) + 6.72 * (\text{EBIT} / \text{total assets}) + 1.05 * (\text{market value of equity} / \text{market value of total liabilities})$.
Supply of trade credit	
<i>AR_CS</i>	The ratio of accounts receivable to the cost of goods sold.
<i>AR_AT</i>	The ratio of accounts receivable to total assets.
<i>AR_LT</i>	The ratio of accounts receivable to total liabilities.

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