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# Internal finance, financial constraint, and pollution emissions: Evidence from China<sup>☆</sup>

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## ABSTRACT

This study explores the role of internal finance on firms' environmental behavior, focusing specifically on sulfur dioxide (SO<sub>2</sub>) emissions in China's rapidly growing industrial sector. Using a rich and unique dataset provided by the Ministry of Environmental Protection (MEP), our baseline results find that firms with stronger internal finances experience a significant reduction in SO<sub>2</sub> emissions. Our empirical analysis uncovers two key mechanisms through which internal finance influences firm behavior. First, firms with stronger internal financial health, as measured by metrics like cash flow, current ratio, and coverage ratio, are more inclined to invest in Research & Development and Total Factor Productivity, especially in credit-constrained sectors. Second, these financially robust firms are more proactive in adopting SO<sub>2</sub> abatement technologies, an effect that becomes more pronounced in the context of credit-constrained firms. Our findings offer a nuanced understanding of how internal financial resources can serve as a dual lever for both innovation and sustainability, particularly in settings where external financing is limited. They also suggest that the shortcomings of the financial systems necessitate regulation to support and accelerate the environmental transition.

## 1. Introduction

Environmental degradation, particularly in the form of air pollution, is a growing concern in China, impacting both public health and social stability. China has seen a significant increase in sulfur dioxide (SO<sub>2</sub>) emissions since joining the World Trade Organization in 2001. Concurrently, the Chinese economy has grown rapidly, largely driven by the private sector's access to internal funds (Guariglia, Liu, & Song, 2011). This growth occurs in an environment where credit constraints are common, leading to distortions in

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firms' asset structures. Against this backdrop, this paper examines the relationship between credit constraints and  $SO_2$  emissions. We specifically investigate how internal financing can enable firms to invest in intangible assets or adopting  $SO_2$  abatement technologies that contribute to environmentally sustainable growth.

Reducing pollution emissions is a challenge that every industrialized and emerging country faces.<sup>1</sup> While credit constraints are known to hamper economic growth, recent studies also indicate that they have environmental consequences. Andersen (2017) argues that credit constraints distort asset allocation toward tangible, pollution-driven assets. In contrast, companies disposing of more internal finance can afford to invest in enhanced productive activities or in research and development (R&D), which target a more environmentally friendly growth and align with policies to regulate polluting emissions. Our paper investigates the finance-induced assets' distortion in China. This contribution is significant because China is one of the fastest-growing economies and addressing a market deficiency could help combat pollution. China was, in 2006, the world's most significant emitter of  $SO_2$ , the largest COD emitter in the world, surpassing the United States, and in 2018 still held the first place. The country hosts more than half of the most polluted cities in the world, according to the WHO.<sup>2</sup> In 2017, it ranked first in the world in terms of the number of natural disasters, surpassing the United States and India.<sup>3</sup> China's contribution to the climate crisis is emphasized by the OECD.<sup>4</sup>

Our research offers a novel investigation into the intricate relationship between financial constraints and sulfur dioxide ( $SO_2$ ) emissions in the context of China's rapid industrial growth. Using a comprehensive data set from China's Ministry of Environmental Protection (MEP), we focus specifically on  $SO_2$  emissions at the firm level,<sup>5</sup> collecting data for nine consecutive years (1999–2007). The dataset used in this study stops in 2007, as data from 2008 onwards is considered less reliable due to known inconsistencies, as highlighted by Brandt, Van Biesebroeck, and Zhang (2012, 2014). For this reason, most studies using this dataset also conclude their analysis by 2007 or, at the latest, 2008. This paper contributes to the understanding of how credit constraints affect  $SO_2$  emissions by leveraging rich micro-level data. To our knowledge, very few studies have explored this issue with such a level of detail in the Chinese context (Fan, Peng, Wang, & Xu, 2021; He, Wang, & Zhang, 2020; Wu, Guo, Zhang, & Bu, 2017; Zhang & Zheng, 2019, among others).

We complement our environmental data with financial metrics from the annual surveys of Chinese manufacturing firms conducted by the National Bureau of Statistics of China (NBS). These surveys provide valuable proxies for internal finance, such as cash flow, current ratio, and coverage ratio, enabling us to explore how variations in internal financial resources correlate with changes in  $SO_2$  emissions

The aim of this study is to highlight the existence of a market imperfection through the responsiveness of pollution to internal finance. We demonstrate that under the assumption that banks are more likely to lend to firms with collateral, reducing pollution requires the use of internal financing by firms that have access to it. Using metrics such as cash flow, current ratio, and coverage ratio as indicators, we find a significant negative association with  $SO_2$  emissions.

This narrative is strengthened by a heterogeneity analysis, which explore how internal financing's effect on  $SO_2$  emissions varies across sectors and regulatory contexts. Our analysis shows that firm's size, credit constraints, bank regulations, and local innovation notably influence the impact of internal finances on emissions. Specifically, larger firms, benefiting from economies of scale, tend to exhibit a higher elasticity of pollution emissions with respect to available internal financing. Financially dependent industries and cities with stringent bank regulations and less competition benefit more from internal financing in reducing emissions. Additionally, cities characterized by high levels of innovation are more effective in utilizing internal financial resources to achieve environmental improvements. Overall, investments aimed at reducing pollution depend on the availability of internal finance, a result that aligns with the literature showing over-investment in tangible assets and distortions in credit allocation, leading to a sub-optimal level of pollution.

Finally, we analyze two distinct mechanisms through which internal finance, primarily in the form of cash flow, influences firm behavior. Firstly, our empirical evidence shows that firms with higher internal cash flows are likely to allocate fewer resources to asset tangibility and instead favor investments in Research & Development (R&D) and Total Factor Productivity (TFP). This reallocation is especially marked in sectors where access to external financing is constrained, implying that internal finance allows firms without access to credit to shift away from traditional tangible asset investments to those that enhance innovation and productivity.

Secondly, our investigation extends to the role of internal finance in environmental responsibility, particularly in the acquisition of  $SO_2$  abatement technologies. We find that companies with robust internal finances are more proactive in investing in pollution control measures. The significance of this investment is magnified in the context of credit-constrained firms, substantiating the notion that liquidity is a crucial factor in facilitating a firm's sustainable practices.

To summarize, our findings highlight the negative impact of financial constraints on firms' ability to innovate and invest in cleaner technologies, thereby hindering the reduction of  $SO_2$  emissions. Firms that are constrained by limited external financing are particularly affected, as they lack the necessary resources to pursue environmentally friendly innovations. Our results underscore the critical role of financial health in enabling firms to not only drive innovation but also meet environmental responsibilities, with financial

<sup>1</sup> As argued in Gu, Teng, & Feng, 2018, the challenge for an emerging country like China is that it has to conduct at the same time and in an economically consistent way its growth and climate-friendly environmental protection strategies.

<sup>2</sup> In 2013, Shijiazhuang had only 47 days with good air quality.

<sup>3</sup> In 2017, the province of Hunan suffered a direct economic loss of about 59 billion RMB due to natural disasters (National Bureau of Statistics of China; Ministry of Ecology and Environment) More statistics can be found at the following link <https://drive.google.com/open?id=1nq-njKZ-TaQyzH30Ncq1R8hlpFE1InSG>.

<sup>4</sup> <https://oecd-development-matters.org/2019/06/20/the-global-souths-contribution-to-the-climate-crisis-and-its-potential-solutions/>.

<sup>5</sup> We extended our analysis to COD, wastewater and waste gas. Results are similar.

constraints posing a significant barrier to achieving these goals.

The rest of this paper is organized as follows: section 2 offers a detailed analysis of growth and pollution dynamics in the Chinese context. Special emphasis is placed on the government's evolving commitment to environmental regulation, as well as the significant regional heterogeneity that underscores the complex and context-dependent relationship between growth and its environmental impacts. Our empirical strategy, data and preliminary evidence are presented in Section 3. Section 4 presents the baseline findings and sources of heterogeneity. Section 5 presents the mechanisms, and finally, the paper concludes in Section 6.

## 2. Internal/external finance and growth/environmental performance: The case of China

The link between economic performance and finance is well-established, particularly in developed countries.<sup>6</sup> Cross-country evidence shows that external finance is linked with better economic performances, financed through the credit market or the equity market (Hsu, Tian, & Xu, 2014). In China, this link is operating in a specific way. The economy grew at an astonishing rate over the past few decades, fueled mainly by private firms, while it is well-established that the financial market was not allocating resources efficiently during that period.<sup>7</sup> Prior works have also demonstrated a negative link between the credit market and the firms' performance due to lending bias (Chen, Li, & Zhang, 2016; Guariglia & Poncet, 2008; Hasan, Wachtel, & Zhou, 2009).<sup>8</sup> Indeed, state-owned enterprises (SOEs hereafter) are the most prominent loan recipients in China, despite their poor economic performance (Hale & Long, 2011). The Chinese government runs the banking system through four banks, which provide 60% of the loans to the economy; among them is a large share of non-performing loans (Allen, Qian, & Qian, 2005). To secure a loan, private firms need to rely on their political connections (Cull, Li, Sun, & Xu, 2015) or provide much more collateral than their SOEs peers (Brandt & Li, 2003). For them, internal finance is key.

Finance is also particularly important in driving the pollution emissions, as emphasized by the flourishing literature on this topic. Andersen (2017) designs a model where private firms suffering from credit constraints invest relatively more in tangible assets, increasing pollution emissions. At the empirical level, Haas De and Popov (2018) uses cross-country level data to evaluate the impact of external finance on the emissions of CO<sub>2</sub>. They find that the emissions of CO<sub>2</sub> are dampened by the equity market's development, while the credit market's impact on aggregated CO<sub>2</sub> emissions is positive and strong. Their conclusions echo the extensive literature on external finance and innovation-led growth. The equity market is more suited to bear the investment risk related to innovation. At the same time, banks have a lower capacity to assess a project's innovative pertinence and support it.<sup>9</sup> China, like many other developing and emerging countries, is characterized by a virtually non-existent stock market, with bank credit playing the dominant role in external financing. In this context, internal finance compensates for the lack of bank credit, enabling the funding of risky and innovative projects that are crucial for combating climate change. Numerous empirical studies highlight the dependency and vulnerability of firms when it comes to the necessary investments in environmental technologies, which are both risky and innovative. Ghisetti, Mancinelli, Mazzanti, and Zoli (2017) assesses the existence of direct negative effects of financial barriers on environmental innovation investment decisions by analyzing small and medium-sized manufacturing firms in Europe. Noailly & Smeets, 2021 focus on European patent data and show that innovative clean energy firms may be particularly vulnerable to financing constraints. In the case of China, starting in the mid-2010s, a growing awareness of the need for regulation has been reflected in the implementation of sanctions against polluting companies. Using Chinese firm's level data and in the context of the Chinese green credit policy in 2012, Fan et al. (2021) shows that firms with a record of noncompliance with environmental regulations saw a larger increase in the interest rate, decrease in loans, and more difficulty in access to loans.

R&D projects and environmental innovation are often denied external financing in developing countries because of the lack of collateral, which is inherent to them. Tangible assets are more likely to be financed for two main reasons. The first reason is that a tangible asset has a finite monetary value and a physical form. Its liquidity might vary, but it can always be transacted with a monetary value, so in the event of default, the bank can convert the assets to cash. Secondly, banks lack the skills to judge innovative projects (Ueda, 2004). By facing difficulties securing a loan from the banks to finance growth, private firms use their internal finance extensively to invest in research and development, innovative projects, and other forms of growth-oriented projects (Carpenter & Petersen, 2002; Chow & Fung, 2000; Guariglia et al., 2011; Li, Liao, & Zhao, 2018; Poncet, Steingress, & Vandenbussche, 2010). This work examines the role of internal finance in reducing SO<sub>2</sub> emissions in a context where bank credit favors investments in tangible assets that increase pollution. While the quality of the data available covers the period preceding China's major environmental regulation initiatives and not beyond (see Brandt et al., 2014), it does have the advantage of highlighting the shortcomings in financing the

<sup>6</sup> For the general case, see the recent meta-analysis in Bijlsma, Kool, and Non (2018). For the specific case of China, see the recent analysis of Xu and Gui (2021). Besides, the literature has used different proxies to evaluate Chinese economic performance, such as the growth level (Guariglia & Poncet, 2008; Hasan et al., 2009), GDP per capita (Boyreau-Debray, 2003), total factor productivity (Ayyagari, Demirgüç-Kunt, & Maksimovic, 2010; Chen & Guariglia, 2013; Li et al., 2018), assets growth (Guariglia et al., 2011).

<sup>7</sup> In regards to this poor functioning, China is not an exception. Most developing economies have poor financial markets, and their equity market is almost nonexistent.

<sup>8</sup> The primary way to get funding in China is through a loan (Hale and Long 2011). By the end of 2002, the banking sector's total assets stood close to 85 % of the total assets of the entire financial sector (Ping Ping, 2003).

<sup>9</sup> The literature on external finance and investment decisions shows that asymmetric information, moral hazard, and tax considerations are the main mechanisms, which explains why the credit market is not suited to finance innovation. The equity market development helps circumvent the problems inherent to the credit market (Hall & Lerner, 2010).

environmental transition and the need for state regulation, which did indeed materialize over the following decade. In this context, internal finance may have played a compensatory role by enabling firms to invest in pollution abatement measures, despite the limited support from the financial system for such investments.

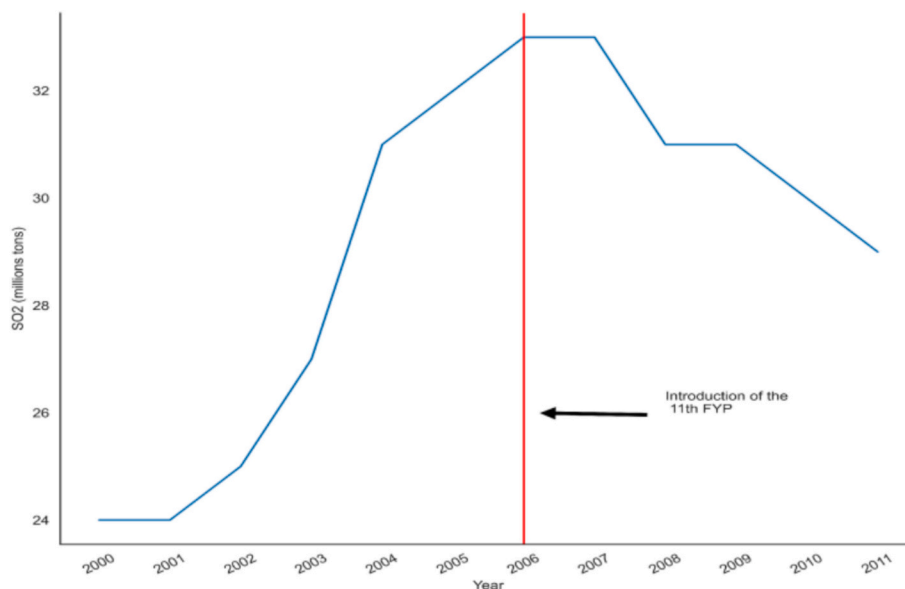
To understand how internal finance supports the environmental transition, and why external finance may prove inadequate, we must first contextualize the environmental challenges China faced during its rapid industrialization. The country's unprecedented economic growth was accompanied by a sharp rise in pollutant emissions, particularly sulfur dioxide (SO<sub>2</sub>), with notable disparities in pollution levels across regions. This deterioration in air quality triggered a policy response from the Chinese government, which progressively implemented environmental regulations and introduced new targets as part of broader development strategies.

Sulfur dioxide (SO<sub>2</sub>), a primary air pollutant, reached its peak emissions in 2005, totaling 32.41 million tons (see Fig. 1). Among the 522 cities monitored by the Chinese Ministry of Environment, approximately 400 cities recorded annual average SO<sub>2</sub> concentrations that complied with the Grade II national standard (0.06 mg/m<sup>3</sup>), while 33 cities met only the least stringent Grade III standard (0.10 mg/m<sup>3</sup>). Following the introduction of the 11th Five-Year Plan (FYP), modest improvements were observed. According to the Ministry of Environment's annual report, by two years into the FYP, 79 % of audited cities had achieved Grade II status, representing a two-percentage-point increase from 2005. Notably, the proportion of cities exceeding the Grade III threshold dropped to less than 1.2 %, a four-percentage-point reduction compared to 2005.

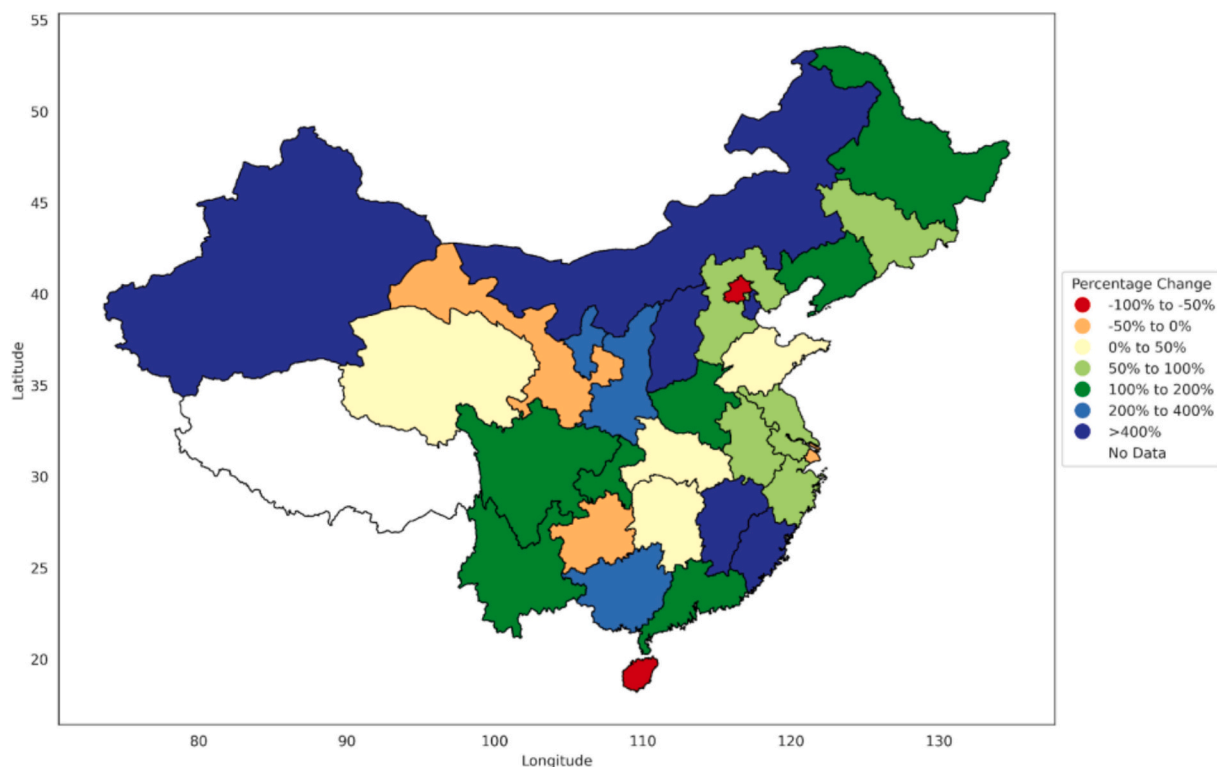
The most severely polluted cities are primarily located in the provinces of Shanxi, Guizhou, Inner Mongolia, and Yunnan. The Chinese government began to take environmental issues more seriously after the SO<sub>2</sub> emission peak of 1995, which had significant adverse effects. Within three years, Beijing had both proposed and enacted legislation to regulate SO<sub>2</sub> emissions. In 1998, the central government implemented the Acid Rain Control Zone and Sulfur Dioxide Pollution Control Zone policy, collectively known as the Two Control Zone (TCZ) policy, to curb SO<sub>2</sub> emissions. Although the initial intent was to apply these regulations nationwide, the State Council subsequently designated 175 cities with particularly poor environmental records as TCZ cities, subjecting them to more rigorous oversight. Cities were selected based on three criteria: exceeding the national Grade II annual average SO<sub>2</sub> standard (0.06 mg/m<sup>3</sup>), surpassing the Grade III daily average standard (0.25 mg/m<sup>3</sup>), or recording significant SO<sub>2</sub> emissions.

Between 1999 and 2007, SO<sub>2</sub> emissions in China exhibited marked regional heterogeneity, especially between eastern and western provinces (see Fig. 2). The eastern provinces, characterized by robust economic growth, implemented more effective pollution control measures, leading to substantial reductions in SO<sub>2</sub> emissions. In contrast, western provinces, with their reliance on heavy industry and less stringent environmental oversight, experienced persistently high emissions, reflecting both slower economic development and weaker pollution management. These regional contrasts underscore the complexity of reconciling economic growth with environmental sustainability across China.

Within this context of strong political commitment to emission reduction, the analysis examines how firms' financial structures, specifically access to internal finance, shape environmental outcomes in the context of China's rapid economic growth. The findings suggest that greater reliance on internal financing is linked to lower emissions. This reflects a complex interplay between financial constraints, investment decisions, and environmental performance, highlighting how the structure of firm financing can influence the environmental trajectory at both regional and national levels.



**Fig. 1.** SO<sub>2</sub> emissions in China from 2000 to 2010. **Note:** The horizontal red line represents the launch of the 11th Five-Year Plan (FYP). From 2006 onward, China enforced more environmental severity with an optimistic target of a reduction in the emissions of SO<sub>2</sub> by 10 % in 2010 as compared with the level in 2005. **Source:** The SO<sub>2</sub> emissions data are from the China Statistical Yearbook (2000,2010).



**Fig. 2.** Percentage Change in SO<sub>2</sub> Emissions by Province (1999–2007). **Note:** The map illustrates the percentage change in sulfur dioxide (SO<sub>2</sub>) emissions by province in China from 1999 to 2007, using a color scale to indicate varying degrees of change: significant reductions are shown in red (–100 % to –50 %), while substantial increases are depicted in dark blue (superior to 400 %). Areas with no data are marked in white. Notably, data for Tibet is not available. **Source:** Authors’ own computation. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

### 3. Empirical strategy and data, preliminary evidence

#### 3.1. Empirical strategy and data

Recent literature highlights how credit constraints can shape firms’ environmental performance by influencing their investment behavior. Theoretical and empirical evidence, primarily from developed economies, suggests that when access to external finance is limited, firms tend to over-invest in tangible, collateralizable assets, typically associated with higher pollution levels, at the expense of intangible or environmentally beneficial investments. However, little is known about the validity of these mechanisms in emerging markets such as China, where financial systems differ significantly.

This study contributes to the growing literature by focusing on the specific characteristics of China’s financial environment. The Chinese financial system is marked by a state-dominated banking sector and underdeveloped capital markets. As a result, access to external finance is often constrained, especially for private and smaller firms. Banks tend to favor large state-owned enterprises (SOEs) or firms with sufficient tangible collateral, criteria that typically exclude firms pursuing green or innovation-driven projects. This credit allocation bias may inadvertently incentivize more polluting investment behavior.

In such a context, internal finance becomes crucial. We argue that firms with greater internal liquidity, proxied by indicators such as cash flow, current ratio, and interest coverage, are better positioned to invest, including in cleaner technologies, especially when environmental policies provide sufficient incentives. This perspective is in line with Andersen (2017), who identifies creditworthiness as a key determinant of firms’ ability to reduce emissions. However, unlike Andersen’s work, which relies on direct measures of creditworthiness (e.g. firm credit ratings or default risk), our analysis cannot rely on such metrics due to data limitations in China. In particular, time-series information on firm-level external credit access and default history is lacking.

Instead, our approach leverages rich firm-level data to emphasize the compensatory role of internal finance. We show that internal liquidity significantly relaxes financing constraints and enables investment, leading to improved environmental outcomes. Specifically, we find that higher levels of internal finance are associated with lower emissions of key pollutants such as sulfur dioxide (SO<sub>2</sub>), chemical oxygen demand (COD), and waste gas intensity.

Our analysis also explores the mechanisms behind this reduction in pollution. Firms with greater internal liquidity tend to invest less in tangible assets, frequently linked to higher emissions, and shift their focus toward intangible assets and R&D, which improve total factor productivity and support cleaner production processes. Additionally, they invest more in pollution abatement equipment, a

type of expenditure typically harder to finance through external credit in China's institutional context.

In sum, our findings underscore the importance of internal finance in shaping environmentally responsible investment in financially constrained environments. They suggest that policies aimed at strengthening internal financial capacity, or reducing external credit market distortions, could play a crucial role in aligning industrial investment with environmental objectives in China and other emerging economies.

The specification of the estimated equation and the datasets we use are as follows:

$$SO_2 \text{ intensity}_{fct} = \alpha_2 \text{internal finance}_{fct-1} + \alpha_3 X_{fct-1} + SO_{2f0}^* \alpha_t + \zeta_f + \gamma_{ct} + \theta_{it} + \epsilon_{fct} \quad (1)$$

$SO_2 \text{ intensity}_{fct}$  denotes the ratio of sulfur dioxide ( $SO_2$ ) emissions to a firm's total output, measured for firm  $f$  in city  $c$  at year  $t$ .  $SO_2$  is a dense, colorless, and toxic gas that poses serious health risks when inhaled due to its highly irritating properties. Firm-level data on  $SO_2$  intensity, as well as other key pollution and waste indicators, have been systematically collected by the Ministry of Environmental Protection (MEP) since 1980. Companies classified as major polluters are required to report essential information, including their name, address, production output, and emissions. They also answer a very detailed questionnaire about their major pollutants' emissions (e.g., wastewater, COD,  $SO_2$ , industrial smoke, and dust). As reported in Jiang, Lin, and Lin (2014) and Wu et al. (2017), the dataset contains information about 85% of pollution emissions from major pollutants in China. The MEP has implemented strict procedures, including unforeseen visits from experts to ensure that these firms have not misreported their emissions. While our analysis primarily focuses on  $SO_2$  emissions, a major air pollutant, across 419 four-digit industries in 286 cities from 1999 to 2007, the results for other pollutants are consistent and are presented in the appendix (COD, wastewater and waste gas). Furthermore, firms are required to report their investment related to pollution abatement equipment (such as sewage treatment devices and air cleaning devices) and their efficiency in terms of pollution removal. The MEP dataset contains a large selection of firms from the National Bureau of Statistics of China's (NBS) surveys, and the two can be connected using a shared firm identifier.

The National Bureau of Statistics of China's (NBS) collects and analyzes information on China's economy and society throughout its territory, to which end it conducts surveys among all non-state-owned enterprises with sales above 5 million RMB and state-owned enterprises. The survey is detailed and thorough insofar as it contains detailed information about the name, address, four-digit CIC industry classification, ownership, and financial variables (including output, sales, and fixed assets). The temptation to cheat and to not provide true figures is minimized by the fact that, according to Chen, Kahn, Liu, and Wang (2018), the NBS is not allowed to share information with other agencies (e.g., tax agencies, government). Our analysis period starts in 1998 and ends in 2008, beyond which the NBS data is considered to be unreliable. As explained in Brandt et al. (2014): "firms can only be easily linked from 1998 onwards and most studies start their sample in that year. The survey has been conducted in all subsequent years, but to the best of our knowledge the latest year with reliable data available is 2008".

Our main variable, *internal finance* $_{fct}$ , is proxied by cash flow, current ratio and coverage ratio lagged by one year. Cash flow is defined as the net income<sup>10</sup> plus depreciation, adjusted to tangible assets. Cash flow is commonly used as a proxy for internal finance in the literature (Chen & Guariglia, 2013; Chow & Fung, 1998; Guariglia et al., 2011). The current ratio is a liquidity ratio that measures a company's ability to pay short-term obligations or those due within one year. Larger values suggest that the company has more liquidity and is less dependent on the credit market. The coverage ratio is a financial metric used to evaluate a company's ability to meet its debt obligations, typically calculated by dividing a firm's income or cash flow by the interest or principal payments due within a given period.

We control for firm-level variables commonly used in the literature ( $X_{fct}$ ):

*Sales to total asset*, *Total asset*, *Employment*, *Age*. All variables are calculated from firm-level data, in log and lagged by one year. *SOE* is a dummy variable capturing the ownership of the firm. When the dummy is equal to 1, it implies the firm is a State-Owned Enterprise. *Foreign capital share* is computed as the share of capital held by foreign entities in the firm's capital. This variable is also lagged by one year.

Our dataset includes a variable that reports the theoretical capacity of an industry to remove  $SO_2$  by kilogram/h. We use this variable to compute  *$SO_2$  removing capacity* $_{fct}$ , set equal to the  $SO_2$  removing capacity divided by the firm's total output.

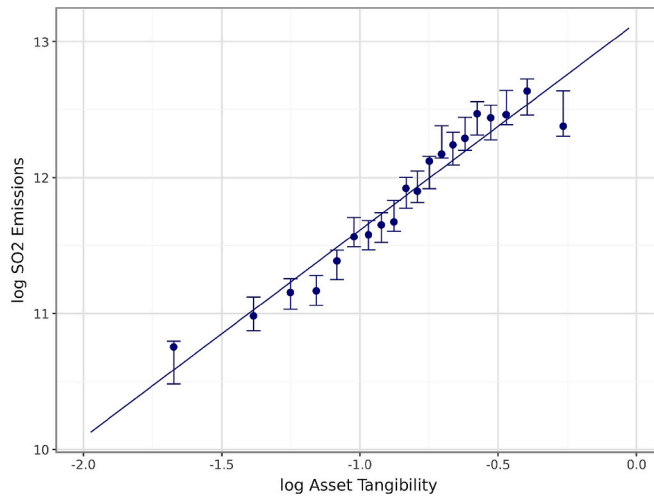
The interaction between  $SO_{2f0}$  and the year fixed effect  $\alpha_t$  allows us to measure the impact of the initial level of pollution, on pollution emissions over time.

Lastly, the model includes a set of fixed effect.  $\zeta_f$  signifies firm-level fixed effects, accounting for constant, firm-specific traits. City-year level fixed effects, denoted as  $\gamma_{ct}$ , account for annual, city-wide events or conditions that might influence all firms or industries within the city equally.  $\theta_{it}$  stands for industry-year fixed effects. Standard errors are clustered at the firm level.

The expected sign of the coefficient of *internal finance* $_{fct}$  is theoretically ambiguous. Greater internal liquidity provides firms with the flexibility to allocate resources across different types of investment, including R&D, productivity-enhancing assets, or technologies aimed at reducing energy consumption. While investments in intangible assets do not automatically translate into lower pollution, they can contribute to environmental improvement, particularly in the context of China's policy efforts to incentivize pollution abatement. Preliminary graphical evidence lends support to this interpretation.

Fig. 3 displays a binned scatter plot illustrating the relationship between the log of sulfur dioxide ( $SO_2$ ) emissions and the log of asset tangibility. The fitted regression line indicates a positive correlation between the two variables, reflecting that firms with higher asset tangibility tend to emit more  $SO_2$ . Error bars are included to reflect the variability in emission levels within each bin, providing a

<sup>10</sup> Net income is defined as the difference between profit before tax but after extraordinary income and income tax.



**Fig. 3.** Log asset tangibility against log  $SO_2$  emissions. **Note:** The Y-axis shows the log of Sulfur Dioxide Emissions ( $SO_2$ ) (in tons) and the X-axis is the log of asset tangibility. A binned scatter plot (or bin scatter) is a graphical tool that plots the average values of a dependent variable within evenly spaced intervals, or bins, of an independent variable. This method is particularly useful for visualizing underlying trends in large datasets while reducing noise (Cattaneo, Crump, Farrell, & Feng, 2024). **Source:** Authors' own computation.

visual sense of dispersion around the average values.

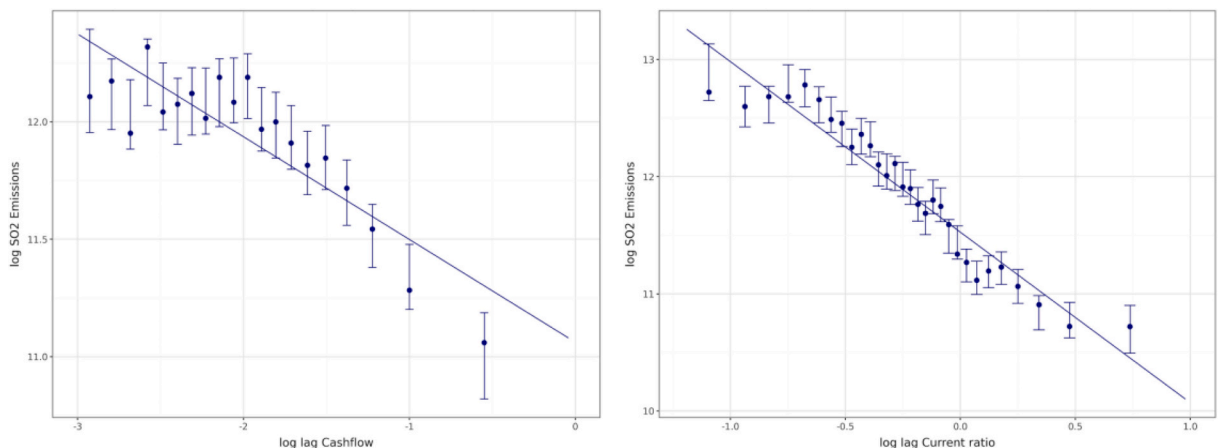
In a context where access to external finance is constrained and tends to favor collateral-backed projects, internal finance plays a compensatory role. It allows firms to undertake investments that are more environmentally friendly. As a result, higher levels of internal finance are associated with lower pollution emissions. In Fig. 4, we plot the two proxies for internal finance against  $SO_2$  emissions. The negative slopes for each of our proxy for internal finance are negative, implying that a larger availability of internal finance leads to lower emissions of  $SO_2$ .

#### 4. Empirical findings and analysis

##### 4.1. The role of internal finance in $SO_2$ mitigation

Table 1 presents the estimation results of eq. 1, highlighting the influence of internal financial availability (as measured by cash flow, current ratio, and interest coverage ratio) on pollution levels. The table is organized with four different specifications. All columns include controls for firm characteristics and fixed effects.

Internal financial factors of cash flow, current ratio and coverage ratio have a negative influence on  $SO_2$  emissions. The findings suggest that firms with stronger internal financial health are better equipped to invest in cleaner technologies, contributing to lower



**Fig. 4.** Log internal finance against log  $SO_2$  emissions. **Note:** The Y-axis shows the log of Sulfur Dioxide Emissions ( $SO_2$ ) (in tons) and the X-axis is the proxy for internal finance. A binned scatter plot (or bin scatter) is a graphical tool that plots the average values of a dependent variable within evenly spaced intervals, or bins, of an independent variable. This method is particularly useful for visualizing underlying trends in large datasets while reducing noise (Cattaneo et al., 2024). **Source:** Authors' own computation.

**Table 1**  
Pollution and internal finance.

Dependent Variable:	SO <sub>2</sub> intensity			
Model:	(1)	(2)	(3)	(4)
<i>Variables</i>				
Cash flow	-0.070*** (0.008)			-0.063*** (0.013)
Current ratio		-0.026** (0.013)		-0.015 (0.017)
Coverage ratio			-0.031*** (0.006)	-0.018*** (0.006)
Sales to asset	-0.174*** (0.022)	-0.191*** (0.021)	-0.180*** (0.026)	-0.166*** (0.026)
Total asset	-0.100*** (0.024)	-0.097*** (0.023)	-0.090*** (0.028)	-0.088*** (0.028)
Employment	-0.055* (0.028)	-0.069** (0.027)	-0.062* (0.032)	-0.059* (0.032)
Foreign capital share	-0.138 (0.102)	-0.153 (0.101)	-0.131 (0.133)	-0.125 (0.132)
SO <sub>2</sub> Abatement capacity	-0.015 (0.025)	-0.015 (0.024)	-0.019 (0.028)	-0.019 (0.028)
Age	-0.172 (0.162)	-0.058 (0.156)	-0.067 (0.193)	-0.077 (0.194)
Age squared	0.072 (0.125)	-0.015 (0.126)	-0.027 (0.143)	-0.020 (0.143)
SOE	0.020 (0.032)	0.037 (0.031)	0.034 (0.036)	0.024 (0.036)
<i>Fixed-effects</i>				
Firm	Yes	Yes	Yes	Yes
City – Year	Yes	Yes	Yes	Yes
Industry – Year	Yes	Yes	Yes	Yes
<i>Fit statistics</i>				
Observations	40,476	43,717	32,017	31,897
R2	0.907	0.904	0.913	0.913
Within R2	0.067	0.067	0.067	0.069

Clustered (Firm) standard-errors in parentheses.

This table reports estimates of eq. 1. Cash flow is defined as net income plus depreciation over total assets. Current ratio is measured as current assets over current liabilities. Coverage ratio is measured as earnings before interest and taxes divided by interest expenses. SO<sub>2</sub> removing capacity is the capacity to remove SO<sub>2</sub> emissions per hour divided by output. Foreign capital share is computed as the share of capital held by foreign entities in the firm's capital. SOE is a dummy variable equal to 1 if the firm is a state-owned enterprise. Beyond these variables, the control variables include sales over assets, total assets, employment, age, age squared. All right-hand-side variables, except SOE, are lagged by one year. All estimations account for initial pollution trends at the firm level. Heteroskedasticity-robust standard errors clustered at the firm level appear in parentheses. \* Significance at 10 %; \*\* significance at 5 %; \*\*\* significance at 1 %.

emissions. Specifically, for each 10 % increase in cash flow, SO<sub>2</sub> emissions decrease by 7 %. Similarly, for a 10 % increase in the current ratio, emissions decrease by 2.7 % (3 % for the coverage ratio). This empirical evidence underscores the potential of internal financing to play a role in lowering emissions.

Control variables including pollution removal capacity, employment, age, and state ownership (SOE) although not significant come with the expected signs. The negative although insignificant impact of SO<sub>2</sub> removal capacity across all models highlights the efficacy of firms' pollution control measures. Specifically, a 10 % increase in SO<sub>2</sub> removal capacity correlates with a 1,7 % to 2,2 % decrease in emissions. State-owned enterprises exhibit higher pollution intensity relative to their private counterparts, whereas firms with greater foreign ownership tend to report lower levels of pollution. Overall, our results confirm the intricate interplay between financial health at the firm level and environmental impact.

#### 4.2. Heterogeneous responses to internal financing in SO<sub>2</sub> emission reduction

This section examines possible heterogeneities in the effect of internal financing on SO<sub>2</sub> emissions intensity. The following sources of heterogeneity are considered: First, we analyze the effect of external credit constraints. Second, we account for firm size, as it may shape the relationship between internal finance and environmental performance. Third, at the city level, we examine bank concentration, measured by the Herfindahl-Hirschman Index. Fourth, at the city level, we construct an innovation indicator that could influence the relationship between internal finance and pollution outcomes. Finally, we assess whether local policy instruments, such as environmental regulations (TCZs) and special economic zones (SPZs), moderate this relationship.<sup>11</sup> Where the sources of heterogeneity

<sup>11</sup> The list of TCZ and SPZ cities are in Table 9 in the appendix.

are defined at levels higher than the firm (e.g., at the industry or at the city level), the fixed effects specification absorbs their variation, preventing separate identification of their additive effects. The results are reported in Table 2.

Column 1 reports the interaction between cash flow and sector-level credit constraints. While earlier studies have relied on U.S. data to assess external finance dependence (e.g., Claessens & Laeven, 2003; Kroszner, Laeven, & Klingebiel, 2007; Rajan & Zingales, 1998), we follow the approach of Jarreau and Poncet (2014), Manova, Wei, and Zhang (2015), and Fan, Lai, and Li (2015), who adapt this methodology to the Chinese context. Specifically, we use the sector-level financial dependency index from Fan et al. (2015), defined as the share of capital expenditures not financed by internal cash flows.<sup>12</sup> We construct a binary indicator of credit constraints equal to one for sectors whose financial dependency exceeds the median value of  $-0.47$ , reflecting a greater reliance on external finance and, consequently, higher exposure to credit market frictions. The interaction term with cash flow has a coefficient of  $-0.031$ , significant at the 5 % level. It confirms the hypothesis that firms in financially dependent industries benefit more from internal financing when aiming to mitigate environmental pollution.

In column 2, we investigate heterogeneity based on firm size by introducing a dummy variable, *Size*, equal to one if a firm's first-year sales exceed the cross-firm median.<sup>13</sup> The negative coefficient on the cash flow  $\times$  Size interaction indicates that larger firms achieve greater reductions in  $SO_2$  emissions than smaller firms. This pattern aligns with the existing literature. Qi, Tang, and Xi (2021) demonstrate that larger firms achieve greater emissions reductions by exploiting increasing returns to scale in pollution-abatement investments. Similarly, Fan et al. (2021) show that large non-compliant firms respond to green credit regulations by investing more effectively in pollution-abatement technologies, which leads to greater emission intensity reductions and helps them maintain favorable loan conditions. In contrast, smaller firms tend to respond by reducing output rather than adopting cleaner equipment. Our results are similar and support the idea that large firms, benefiting from scale economies in abatement investments, can convert improved access to internal finance into larger reductions in pollution emissions.

In column 3, we examine how the effect of internal finance on firm outcomes varies with the degree of banking competition across cities. Following the methodology of Ye, Zhang, and Dong (2019), we construct a Herfindahl-Hirschman Index (HHI) to measure the concentration of the banking sector in each city, defined as:

$$HHI_{ct} = \sum_{b=1}^{B_{ct}} \left( \text{branch}_{ct}^b / \text{total number of branches}_{ct} \right)^2 \quad (2)$$

where  $\text{branch}_{ct}^b$  denotes the number of branches of bank  $b$  in city  $c$  in year  $t$ , and  $\text{total number of branches}_{ct}$  is the total number of branches in that city at year  $t$ . This measure captures the extent to which the banking sector in a city is dominated by a few banks. Higher values indicate greater market concentration and, therefore, lower levels of competition.

To facilitate interpretation, we define a new variable:

$$\text{Deregulation}_{ct} = 1 - HHI_{ct}.$$

Higher values of this variable correspond to more competitive and accessible financial environments, while lower values reflect greater market concentration.<sup>14</sup> This variable is assumed to reflect the level of banking deregulation introduced in China starting with the deregulation reforms of 1995, which opened the banking market to new entrants. It may vary significantly across cities.

Empirically, we find a negative and statistically significant coefficient on the interaction between cash flow and deregulation, indicating that the emissions-reducing effect of internal finance is stronger in cities with more competitive banking markets. Theoretically, greater credit access in such environments should reduce firms' reliance on internal funds, weakening this relationship. Yet, we observe the opposite, suggesting a lack of substitutability between internal and external finance. These results highlight how structural financial frictions, proxied by local banking concentration, can indirectly affect environmental outcomes by shaping how firms finance cleaner production investments.

The innovation capacity variable captures a city's ability to adopt new technologies and sustainable practices that may influence pollution outcomes. We adopt the methodology from Kou and Liu (2017)'s paper, which measures innovation on a city-industry-year basis by evaluating the stock of intangible capital through patent values. For our analysis, we aggregate the innovation index from the city-industry level to the city level by calculating the sum of the innovation index across all industries within each city, which is the earliest year with available data.

The interaction term between *Inn. capacity* and *cash flow* in column 3 has a coefficient of  $-0.012^{**}$ , significant at the 5 % level. This suggests that cities marked by high innovation are more adept at leveraging internal finances for environmental improvements. Specifically, an increase in firm's cash flow in these cities leads to a more substantial reduction in  $SO_2$  emissions compared to less innovative areas. This could be due to factors like superior eco-efficient infrastructures or progressive environmental policies that incentivize sustainable practices.

In column 4, the interaction term between *cash flow* and *Two Control Zone* (TCZ) policy has a negative coefficient but is not statistically significant. The *Two Control Zone* variable is a policy indicator that takes the value of 1 if the company is located in a region that has been specifically designated for the control of acid rain or sulfur dioxide pollution. This policy was promulgated in 1998 with the explicit aim of limiting  $SO_2$  emissions. The absence of statistical significance in the interaction term suggests that the TCZ policy

<sup>12</sup> Appendix Table 8 reports the financial dependency values for China's 29 industries.

<sup>13</sup> Our results are robust when we define the size of large firms based on sales above the 75th (80th) percentile of the sales distribution.

<sup>14</sup> As a robustness check, we follow Chen, Poncet, and Xiong (2020) by using the number of city commercial bank branches as a proxy for local financial development. The results are consistent with those obtained using the *deregulation* variable. Detailed results are available upon request.

**Table 2**  
Heterogeneity.

Dependent Variable:	SO <sub>2</sub> intensity					
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Variables</i>						
Cash flow	−0.056*** (0.011)	−0.051*** (0.011)	−0.130*** (0.028)	−0.077*** (0.010)	−0.067*** (0.017)	−0.066*** (0.011)
Cash flow × Credit constraint	−0.031** (0.015)					
Cash flow × Size		−0.042** (0.017)				
Cash flow × Deregulation			−0.300** (0.138)			
Cash flow × Inn.capacity				−0.012** (0.006)		
Cash flow × tcz					−0.005 (0.019)	
Cash flow × spz						−0.029 (0.018)
Sales to asset	−0.173*** (0.022)	−0.151*** (0.022)	−0.191*** (0.024)	−0.130*** (0.024)	−0.174*** (0.022)	−0.189*** (0.022)
Total asset	−0.100*** (0.024)		−0.112*** (0.027)	−0.091*** (0.025)	−0.100*** (0.024)	−0.108*** (0.025)
Employment	−0.055* (0.028)	−0.096*** (0.027)	−0.043 (0.030)	−0.037 (0.030)	−0.055* (0.028)	−0.043 (0.029)
Foreign capital share	−0.140 (0.102)	−0.138 (0.101)	−0.091 (0.115)	−0.086 (0.106)	−0.138 (0.102)	−0.133 (0.102)
SO <sub>2</sub> Abatement capacity	−0.015 (0.025)	−0.017 (0.025)	−0.019 (0.027)	−0.047* (0.028)	−0.015 (0.025)	−0.021 (0.025)
Age	−0.172 (0.162)	−0.162 (0.162)	−0.177 (0.151)	−0.254 (0.175)	−0.172 (0.162)	−0.108 (0.178)
Age squared	0.072 (0.125)	0.047 (0.125)	0.098 (0.122)	0.097 (0.137)	0.072 (0.125)	0.088 (0.134)
SOE	0.019 (0.032)	0.017 (0.032)	0.024 (0.033)	0.008 (0.038)	0.020 (0.032)	0.033 (0.033)
<i>Fixed-effects</i>						
Firm	Yes	Yes	Yes	Yes	Yes	Yes
City – Year	Yes	Yes	Yes	Yes	Yes	Yes
Industry – Year	Yes	Yes	Yes	Yes	Yes	Yes
<i>Fit statistics</i>						
Observations	40,476	40,476	34,245	32,407	40,476	40,358
R2	0.907	0.907	0.909	0.917	0.907	0.903
Within R2	0.068	0.067	0.066	0.036	0.067	0.044

Clustered (Firm) standard-errors in parentheses.

This table reports estimates of eq. 1. Cash flow is defined as net income plus depreciation over total assets. SO<sub>2</sub> removing capacity is the capacity to remove SO<sub>2</sub> emissions per hour divided by output. Foreign capital share is computed as the share of capital held by foreign entities in the firm's capital. SOE is a dummy variable equal to 1 if the firm is a state-owned enterprise. Other control variables are sales over assets, total assets, employment, age, age squared. All right-hand-side variables, except SOE, are lagged by one year. Size equals to one if a firm's first-year sales is above the median. Credit constraints is a dummy variable taking the value of 1 if the industry is financially dependent. Deregulation is defined as 1 minus Herfindahl-Hirschman Index (HHI), where the HHI captures bank branch concentration in a city; higher values of the variable indicate greater banking competition and financial accessibility. Inn. capacity is the patent value-adjusted index at the city level in 2001. Two Control Zone and Special Policy Zone are cities targeted by environmental policies or growth-oriented policies. All estimations account for initial pollution trends at the firm level. Heteroskedasticity-robust standard errors clustered at the firm level appear in parentheses. \* Significance at 10 %; \*\* significance at 5 %; \*\*\* significance at 1 %.

does not substantially modulate the effect of cash flow on SO<sub>2</sub> emissions. It may reflect the fact that the impact of environmental policies, such as mandates and the TCZ program, operates more through firm relocation than through increased sensitivity of internal finance to pollution constraints. This interpretation is supported by Wu et al. (2017), who show that stricter environmental regulations in coastal provinces led to a geographic shift in the entry of polluting firms toward inland regions with more relaxed mandates.

In column 5, the *cash flow* and *Special Policy Zone* (SPZ) interaction term has a coefficient of  $-0.032^*$ , which is statistically significant. The *Special Policy Zone* is a binary variable that indicates whether a firm is located within a designated SPZ, a zone characterized by growth-driven policies that make these locales particularly attractive to foreign companies, exporters or high-tech companies. Such firms typically enjoy numerous benefits, such as reduced tax rates and access to more affordable credit or subsidies (Hering & Poncet, 2014; Wang & Wei, 2008). An incremental increase in cash flow has a noticeably amplified effect on reducing SO<sub>2</sub> emissions. Firms in these zones are more inclined to allocate their internal finances toward eco-friendly technologies and practices.

## 5. Mechanisms

We now explore the potential mechanisms through which internal financing and financial constraints may affect pollution reduction. Existing research suggests that access to internal finance typically leads firms to decrease their investment in tangible assets while increasing funding for intangible assets, including R&D, and boosting investments in pollution abatement technologies. These pathways enable internal funds to facilitate emissions reductions by supporting targeted environmental investments.

In the following analysis, we examine these transmission channels separately to better understand their indirect effects on pollution.

### 5.1. The differential impact of internal finance on asset tangibility, R&D, and TFP

The literature shows that firms with greater internal financial resources tend to invest less in tangible assets and allocate more cash flow to innovation and R&D activities (Chen & Guariglia, 2013; Fazzari, Hubbard, & Petersen, 2000; Rajan & Zingales, 1998). From a financing perspective, banks are generally hesitant to support intangible assets since these lack valuable collateral (Brown & Petersen, 2009). This bias, favoring tangible assets in external financing and relegating intangible investments to internal funds, may have varying effects on pollution levels.

This section focuses on three key channels through which internal finance may promote pollution reduction: (i) lowering investment in polluting tangible assets, (ii) increasing investment in intangible assets, measured by R&D expenditure, and (iii) enhancing total factor productivity (TFP). Understanding these mechanisms sheds light on how internal finance contributes to more environmentally sustainable firm behavior.

However, the environmental impact of R&D and total factor productivity (TFP) remains inherently ambiguous. Productivity improvements can result either from adopting cleaner technologies or from increasing the use of polluting inputs. The relationships between internal finance, R&D, TFP, and environmental outcomes are therefore complex. Our analysis can only suggest potential

**Table 3**  
The impact of internal finance on Asset tangibility, R&D and TFP.

Dependent Variables:	asset tangibility	R&D	TFP	Productivity	asset tangibility	R&D	TFP	productivity
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Variables</i>								
Cash flow	-0.105*** (0.004)	0.001* (0.000)	0.043*** (0.003)	0.126*** (0.005)	-0.097*** (0.005)	0.001 (0.000)	0.047*** (0.003)	0.128*** (0.006)
Cash flow × Credit constraint					-0.017** (0.007)	0.000 (0.000)	-0.009** (0.004)	-0.003 (0.007)
Sales to asset	0.037*** (0.007)	0.000 (0.001)	0.029*** (0.007)	0.193*** (0.012)	0.037*** (0.007)	0.000 (0.001)	0.029*** (0.007)	0.193*** (0.012)
Total asset	0.104*** (0.010)	0.000 (0.000)	-0.017*** (0.007)	0.141*** (0.014)	0.104*** (0.010)	0.000 (0.000)	-0.017*** (0.007)	0.141*** (0.014)
Employment	-0.047*** (0.008)	0.000 (0.000)	-0.017** (0.007)	-0.139*** (0.015)	-0.047*** (0.008)	0.000 (0.000)	-0.017** (0.007)	-0.139*** (0.015)
Foreign capital share	0.010 (0.020)	0.000 (0.001)	0.012 (0.019)	-0.012 (0.037)	0.009 (0.020)	0.000 (0.001)	0.012 (0.019)	-0.012 (0.037)
SO2Abatement capacity	0.004 (0.005)	-0.001* (0.000)	0.000 (0.006)	0.018* (0.009)	0.004 (0.005)	-0.001* (0.000)	0.000 (0.006)	0.018* (0.009)
Age	0.021 (0.042)	-0.001 (0.002)	0.047 (0.042)	0.071 (0.067)	0.020 (0.042)	-0.001 (0.002)	0.047 (0.042)	0.071 (0.067)
Age squared	-0.015 (0.036)	0.001 (0.003)	-0.021 (0.032)	-0.094* (0.054)	-0.014 (0.036)	0.001 (0.003)	-0.021 (0.032)	-0.094* (0.054)
SOE	0.017** (0.008)	-0.001 (0.001)	-0.003 (0.008)	-0.025* (0.014)	0.016* (0.008)	-0.001 (0.001)	-0.003 (0.008)	-0.025* (0.014)
<i>Fixed-effects</i>								
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City – Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry – Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>Fit statistics</i>								
Observations	50,967	19,344	49,490	50,967	50,967	19,344	49,490	50,967
R2	0.870	0.566	0.785	0.900	0.870	0.566	0.785	0.900
Within R2	0.111	0.000	0.018	0.069	0.112	0.000	0.018	0.069

Clustered (Firm) standard-errors in parentheses.

This table reports estimates of eqs. 3, 4 and 5. Asset tangibility represents the proportion of tangible assets to total assets. RD measures research and development expenditure. TFP is Total Factor Productivity, computed using the Olley-Pakes algorithm (Olley & Pakes, 1996). Productivity is calculated as the firm's value added divided by employment. Cash flow is defined as net income plus depreciation over total assets. Foreign capital share is computed as the share of capital held by foreign entities in the firm's capital. SOE is a dummy variable equal to 1 if the firm is a state-owned enterprise. Additional control variables are sales over assets, total assets, employment, age, age squared. All right-hand-side variables, except SOE, are lagged by one year. Credit constraints is a dummy variable taking the value of 1 if the industry is financially dependent. Heteroskedasticity-robust standard errors clustered at the firm level appear in parentheses. \* Significance at 10 %; \*\* significance at 5 %; \*\*\* significance at 1 %.

channels through which these factors interact, without fully disentangling them or establishing definitive causal links.

Eqs. 3, 4 and 5 provide insights into these hypothesized transmission channels. Eq. 3 examines how the composition of assets, tangible versus intangible, is influenced by the availability of internal finance, proxied by cash flow. Eq. 4 models how productivity-enhancing activities, such as R&D and technology adoption, primarily depend on a firm's internal financial resources. Finally, Eq. 5 assesses the effect of internal finance on TFP, acknowledging that technological upgrading and innovation can contribute to improved environmental performance (Grossman & Krueger, 1995; Panayotou, 1995; Kahn & Zheng, 2016; Peters et al. 2017).

$$\text{asset tangibility}_{fct} = \beta_1 \text{internal finance}_{fct-1} + \beta_5 X_{fct-1} + \zeta_f + \gamma_{ct} + \theta_{it} + \epsilon_{fct} \quad (3)$$

$$RD_{fct} = \beta_1 \text{internal finance}_{fct-1} + \beta_5 X_{fct-1} + \zeta_f + \gamma_{ct} + \theta_{it} + \epsilon_{fct} \quad (4)$$

$$TFP_{fct} = \beta_1 \text{internal finance}_{fct-1} + \beta_5 X_{fct-1} + \zeta_f + \gamma_{ct} + \theta_{it} + \epsilon_{fct} \quad (5)$$

Where *asset tangibility*<sub>fct</sub> in eq. 3 refers to the share of asset tangibility over total assets, and *R&D*<sub>fct</sub> in eq. 4 represents the share of research expenditure over total asset.

In Eq. (5), the dependent variable, *TFP*<sub>fct</sub>, denotes the total factor productivity of firm *f*, estimated using a structural approach based on the Olley-Pakes algorithm (Olley & Pakes, 1996). As a robustness check, we also employ a measure of labor productivity, proxied by the ratio of value added to the number of employees.

We use *cash flow*<sub>fct</sub> as a proxy for internal finance following the methodology explained in section 3.1.

Analyses are done at firm-level, *f*, city *c* and year *t*. *X*<sub>fct</sub> includes the same set of firm-level controls as in eq. 1, namely *sales to assets*, *total asset*, *employment*, *age* and *SOE*, a dummy variable to indicate the firm's ownership type (1 for state-owned vs. 0 for private). We also control for the share of foreign ownership in the firm's capital and *SO*<sub>2</sub> abatement capacity. Each right-hand-side variable, except for *SOE*, is lagged by one year.

We include three set of fixed effect.  $\zeta_f$  removes all unobserved factors contributing to a firm's assets accumulation within a city. City-year fixed effects ( $\gamma_{ct}$ ) capture all factors unique to a particular city in a specific year, such as local shocks or policies, that would affect every firm or industry there uniformly. Industry-year fixed effects ( $\theta_{it}$ ) control for time-variant differences across sectors. Standard errors are clustered at the firm level.

Table 3 (columns 1–4) reports the estimated elasticities of asset tangibility, R&D, and TFP with respect to internal finance, proxied by cash flow. The results reveal distinct patterns in how firms allocate internal resources.

Cash flow is negatively associated with asset tangibility (elasticity = −0.10, significant at the 1 % level), suggesting that firms with stronger internal liquidity tend to reduce their reliance on tangible, collateral-based assets. In contrast, cash flow has a positive and statistically significant effect on both R&D (elasticity = 0.001, 10 % level) and TFP (elasticity = 0.04, 1 % level), indicating that improved internal financial conditions foster investment in innovation and productivity-enhancing activities.

These findings are consistent with our theoretical framework and highlight the differentiated role of internal finance: firms appear to prioritize intangible and efficiency-enhancing investments over capital accumulation when internal funds are available.

Columns 5 to 8 in Table 3 extend the earlier analyses by incorporating the interaction of internal finance, represented by cash flow, with our credit constraint dummy defined at the sector level. This interaction allows us to explore the mechanism by which internal finance affects asset tangibility, R&D, and TFP, under varying conditions of credit constraint and varying sensitivity of different sectors to banking influences.

In the asset tangibility column, we observe that the interaction term between *cash flow* and *credit constraint* has a statistically significant coefficient of −0.017 at the 5 % level. This suggests that for firms in financially dependent industries (where the credit constraint dummy takes the value of 1), higher cash flow has an even more pronounced downward effect on asset tangibility compared to firms in less financially constrained sectors.

Regarding TFP, the interaction term is not statistically significant. While the sign is positive, it does not provide strong evidence to support the notion that internal finance differently affects TFP under credit constraints. Thus, the relationship between cash flow and TFP appears to be fairly stable across different levels of financial dependency.

Our results support the idea that internal finance plays a significant role in the firm's investment behavior, and that its influence varies depending on the level of credit constraint a firm faces. Specifically, firms in credit-constrained industries appear to make more strategic use of their internal finances in making investment choices. These companies avoid investing in physical assets, possibly to prioritize research and development when they have a surplus of internal funds.

## 5.2. Internal finance and SO<sub>2</sub> abatement equipment

In contrast to the previous section, which examined the effect of internal finance on intangible investments, specifically R&D spending and total factor productivity (TFP) growth, this section focuses on its impact on a specific tangible asset: pollution abatement equipment. This extension requires clarification to remain consistent with the overarching argument that internal finance plays a particularly important role in enabling investments that are difficult to finance through external capital markets.

The underlying hypothesis is that pollution abatement equipment, while classified as a tangible asset, shares key financing characteristics with intangible assets, namely, low resale value and limited collateralizability. This view aligns with Braun (2005), and Zhang (2021), who emphasizes that in underdeveloped financial systems, the availability of "hard" assets with high collateral value disproportionately determines access to external finance. Assets with limited recoverable value in the event of default, whether

**Table 4**  
The Impact of Internal finance on SO<sub>2</sub> pollution abatement equipment.

Dependent Variables:	SO <sub>2</sub> Abatement capacity	SO <sub>2</sub> removed intensity	SO <sub>2</sub> removal per hour intensity	SO <sub>2</sub> Abatement capacity	SO <sub>2</sub> removed intensity	SO <sub>2</sub> removal per hour intensity
Model:	(1)	(2)	(3)	(4)	(5)	(6)
<i>Variables</i>						
cash flow	0.015* (0.009)	0.097*** (0.025)	0.088*** (0.008)	0.023* (0.012)	0.101*** (0.034)	0.085*** (0.010)
cash flow × Credit constraint				0.018* (0.011)	0.007 (0.038)	0.006 (0.013)
Sales to asset	0.052** (0.025)	0.105 (0.070)	0.244*** (0.022)	0.053** (0.025)	0.105 (0.070)	0.244*** (0.022)
Total asset	0.061** (0.028)	-0.024 (0.075)	0.214*** (0.024)	-0.061*** (0.028)	-0.024 (0.075)	0.214*** (0.024)
Employment	0.059** (0.026)	-0.010 (0.083)	0.121*** (0.027)	0.059** (0.026)	-0.010 (0.083)	0.121*** (0.027)
Foreign capital share	-0.038 (0.039)	0.116 (0.295)	0.123** (0.061)	-0.039 (0.039)	0.116 (0.295)	0.123** (0.061)
Age	0.065 (0.198)	-0.406 (0.555)	0.477*** (0.161)	0.064 (0.198)	-0.406 (0.555)	0.477*** (0.161)
Age squared	-0.060 (0.132)	0.066 (0.420)	-0.319** (0.132)	-0.059 (0.132)	0.066 (0.420)	-0.319** (0.132)
SOE	0.045 (0.036)	-0.044 (0.095)	0.018 (0.032)	0.044 (0.036)	-0.045 (0.095)	0.018 (0.032)
<i>Fixed-effects</i>						
Firm	Yes	Yes	Yes	Yes	Yes	Yes
City – Year	Yes	Yes	Yes	Yes	Yes	Yes
Industry – Year	Yes	Yes	Yes	Yes	Yes	Yes
<i>Fit statistics</i>						
Observations	50,967	42,935	50,967	50,967	42,935	50,967
R <sup>2</sup>	0.740	0.822	0.838	0.740	0.822	0.838
Within R <sup>2</sup>	0.001	0.001	0.017	0.001	0.001	0.017

Clustered (Firm) standard-errors in parentheses.

This table reports estimates of eq. 6. Abatement Capacity refers to the firm's equipment designed to mitigate SO<sub>2</sub> emissions. SO<sub>2</sub> Removed intensity quantifies the annual amount of SO<sub>2</sub> mitigated by the firm through end-of-pipe solutions following production divided by the output. SO<sub>2</sub> removal per hour intensity represents the rate at which SO<sub>2</sub> is eliminated, measured in kilograms per hour divided by the output. Cash flow is defined as net income plus depreciation over total assets. Foreign capital share is computed as the share of capital held by foreign entities in the firm's capital. SOE is a dummy variable equal to 1 if the firm is a state-owned enterprise. Other control variables include sales over assets, total assets, employment, age, age squared. All right-hand-side variables, except SOE, are lagged by one year. All estimations account for initial pollution trends at the firm level. Heteroskedasticity-robust standard errors clustered at the firm level appear in parentheses. \* Significance at 10 %; \*\* significance at 5 %; \*\*\* significance at 1 %.

tangible or intangible, are more reliant on internal funding. Although pollution abatement equipment appears as a physical capital item on the balance sheet, it is less attractive to lenders due to its lower liquidation value, making internal finance a more viable funding source. This hypothesis is consistent with observed trends in China, where the financing of environmental investments has gradually shifted from government subsidies to firm-generated profits (Wang & Chen, 1999), thereby expanding the role of internal funds. It also reflects an evolving institutional context in which environmental criteria have been increasingly integrated into credit allocation, initially through guidance from the People's Bank of China in 1995, and later formalized with the issuance of the Green Credit Guidelines by the China Banking and Insurance Regulatory Commission in 2012. Thus, while pollution abatement equipment is technically a tangible asset, its financing behavior closely resembles that of intangibles. The following table tests this hypothesis by examining the relationship between internal finance and the acquisition of SO<sub>2</sub> abatement equipment.

The MEP data allows us to investigate three different but interconnected measures that indicate a firm's efforts in pollution abatement: *SO<sub>2</sub> Abatement Capacity*, *SO<sub>2</sub> Removed intensity*, and *SO<sub>2</sub> Removal Per Hour intensity*.<sup>15</sup> Using this enriched dataset to study the behavior of firms in the context of SO<sub>2</sub> emission reduction from 1998 to 2007, we estimate the following equation:

$$\text{Pollution abatement}_{fct} = \alpha_1 \text{internal finance}_{fct-1} + \alpha_2 X_{fct-1} + \text{SO}_{2f0} \alpha_t + \zeta_{ct} + \gamma_{ct} + \theta_{it} + \epsilon_{fct} \quad (6)$$

*pollution abatement<sub>fct</sub>* refers to the three interconnected measures of a firm's pollution abatement efforts for each year in the sample. The key explanatory variable is *cash flow<sub>fct</sub>*, while *X<sub>fct</sub>* denotes a matrix of control variables. By interacting *SO<sub>2f0</sub>* with the year fixed effect  $\alpha_t$  we can trace how a firm's initial pollution level shapes its emissions trajectory over time.

The specification retains the same set of control variables and the same fixed effects structure as in the previous sections (Eqs. 1 to 5). Each right-hand-side variable, except for SOE, is lagged by one year.

<sup>15</sup> We scale SO<sub>2</sub> Removed, and SO<sub>2</sub> Removal Per Hour by the firm's output, hence the term "intensity".

Results are presented in Table 4. The positive and statistically significant coefficient for *cash flow* in all three measures is consistent with the theoretical expectation that firms with greater liquidity are more inclined to invest in the efficiency of their pollution abatement activities. This supports the theoretical premise that liquidity-rich firms are more capable of allocating funds to environmentally beneficial technologies, likely in response to social pressures and potential regulatory incentives.

The last three columns of 4 focus on the effect of internal finance on the acquisition of pollution abatement equipment when a firm is credit constrained. The interaction term between cash flow and credit constraint is statistically significant only in the case of SO<sub>2</sub> abatement capacity. This finding suggests that for firms identified as credit constrained (i.e., when the credit constraint dummy equals 1), higher cash flow is associated with an additional positive impact on SO<sub>2</sub> abatement capacity, beyond the baseline effect of cash flow alone. The estimated coefficient for the interaction term is 0.018 and is statistically significant at the 10 % level. Although similar positive coefficients are observed for SO<sub>2</sub> removed (0.007) and SO<sub>2</sub> removal per hour (0.006), these estimates do not reach conventional significance thresholds.

This implies that for firms operating in financially dependent industries, or otherwise facing limitations in external financing, internal cash flow is particularly crucial for investments in pollution abatement technologies. Our analysis provides evidence that financial limitations can influence a company's ability to be environmentally responsible, suggesting a more intricate relationship between financial structure and sustainability efforts.

## 6. Conclusion

Our study makes a significant contribution to understanding the relationship between internal finance and pollution emissions intensity in the context of China's industrial landscape. Using a comprehensive dataset from China's Ministry of Environmental Protection (MEP), we focus specifically on SO<sub>2</sub> emissions at the enterprise level over nine consecutive years (1999–2007). Those environmental data are complemented by annual surveys of Chinese manufacturing enterprises conducted by the National Bureau of Statistics of China (NBS), which adds detailed information on the state of internal finance, such as cash flow, current ratio and coverage ratio, and allow us to study the correlation between changes in internal financial resources and changes in SO<sub>2</sub> emissions. We show that the presence of internal finance, as indicated by cash flow, current ratio, and coverage ratio, has a mitigating effect on pollution emission. Internal finance plays a dual role in influencing firm behavior. On one hand, firms with stronger internal finances are more likely to invest in R&D and Total Factor Productivity, particularly in sectors where external financing is constrained. On the other hand, such firms are also more proactive in acquiring SO<sub>2</sub> abatement technologies, an effect that becomes more pronounced in the context of credit-constrained firms.

In the Chinese context, internal financing is essential, and it appears to be reactive to the injunctions of the national environmental regulatory policies. Addressing the tendency of bank lending to favor tangible assets, as well as encouraging pollution control investments, particularly within state-owned enterprises, whether through green innovation or emission reduction equipment, would further protect the environment.

## Data availability

The authors do not have permission to share data.

## Appendix A. Appendix

**Table 5**  
Pollution, asset tangibility and internal finance.

Dependent Variable:	COD intensity			
Model:	(1)	(2)	(3)	(4)
<i>Variables</i>				
Cash flow	-0.081*** (0.012)			-0.088*** (0.017)
Current ratio		-0.065*** (0.018)		-0.059*** (0.023)
Coverage ratio			-0.039*** (0.008)	-0.019** (0.009)
Sales to asset	-0.213*** (0.031)	-0.253*** (0.029)	-0.237*** (0.036)	-0.223*** (0.037)
Total asset	-0.128*** (0.034)	-0.146*** (0.034)	-0.132*** (0.040)	-0.130*** (0.040)
Employment	0.024 (0.039)	0.033 (0.037)	0.047 (0.046)	0.051 (0.046)
Foreign capital share	-0.080 (0.118)	-0.049 (0.117)	-0.087 (0.137)	-0.067 (0.135)

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Table 5 (continued)

Dependent Variable:	COD intensity			
Model:	(1)	(2)	(3)	(4)
SO <sub>2</sub> Abatement capacity	-0.022 (0.034)	-0.022 (0.033)	-0.024 (0.037)	-0.025 (0.037)
Age	0.310 (0.229)	0.353 (0.221)	0.460* (0.263)	0.439* (0.258)
Age squared	-0.188 (0.180)	-0.216 (0.173)	-0.352* (0.207)	-0.330 (0.205)
SOE	-0.021 (0.041)	0.007 (0.039)	-0.001 (0.045)	-0.006 (0.046)
<i>Fixed-effects</i>				
Firm	Yes	Yes	Yes	Yes
City – Year	Yes	Yes	Yes	Yes
Industry – Year	Yes	Yes	Yes	Yes
<i>Fit statistics</i>				
Observations	32,760	35,269	26,164	26,074
R <sup>2</sup>	0.894	0.891	0.903	0.903
Within R <sup>2</sup>	0.010	0.009	0.010	0.012

Clustered (Firm) standard-errors in parentheses.

This table reports estimates of eq. 1. COD intensity refers to the intensity of chemical oxygen demand emission (COD) divided by the firm's output. Asset tangibility denotes tangible assets divided by total assets. Cash flow is defined as net income plus depreciation over total assets. Current ratio is measured as current assets over current liabilities. Coverage ratio is measured as earnings before interest and taxes divided by interest expenses. SO<sub>2</sub> removing capacity is the capacity to remove SO<sub>2</sub> emissions per hour divided by output. Foreign capital share is computed as the share of capital held by foreign entities in the firm's capital. SOE is a dummy variable equal to 1 if the firm is a state-owned enterprise. Other control variables include sales over assets, total assets, employment, age, age squared. All right-hand-side variables, except SOE, are lagged by one year. All estimations account for initial pollution trends at the firm level. Heteroskedasticity-robust standard errors clustered at the firm level appear in parentheses. \* Significance at 10 %; \*\* significance at 5%; \*\*\* significance at 1 %.

Table 6

Pollution, asset tangibility and internal finance.

Dependent Variable:	Waste gas intensity			
Model:	(1)	(2)	(3)	(4)
<i>Variables</i>				
Cash flow	-0.072*** (0.007)			-0.073*** (0.010)
Current ratio		-0.026** (0.012)		-0.027* (0.015)
Coverage ratio			-0.024*** (0.005)	-0.009 (0.006)
Sales to asset	-0.173*** (0.020)	-0.200*** (0.019)	-0.213*** (0.024)	-0.199*** (0.024)
Total asset	-0.084*** (0.022)	-0.083*** (0.021)	-0.068** (0.027)	-0.067** (0.027)
Employment	0.010 (0.026)	0.001 (0.024)	-0.001 (0.031)	0.000 (0.031)
Foreign capital share	0.131 (0.101)	0.103 (0.094)	0.076 (0.129)	0.102 (0.127)
SO <sub>2</sub> Abatement capacity	0.069*** (0.020)	0.082*** (0.020)	0.068*** (0.023)	0.069*** (0.023)
Age	-0.060 (0.163)	-0.020 (0.152)	-0.092 (0.196)	-0.090 (0.196)
Age squared	0.052 (0.122)	0.025 (0.115)	0.066 (0.144)	0.068 (0.144)
SOE	-0.023 (0.029)	0.010 (0.028)	-0.025 (0.034)	-0.034 (0.034)
<i>Fixed-effects</i>				
Firm	Yes	Yes	Yes	Yes
City – Year	Yes	Yes	Yes	Yes
Industry – Year	Yes	Yes	Yes	Yes
<i>Fit statistics</i>				
Observations	40,647	43,905	32,154	32,031
R <sup>2</sup>	0.929	0.927	0.935	0.935
Within R <sup>2</sup>	0.019	0.016	0.017	0.020

Clustered (Firm) standard-errors in parentheses.

This table reports estimates of eq. 1. Waste gas intensity refers to the intensity of waste gas emission (Waste gas) divided by the firm's output. Asset tangibility denotes tangible assets divided by total assets. Cash flow is defined as net income plus depreciation over total

assets. Current ratio is measured as current assets over current liabilities. Coverage ratio is measured as earnings before interest and taxes divided by interest expenses. SO<sub>2</sub> removing capacity is the capacity to remove SO<sub>2</sub> emissions per hour divided by output. Foreign capital share is computed as the share of capital held by foreign entities in the firm's capital. SOE is a dummy variable equal to 1 if the firm is a state-owned enterprise. Other control variables include sales over assets, total assets, employment, age, age squared. All right-hand-side variables, except SOE, are lagged by one year. All estimations account for initial pollution trends at the firm level. Heteroskedasticity-robust standard errors clustered at the firm level appear in parentheses. \* Significance at 10 %; \*\* significance at 5%; \*\*\* significance at 1 %.

**Table 7**  
Pollution, asset tangibility and internal finance.

Dependent Variable:	Waste water intensity			
Model:	(1)	(2)	(3)	(4)
<i>Variables</i>				
Cash flow	-0.071*** (0.009)			-0.059*** (0.014)
Current ratio		-0.028** (0.014)		-0.033* (0.019)
Coverage ratio			-0.028*** (0.006)	-0.015** (0.006)
Sales to asset	-0.203*** (0.024)	-0.237*** (0.023)	-0.221*** (0.028)	-0.208*** (0.028)
Total asset	-0.129*** (0.029)	-0.138*** (0.028)	-0.095*** (0.033)	-0.093*** (0.034)
Employment	0.021 (0.029)	0.036 (0.028)	0.017 (0.035)	0.019 (0.035)
Foreign capital share	-0.151* (0.087)	-0.151* (0.087)	-0.199* (0.106)	-0.186* (0.105)
SO <sub>2</sub> Abatement capacity	0.052** (0.026)	0.046*** (0.025)	0.056*** (0.031)	0.057* (0.031)
Age	0.396** (0.180)	0.389** (0.173)	0.352* (0.206)	0.343* (0.205)
Age squared	-0.179 (0.144)	-0.200 (0.139)	-0.132 (0.160)	-0.122 (0.159)
SOE	0.021 (0.029)	0.048* (0.028)	0.029 (0.033)	0.023 (0.033)
<i>Fixed-effects</i>				
Firm	Yes	Yes	Yes	Yes
City – Year	Yes	Yes	Yes	Yes
Industry – Year	Yes	Yes	Yes	Yes
<i>Fit statistics</i>				
Observations	36,460	39,364	29,038	28,936
R2	0.907	0.904	0.912	0.912
Within R2	0.014	0.012	0.011	0.012

Clustered (Firm) standard-errors in parentheses.

This table reports estimates of eq. 1. Waste water intensity refers to the intensity of waste water emission (Waste water) divided by the firm's output. Asset tangibility denotes tangible assets divided by total assets. Cash flow is defined as net income plus depreciation over total assets. Current ratio is measured as current assets over current liabilities. Coverage ratio is measured as earnings before interest and taxes divided by interest expenses. SO<sub>2</sub> removing capacity is the capacity to remove SO<sub>2</sub> emissions per hour divided by output. Foreign capital share is computed as the share of capital held by foreign entities in the firm's capital. SOE is a dummy variable equal to 1 if the firm is a state-owned enterprise. Other control variables include sales over assets, total assets, employment, age, age squared. All right-hand-side variables, except SOE, are lagged by one year. All estimations account for initial pollution trends at the firm level. Heteroskedasticity-robust standard errors clustered at the firm level appear in parentheses. \* Significance at 10 %; \*\* significance at 5%; \*\*\* significance at 1 %.

**Table 8**  
External finance dependencies.

Industry	CIC	Value
General Purpose Machinery	35	-2.59
Tobacco	16	-1.54
Measuring Instruments and Machinery for Cultural Activity and Office Work	41	-1.34
Textile Wearing Apparel, Footwear, and Caps	18	-1.32
Leather, Fur, Feather and Related Products	19	-1.11
Metal Products	34	-0.93
Printing, Reproduction of Recording Media	23	-0.80
Beverages	15	-0.72
Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products	20	-0.72
Transport Equipment	37	-0.72
Furniture	21	-0.65

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Table 8 (continued)

Industry	CIC	Value
Artwork and Other Manufacturing	42	-0.62
Textile	17	-0.48
Processing of Food from Agricultural Products	13	-0.47
Plastics	30	-0.47
Medicines	27	-0.44
Electrical Machinery and Equipment	39	-0.44
Chemical Fibers	28	-0.41
Articles For Culture, Education and Sport Activity	24	-0.40
Foods	14	-0.32
Non-metallic Mineral Products	31	-0.29
Special Purpose Machinery	36	-0.27
Rubber	29	-0.26
Raw Chemical Materials and Chemical Products	26	-0.23
Smelting and Pressing of Non-ferrous Metals	33	-0.10
Communication Equipment, Computers and Other Electronic Equipment	40	0.02
Paper and Paper Products	22	0.07
Smelting and Pressing of Ferrous Metals	32	0.33
Processing of Petroleum, Coking, Processing of Nuclear Fuel	25	0.62

Table 9

TCZ and SPZ cities in China.

City	Code	TCZ	SPZ	City	Code	TCZ	SPZ
Linyi	3713	1	0	Tongling	3407	0	0
Suihua	2312	1	0	Tianshui	6205	1	0
Wuzhong	6403	1	0	Lanzhou	6201	0	1
Chuzhou	3411	1	0	Wuwei	6206	1	0
Fuyang	3412	1	0	Pingliang	6208	1	0
Suizhou	4213	1	0	Qingyang	6210	1	0
Huaihua	4312	1	0	Zhangye	6207	0	0
Zhaotong	5306	1	0	Jiuquan	6209	1	0
Huaian	3208	1	0	Dingxi	6211	1	0
Heze	3717	1	0	Jinchang	6203	0	0
Hezhou	4511	1	0	Longnan	6212	1	0
Anshun	5204	1	0	Jiayuguan	6202	1	0
Tongliao	1505	1	0	Shijiazhuang	1301	0	1
Lu'an	3415	1	0	Zhangjiakou	1307	0	0
Jinzhong	1407	1	0	Baoding	1306	0	1
Baoshan	5305	1	0	Cangzhou	1309	1	0
Ziyang	5120	1	0	Handan	1304	0	0
Nanchong	5113	1	0	Qinhuangdao	1303	1	1
Guang'an	5116	1	0	Langfang	1310	1	0
Yunfu	4453	1	0	Hengshui	1311	0	0
Chaozhou	4451	1	0	Xingtai	1305	0	0
Xuancheng	3418	1	0	Chengde	1308	0	0
Baicheng	2208	1	0	Tangshan	1302	0	0
Suqian	3213	1	0	Pingdingshan	4104	1	0
Bazhong	5119	1	0	Xuchang	4110	1	0
Ya'an	5118	1	0	Nanyang	4113	1	0
Huludao	2114	1	0	Xinyang	4115	1	0
Baise	4510	1	0	Anyang	4105	0	0
Matsubara	2207	1	0	Luoyang	4103	0	1
Bayannaoer	1508	1	0	Zhengzhou	4101	0	1
Wulanchabu	1509	1	0	Kaifeng	4102	1	0
Zhangjiajie	4308	1	0	Xinxiang	4107	1	0
Chongzuo	4514	1	0	Luohe	4111	1	0
Zhongwei	6405	1	0	Zhoukou	4116	1	0
Erdos	1506	1	0	Hebi	4106	1	0
Jieyang	4452	1	0	Zhumadian	4117	1	0
Chizhou	3417	1	0	Shangqiu	4114	1	0
Laiwu	3712	1	0	Jiaozuo	4108	0	0
Simao	5308	1	0	Puyang	4109	1	0
Lijiang	5307	1	0	Sanmenxia	4112	0	0
Sanya	4602	1	0	Wuhan	4201	0	1
Bozhou	3416	1	0	Xianning	4212	0	0
Hefei	3401	1	1	Xiaogan	4209	1	0
Bengbu	3403	1	0	Yichang	4205	0	0
Wuhu	3402	0	1	Xiangfan	4206	1	1
Anqing	3408	1	0	Huanggang	4211	0	0

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Table 9 (continued)

City	Code	TCZ	SPZ	City	Code	TCZ	SPZ
Huaibei	3406	1	0	Jingzhou	4210	1	0
Huainan	3404	1	0	Shiyan	4203	1	0
Ma'anshan	3405	0	0	Huangyou	4202	0	0
Huangshan	3410	1	0	Jingmen	4208	0	0
City	Code	TCZ	SPZ	City	Code	TCZ	SPZ
Ezhou	4207	0	0	Zunyi	5203	0	0
Yongzhou	4311	0	0	Liupanshui	5202	1	0
Chenzhou	4310	0	0	Guiyang	5201	0	1
Changsha	4301	0	1	Nanjing	3201	0	1
Changde	4307	0	0	Xuzhou	3203	0	0
Xiangtan	4303	0	0	Yancheng	3209	1	0
Hengyang	4304	0	0	Lianyungang	3207	1	1
Yueyang	4306	0	0	Nantong	3206	0	1
Zhuzhou	4302	0	0	Yangzhou	3210	0	0
Yiyang	4309	0	0	Zhenjiang	3211	0	1
Shaoyang	4305	1	0	Changzhou	3204	0	1
Loudi	4313	0	0	Wuxi	3202	0	1
Changchun	2201	1	1	Shangrao	3611	0	1
Siping	2203	0	0	Ji'an	3608	1	0
Liaoyuan	2204	1	0	Nanchang	3601	0	1
Jilin	2202	0	1	Ganzhou	3607	0	0
Tonghua	2205	0	0	Xinyu	3605	1	0
Xiamen	3502	0	1	Jiujiang	3604	0	0
Longyan	3508	1	0	Pingxiang	3603	0	0
Ningde	3509	0	0	Jingdezhen	3602	1	0
Putian	3503	1	0	Yingtian	3606	0	0
Sanming	3504	0	0	Yinchuan	6401	0	0
Zhangzhou	3506	0	0	Shizuishan	6402	0	0
Nanping	3507	1	0	Xining	6301	1	0
Quanzhou	3505	0	0	Hanzhong	6107	1	0
Linfen	1410	0	0	Yan'an	6106	1	0
Taiyuan	1401	0	1	Baoji	6103	1	1
Datong	1402	0	0	Xianyang	6104	1	1
Yuncheng	1408	0	0	Weinan	6105	0	0
Changzhi	1404	1	0	Xi'an	6101	0	1
Xinzhou	1409	1	0	Shangluo	6110	1	0
Shuozhou	1406	0	0	Tongchuan	6102	0	0
Jincheng	1405	1	0	Mianyang	5107	0	1
Luliang	1411	0	0	Chengdu	5101	0	1
Yangquan	1403	0	0	Deyang	5106	0	0
Qujing	5303	0	0	Yibin	5115	0	0
Kunming	5301	0	1	Meishan	5114	0	0
Yuxi	5304	0	0	Dazhou	5117	1	0
Lincang	5309	1	0	Leshan	5111	0	0
Beijing	1101	0	1	Luzhou	5105	0	0
Nanning	4501	0	1	Zigong	5103	0	0
Liuzhou	4502	0	0	Guangyuan	5108	1	0
Guigang	4508	0	0	Neijiang	5110	0	0
Beihai	4505	1	1	Suining	5109	0	0
Guilin	4503	0	1	Panzhihua	5104	0	0
Qinzhou	4507	1	0	Tianjin	1201	0	1
Wuzhou	4504	0	0	Dandong	2106	1	0
Laibin	4513	0	0	Shenyang	2101	0	1
Hechi	4512	1	0	Yingkou	2108	1	0
Fangchenggang	4506	0	0	Jinzhou	2107	0	0
City	Code	TCZ	SPZ	City	Code	TCZ	SPZ
Tieling	2112	1	0	Meizhou	4414	1	0
Fuxin	2109	0	0	Heyuan	4416	1	0
Chaoyang	2113	1	0	Shanwei	4415	0	0
Dalian	2102	0	1	Qingyuan	4418	0	0
Liaoyang	2110	0	0	Dongguan	4419	0	0
Anshan	2103	0	1	Harbin	2301	1	1
Panjin	2111	1	0	Mudanjiang	2310	1	0
Benxi	2105	0	0	Heihe	2311	1	0

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Table 9 (continued)

City	Code	TCZ	SPZ	City	Code	TCZ	SPZ
Fushun	2104	0	0	Qiqihar	2302	1	0
Weifang	3707	0	1	Jiamusi	2308	1	0
Qingdao	3702	0	1	Jixi	2303	1	0
Yantai	3706	0	1	Daqing	2306	1	1
Zaozhuang	3704	0	0	Shuangyashan	2305	1	0
Jinan	3701	0	1	Hegang	2304	1	0
Dezhou	3714	1	0	Qitaihe	2309	1	0
Liaocheng	3715	1	0	Hohhot	1501	0	0
Binzhou	3716	1	0	Hulunbeier	1507	1	0
Jining	3708	0	0	Chifeng	1504	0	0
Tai'an	3709	0	0	Baotou	1502	0	1
Weihai	3710	1	1	Wuhai	1503	0	0
Zibo	3703	0	1				
Dongying	3705	1	0				
Rizhao	3711	1	0				
Shanghai	3101	0	1				
Urumqi	6501	0	1				
Karamay	6502	1	0				
Ningbo	3302	0	1				
Hangzhou	3301	0	1				
Huzhou	3305	0	0				
Wenzhou	3303	0	1				
Quzhou	3308	0	0				
Shaoxing	3306	0	0				
Zhoushan	3309	1	0				
Jinhua	3307	0	0				
Lishui	3311	0	0				
Jiaying	3304	0	0				
Chongqing	5001	0	0				
Shaoguan	4402	0	0				
Foshan	4406	0	1				
Zhanjiang	4408	0	1				
Canton	4401	0	1				
Shenzhen	4403	0	1				
Shantou	4405	0	1				
Maoming	4409	1	0				
Jiangmen	4407	0	0				
Zhuhai	4404	0	1				
Zhongshan	4420	0	1				
Zhaoqing	4412	0	0				
Huizhou	4413	0	1				
Yangjiang	4417	1	0				

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