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*Original Research*

# Commercial Bank Expansion and Environmental Pollution: Micro Evidence from Industrial Firms in China

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## Abstract

This paper uses the web crawler method to obtain information on the distribution of commercial bank branches in China and uses the multidimensional fixed-effects model to explore the impact of commercial bank expansion on firm pollution emissions and its mechanism. The findings reveal that commercial bank expansion significantly reduces firms' pollution emissions and that there is an optimal geographical radius for this suppression effect. The number of commercial bank branches within 20 km of the firm has the biggest inhibiting influence on the firm's pollution emission, which diminishes as geographical distance increases. This dampening effect remains robust after testing using the instrumental variable method and the Difference-In-Differences method. Examination of heterogeneity demonstrates that the influence of commercial bank expansion on firm pollution emission depends on the degree of regional low-carbon policies and laws, the level of pollution in the industry, and capital intensity of the industry, as well as the firm's size and ownership. The mechanism test proves that commercial bank expansion reduces firm pollution emissions by promoting technological progress and increasing their investment in pollution reduction.

**Keywords:** Firm's pollution emissions, Commercial bank expansion, Technological progress, Pollution abatement investments

## Introduction

Globally, the problem of environmental contamination has become more severe as industrialization has advanced. Expansive economic growth in developing countries has led to excessive consumption of resources, putting enormous pressure on environmental management (Chen et al., 2022) [1]. Environmental degradation leads to the spread of diseases (Siddiqua et al., 2022) [2], degrades environmental quality, destroys ecological balance, and constraints sustainable economic growth (Li Wu, 2017) [3]. As the largest developing nation, China's rapid economic growth has exacerbated environmental pollution issues (Yang et al., 2013) [4]. According to China's National Bureau of Statistics, China's total energy consumption increased by 2.9% in 2022 compared to 2021, reaching 5.41 billion tonnes of standard coal. Industrial firms are the main

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source of pollutant emissions (Chen et al., 2023) [5], accounting for 90% of China's air pollution issues and 50% of its river pollution issues (Xia and Liu, 2022) [6]. In response, the Chinese government developed a variety of environmental laws, including market-based, command-and-control, and voluntary policy measures, to regulate firms' pollution emissions. Therefore, it is of profound relevance to study the pollution emissions of industrial firms and explore how to promote environmentally sustainable development.

The banking sector in China has undergone profound changes in recent decades, which provides a valuable context for investigating the connection between commercial bank expansion and firms' pollution emissions. In China, bank loans are the main form of external financing (Jiang et al., 2017) [7] and play an important role in allocating credit resources. Banking reforms and the implementation of bank deregulation policies have contributed to the transformation of China's banking sector from an inefficient monolithic banking system to a modern one, most visibly manifested by a significant increase in bank branch outlets. Financial licensing data provided by the China Banking Regulatory Commission shows that the number of financial institutions in China increased from 6,719 in 1978 to 261,382 in March 2023, with a significant increase in the coverage of bank branches. Previous research has concentrated on the effects of financial development at the provincial or city level. In contrast, the role of commercial bank expansion on the environmental behavior of firms at the firm level has been neglected. There are large imbalances in financial development across regions in China (Dollar and Wei, 2007) [8], with a highly segmented regional credit market and relatively independent regional financial systems (Huang et al., 2020) [9], resulting in significant imbalances in the allocation of credit resources at the micro firm level. The environmental behavior of firms can be influenced by financing constraints (Xu and Kim, 2022) [10], and the number of commercial bank branches in a firm's vicinity can be somewhat indicative of the ease of access to credit resources (Agarwal and Hauswald, 2010) [11]. Indeed, the geographical expansion of commercial banks has often occurred in the context of bank deregulation and liberalization in other countries (Z. Chen et al., 2020) [12], and this study fills a gap in previous research. Therefore, exploring the pollution abatement effects of commercial bank expansion is essential.

By using financial licensing data provided by the China Banking and Insurance Regulatory Commission, the Chinese Industrial Enterprises Database, the Environmental Survey and Reporting Database of the Chinese Ministry of Environmental Protection, and the patent application dataset of the State Intellectual Property Office of China, we analyzed the impact of commercial bank expansion on industrial firms' pollution emissions and the potential transmission mechanisms. We consider the endogeneity of the impact of financial development on environmental pollution (Khan et al., 2020) [13]. To this end, we follow Chen et al. (2023) [5] and build a DID model to investigate the effect of commercial bank expansion on firms' pollution emissions using the 2009 bank deregulation policy as an exogenous shock. Moreover, this study assesses the heterogeneous impact of commercial bank expansion on firms' pollution emissions by analyzing whether the region where the firm is located is a low-carbon city, the legal environment of the region, the level of pollution and capital intensity of the industry, and the size and ownership of the firm.

The following are the primary contributions of this paper. First, this study provides the first direct evidence that commercial bank expansion affects firms' pollution emissions. Prior research has typically centered on the effects of provincial or prefectural financial development (Adeel-Farooq et al., 2022) [14], regional banking competition (Xia et al., 2021) [15], and regional banking development (Chen et al., 2021) [16] on environmental pollution, lacking a firm-level perspective and ignoring the environmental benefits of commercial bank expansion. Second, most studies on the finance-environment nexus utilize aggregated macro-level data, making it difficult to investigate potential microlevel transmission mechanisms. Unlike previous studies, this study uses firm-level data to explore the micro-transmission mechanisms between the two in detail. In addition, this paper provides a heterogeneity analysis at the macro, meso and micro levels. Third, the literature tends to encounter endogeneity problems when exploring the connection between finance and the environment. First, the number of local commercial bank branches tends to be related to regional economic development, suggesting that existing studies using macrolevel banking institution aggregates may make it difficult to reliably estimate the effect of the former due to issues such as omitted variables. Second, using macro-level aggregated data may lead to endogeneity problems due to measurement errors. There is a precise segmentation of business between cities in China where the same bank branch is situated, making it difficult for firms to access loans from banks based in different towns (Chong et al., 2013) [17], and the financial system is relatively independent across regions in China. In addition, there is a "threshold radius" (Skrastins and Vig, 2019) [18] for firms to access external finance, i.e., it may be difficult for firms to be influenced by banks located farther away, even if they are in the same city. Therefore, this paper uses the latitude and longitude data of firms and commercial bank branches to calculate the geographical distance of the two located in the same county, and then counts commercial bank branch quantity in a particular vicinity surrounding the firm to measure commercial bank expansion. This identification strategy, which considers both "geographical factors" and the independence of financial systems in different regions, can somewhat alleviate the endogeneity problems associated with using macroaggregated data

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in previous studies and thus obtain more accurate estimation results.

## Literature Review and Research Hypotheses

This paper intends to investigate the actual influence of commercial bank expansion on the pollution emissions of firms. While this is one of the first studies to examine the connections and mechanisms between commercial bank expansion and environmental pollution at the corporate level, prior research has greatly contributed to our understanding of the topic. Due to data availability, there has long been little literature discussing pollutant emissions at the micro firm level. Most of the literature has looked at the macro level at the national, provincial and city levels, with results suggesting that emissions reduction policies (Dong et al., 2022) [19], technological progress (Ahmad et al., 2021) [20], and environmental regulation (Wang & Zhang, 2022) [21] are all conducive to reducing pollutant emissions. There are competing views regarding the relationship between financial development and environmental pollution, with some scholars suggesting that financial development benefits environmental protection (Adeel-Farooq et al., 2022) [14]. On the one hand, the development of the financial sector can help alleviate the financing constraints confronted by firms and diversify their financing sources, thereby promoting the development of energy-efficient production technologies, reducing pollution emissions, and effectively curbing environmental pollution (Chen et al., 2023) [5]. On the other hand, a well-developed financial system can provide sufficient credit support for a firm's R&D (Qayyum et al., 2021) [22], which is conducive to the protection of the ecological environment. Moreover, financial development can also provide funds for clean energy projects (Nasir et al., 2019) [23], improve the firm's governance structure, and reduce pollution emissions. However, some scholars hold the opposite view, and they believe that financial development will exacerbate environmental pollution (Khan et al., 2020) [24]. Financial development attracts more foreign direct investment inflows (Khan et al., 2022) [25], leading to increased pollution emissions, while financial deepening promotes industrialization, leading to increased industrial pollution. In addition, the growing financial sector can exacerbate electricity consumption (Mararrasso et al., 2019) [26], increase the purchase of equipment such as cars (Alsagr & van Hemmen, 2021) [27], and have a detrimental effect on the environment. Some literature argues that financial development inhibits environmental quality in developing economies but has little effect on environmental quality in developed countries (Ling et al., 2022) [28] and that more attention should be paid to the environmental impacts of financial development in developing countries. Interestingly, there are also some studies showing that financial development is not significantly related to environmental degradation (Bekhet et al., 2017) [29]. Studies for China. Xu et al. (2021) [30] and Kihombo et al. (2021) [31] investigated the impact of financial development on carbon emission and environmental pollution, but they arrived at a different view. It is worth noting that there are two limitations of the existing studies. First, these studies do not consider the impact of "geographical factors". Nguyen (2019) [32] found that geographical distance still plays an important role in bank lending. In the Chinese context, there is a clear segmentation of business between cities where the same bank branch is located, which makes it difficult for firms to obtain loans across cities. Financial development in the region does not mean that all firms in the region can benefit from it. Hence, studies in China need to consider the impact of geographical distance between banks and firms on environmental issues (Zhou & Zhang, 2023) [33]. Second, it is difficult to circumvent potential endogeneity issues by using macro-level data. Analyses based on macro-level aggregated data may lead to different results than micro-level data (Martins et al., 2023) [34], which may explain the inconsistent findings of existing studies on the relationship between financial development and environmental pollution.

Considering the characteristics of China's banking sector, we believe that commercial bank expansion will affect firms' pollution emissions through two channels.

1. Technological progress effect. To maximize profits, companies may resort to technological innovation to enhance their advantage in the competitive marketplace through product development and technological research and development. Commercial bank expansion implies a rise in the number of banks in the vicinity of the firm, which has an essential impact on the technological progress of the firm. First, growth in the number of banks in the vicinity of a firm will alleviate the firm's credit constraints and give it greater access to substantial funds for technological research and development. Inadequate internal financing can hardly have a negative impact on innovation, while an improved external financing environment can help firms' R&D activities (Buera and Shin, 2013) [35]. A rise in the number of banks near a firm may increase the level of bank competition in the region, which in turn may encourage banks to lower their lending rates and loosen their lending conditions to attract firms to lend (Beck and Demirguc-Kunt, 2006) [36], thereby further alleviating firms' financing difficulties. Second, a rise in the number of banks surrounding a firm can minimize its innovation risk. Technological innovation is highly uncertain and risky (H. Yu et al., 2022) [37], and the risks associated with technological innovation can be transferred by local financial institutions to other shareholders with high risk-taking capacity (Saeed and Izzeldin, 2016) [38], mitigating the problem of risk-induced lending constraints (Sarmiento and Galán, 2017) [39]. Technological progress helps to improve environmental quality (Ahmad et al., 2021) [20], and as innovative individuals, firms can use the large amounts of capital generated by commercial

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bank expansion for technological innovation activities. Therefore, commercial bank expansion encourages firms' technological progress, reducing their pollution emissions.

2. Pollution abatement investment effect. The relaxation of credit conditions due to commercial bank expansion may stimulate firms to increase investment in pollution abatement, thereby reducing pollutant emissions. The easing of financing constraints may decrease the marginal cost of pollution abatement and, hence, decrease emissions (Xu and Kim, 2022) [10]. Under the Equator Principles, financial institutions evaluate the socioeconomic consequences of a firm's environmental behavior (Su et al., 2022) [40]. Supply-side factors in financial markets affect firms' financing decisions (Lemmon and Roberts, 2010) [41]. In this scenario, firms will increase their pollution control and environmental protection investments by cutting back on growth investments to avoid penalties for environmental violations (Shi et al., 2022) [42]. Therefore, commercial bank expansion may stimulate firms to expand further in pollution abatement investment and thus reduce pollution emissions. Increased investment in pollution abatement favors the substitution of renewable energy sources and mitigates environmental pollution problems caused by the production activities of enterprises. Ren et al. (2022) [43] argue that increased investment in pollution abatement reduces the emission of air pollutants. Therefore, this paper proposes the following hypothesis:

H1. Commercial bank expansion will reduce firms' pollutant emissions.

H2. Commercial bank expansion will promote the technological progress of firms, thus reducing their pollution emissions.

H3. Commercial bank expansion will increase firms' investment in pollution abatement, reducing pollution emissions.

## Data, Models and Variables

### Variable Selection

#### *Explained Variables*

The explanatory variable in this paper is the firm's pollution emissions ($SO_2$), which is measured as the logarithm of the firm's sulfur dioxide ($SO_2$) emissions in period t (Yang et al., 2022) [44]. Sulfur dioxide ($SO_2$) emissions have been a major pollution problem for humans globally. China is the world's largest producer and consumer of coal (Chandranet al., 2013) [45], i.e., coal-based air pollution is the main form of environmental pollution in China, and $SO_2$ is the main air pollutant produced by coal combustion in China. Therefore, in this paper, $SO_2$ emissions are chosen to measure the pollution emission level of firms. In addition, firms' smog emissions (*Dust*) are used as a proxy variable in the robustness test part of this paper.

#### *Core Explanatory Variable*

The core explanatory variable in this paper is commercial bank expansion (*Br*), which is measured by the number of commercial bank branches within a certain radius of the firm. Drawing on Avramidis et al. (2022) [46], we determine the geographical distance between the firm and the commercial bank using latitude and longitude data and then count the number of commercial bank branches within a specified radius of the firm's location. Specifically, we calculated the number of commercial bank branches around the firm within radii of 5, 10, 15, 20, 25 and 30 km. Since there is a "threshold radius" (Skrastins and Vig, 2019) [18] within the geographical range of external financing available to the firm, this suggests that if the firm is far away from the bank, the firm may not be affected by this bank branch. Therefore, we only count the number of commercial bank branches within 5-30 km. It is important to note that this paper differs from Avramidis et al. (2022) [46] and related literature in that we first identify whether a firm and a commercial bank branch are within the same county based on their latitude and longitude data and then calculate the geographical distance between the firm and the commercial bank institution within the same county to measure the number of commercial bank branches around the firm. This is because, in China, there is a clear segmentation of business between cities where the same bank branch is located, making it difficult for firms to access loans across cities (Chong et al., 2013) [17]. Thus, even if a banking institution is geographically close to a firm, the firm's pollution emission levels are unlikely to be influenced by other commercial bank branches within the county. Using geographical information to construct firm-level variables can largely mitigate the endogeneity problem compared to previous literature at the national and regional levels. In contrast, previous studies investigating the economic consequences of financial variables using aggregated data would have ignored variables such as institutional conditions and struggled to identify the actual effects of financial variables. Notably, we focus on four state-owned commercial banks, urban commercial banks, joint-stock commercial banks and foreign banks in China.

#### *Control Variables*

The following control variables were selected based on previous studies (Wang and Lee, 2022) [47]. (1) The firm's age (*Age*) is determined by subtracting the current year from the year it was officially established and then taking the natural logarithm of that number. (2) Firm debt ratio (*Lev*) is measured as the ratio of the current year's debt to total assets. (3) The profitability of the firm's assets (*Roa*) is estimated as the proportion

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of the firm's profit for the year to its total assets. (4) The firm fixed assets ratio (*FA*) is calculated using the percentage of fixed assets to total assets. (5) The firm's size (*Size*) is calculated as the logarithm of the firm's fixed assets. Larger firms are more likely to invest in cleaner manufacturing equipment and innovate cleaner production technologies, leading to lower pollution levels (Wu et al., 2017) [48]. (6) The state-owned enterprise dummy variable (*SOE*) is used to control for ownership of the firm as a confounder to interfere with the regression results. (7) Firm exports (*EX*), which we define as a binary variable, are defined as 1 only when the firm has exported during the year, i.e., if the export amount is larger than 0, and 0 and vice versa.

### *Mechanism Variables*

Theoretical analysis shows that commercial bank expansion will promote the technological progress of firms and increase their investment in pollution reduction, thus reducing pollutant emissions. This paper selects the following variables as mechanism variables: (1) Technological progress. Existing research suggests that firms' innovation outcomes can be reflected by the value of new product output (Liu et al., 2007) [49]. Owing to the availability of data, we use the output value of new goods (*New*) as a proxy for technical progress. Furthermore, following Liu et al. (2022) [50], this study utilizes the total number of patent applications (*Pat*) in the Chinese patent database as a proxy for technical innovation. (2) Pollution abatement investment. As firms alleviate their financial predicament by expanding their investment in pollution abatement (Xu and Kim, 2022) [10], three indicators of firms' pollution abatement behaviors are employed in this article. The first indicator is the capacity of a firm's facility to decrease wastewater (*RW*), which is calculated using the logarithm of the facility's capacity to treat wastewater and represents the firm's fixed cost of emissions reduction. The second indicator is $SO_2$ removal (*RS*), which is calculated using the logarithm of $SO_2$ removal and represents the variable cost of reducing the $SO_2$ pollutant. The third indicator is the ratio of $SO_2$ removal to $SO_2$ generation (*RS_r*), which indicates the average effectiveness of pollution abatement.

## Data Source and Processing

The sample data for this paper were obtained from the Annual Survey of Industrial Firms (ASIF) issued by the National Bureau of Statistics of China, the Environmental Survey and Reporting (ESR) database from the Ministry of Environment Protection of China, the financial licensing data published by the China Banking and Insurance Regulatory Commission (CBIRC), the patent application dataset provided by the State Intellectual Property Office of China (CNIPA), the China City Statistical Yearbook (CCSY), and the China Statistical Yearbook (CSY). Considering that bank loans are the primary source of external funding for unlisted firms (Chemmanur et al., 2020) [51], this study examines the effect of commercial bank expansion on firms' pollution emissions using a database of Chinese industrial firms from 1998 to 2013. The Industrial Enterprise Database is commonly employed in economics research (Yu et al., 2022) [52]. While the data in this database are only published through 2015, and the data for 2014 and 2015 are of poor quality, the sample period for this paper is limited to 1998 to 2013. This is consistent with the approach of similar studies. This work adopts the strategy of Brandt et al. (2012) [53] to standardize the database of Chinese industrial enterprises by deleting sample firms that do not conform with accounting rules and unifying the industry codes. Next, samples with negative emission indicators were excluded from the Chinese enterprise pollutant emission database. The firms were subsequently linked with the China Industrial Enterprise Pollution Emission Database and the China Patent Database on the basis of their names, unique identification codes, and year factors. For commercial bank branch data, this paper retains only a sample of commercial bank branches in the current year based on the China Banking Regulatory Commission's "Rules for the Preparation of Financial Licensing Institution Codes (for Trial Implementation)" and the establishment and withdrawal dates of commercial bank branches.

## Model Selection

### *Basic Model*

Panel data are widely used in the field of environmental economics. In this paper, a fixed effects model is used to examine the impact of commercial bank expansion on firm pollution emissions and the model is constructed as follows:

$$SO2_{jkit} = \alpha_0 + \alpha_1 Br_{jkit} + \alpha_2 \sum CV + \{FE\} + \varepsilon_{jkit} \tag{1}$$

where the explanatory variable $SO_{2jkit}$ is the logarithm of the sulfur dioxide emissions of firm *i* in industry *k* in region *j* in period *t*, and the explanatory variable $Br_{jkit}$ is the logarithm of the number of commercial bank branches within a certain range around firm *k* industry *i* and in the same county *j* in period *t*, specifically the logarithm of the number of commercial bank branches within 5, 10, 15, 20, 25 and 30 km of the center of the firm. *CV* is the set of control variables, including firm age (*Age*), firm size (*Size*), gearing (*Lev*), profitability (*ROA*), fixed assets (*FA*), ownership (*SOE*), and exports (*EX*). $FE = \{\delta_j, \delta_k, \delta_i, \delta_t\}$ represents region, industry, firm, and year fixed effects, and $\varepsilon_{jkit}$ represents the random disturbance term. In addition, considering possible heteroskedasticity and autocorrelation issues, we used county-level clustering standard errors.

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Table 1. Descriptive statistics of all variables.

| Variable | Obs | Mean | SD | Min | Max | Source | Form |
|---|---|---|---|---|---|---|---|
| $SO_2$ | 406365 | 8.470 | 3.940 | 0.000 | 21.50 | ESR | Logarithm |
| *Br_5km* | 406365 | 2.610 | 1.430 | 0.000 | 6.710 | CBRC | Logarithm |
| *Br_10km* | 406365 | 3.540 | 1.400 | 0.000 | 7.500 | CBRC | Logarithm |
| *Br_15km* | 406365 | 4.090 | 1.350 | 0.000 | 7.900 | CBRC | Logarithm |
| *Br_20km* | 406365 | 4.480 | 1.320 | 0.000 | 8.050 | CBRC | Logarithm |
| *Br_25km* | 406365 | 4.790 | 1.300 | 0.000 | 8.150 | CBRC | Logarithm |
| *Br_30km* | 406365 | 5.050 | 1.270 | 0.000 | 8.200 | CBRC | Logarithm |
| *Age* | 406365 | 2.430 | 0.870 | 0.000 | 4.170 | ASIF | Logarithm |
| *ROA* | 406365 | 0.060 | 0.150 | -0.230 | 0.840 | ASIF | Proportion |
| *LEV* | 406365 | 0.630 | 0.300 | 0.030 | 1.630 | ASIF | Proportion |
| *FA* | 406365 | 0.400 | 0.210 | 0.030 | 0.910 | ASIF | Proportion |
| *LnSize* | 406365 | 9.870 | 1.760 | 5.710 | 14.63 | ASIF | Logarithm |
| *EX* | 406365 | 0.287 | 0.457 | 0.000 | 1.000 | ASIF | Binary |
| *SOE* | 406365 | 0.225 | 0.417 | 0.000 | 1.000 | ASIF | Binary |
| *Pat* | 406365 | 0.060 | 0.290 | 0.000 | 1.950 | CSIPO | Level value |
| *New* | 324435 | 1.210 | 3.280 | 0.000 | 12.78 | ESR | Level value |
| *RW* | 227137 | 1.690 | 1.180 | 0.000 | 4.940 | ESR | Logarithm |
| *RS* | 200062 | 0.860 | 1.090 | 0.000 | 4.550 | ESR | Logarithm |
| *RS_r* | 203,134 | 0.250 | 0.500 | 0.000 | 2.620 | ESR | Proportion |

*Conduction Mechanism Model*

This study hypothesizes that commercial bank expansion can indirectly influence firms' pollution emissions by enhancing technological progress and investment in pollution abatement. To test this hypothesis empirically, the following model is set up.

$$INOV_{jkit} = \beta_0 + \beta_1 Br_5km_{jkit} + \beta_2 \sum CV + \{FE\} + \varepsilon_{jkit} \quad (2)$$

$$SO2_{jkit} = \lambda_0 + \lambda_1 Br_5km_{jkit} + \lambda_2 INOV_{jkit} + \lambda_3 \sum CV + \{FE\} + \varepsilon_{jkit} \quad (3)$$

$$Remov_{jkit} = \gamma_0 + \gamma_1 Br_5km_{jkit} + \gamma_2 \sum CV + \{FE\} + \varepsilon_{jkit} \quad (4)$$

In the above model, *INOV* represents the technological progress channel, including the value of new product output (*New*) and the number of patent applications (*Pat*), and *Remov* represents the pollution abatement investment channel, including the capacity of the firms' equipment to reduce wastewater (*RW*), $SO_2$ removal (*RS*), and the ratio of $SO_2$ removal to $SO_2$ production (*RS _r*).

## Results and Discussion

### Descriptive Statistics

Descriptive statistics for all variables are given in Table 1. The mean value of the dependent variable $SO_2$ is 8.470, and the standard deviation is 3.940, indicating a significant difference in the level of $SO_2$ pollution emissions between the different firms. In terms of the spatial distribution of commercial bank branches, there are, on average, 14 ($e^{2.61}$) commercial bank branches within 5 km of the firm that belongs to the same county as the firm, which indicates that there are more commercial banks around the firm. Based on the mean value of the dependent variable *Br_5km* to *Br_30km*, we can learn that the average number of commercial bank branches around the firm increases significantly as the geographical radius increases.

### Baseline Regression Analysis

Table 2 shows the estimates of the impact of commercial bank expansion on firms' pollution emissions derived from Equation (1). We estimate Equation (1) without control variables and Equation (1) including control variables separately. The estimation outcomes are displayed in Table 2's panels A and B.

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Table 2. Baseline estimation results.

| Panel A: Without control variables | | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ |
| *Br_5km* | -0.123*** | | | | | |
| | (0.012) | | | | | |
| *Br_10km* | | -0.163*** | | | | |
| | | (0.023) | | | | |
| *Br_15km* | | | -0.184*** | | | |
| | | | (0.032) | | | |
| *Br_20km* | | | | -0.218*** | | |
| | | | | (0.042) | | |
| *Br_25km* | | | | | -0.193*** | |
| | | | | | (0.054) | |
| *Br_30km* | | | | | | -0.161*** |
| | | | | | | (0.061) |
| CVs | No | No | No | No | No | No |
| Fixed effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs | 406365 | 406365 | 406365 | 406365 | 406365 | 406365 |
| $R^2$ | 0.301 | 0.220 | 0.220 | 0.220 | 0.219 | 0.219 |
| Panel B: With control variables | | | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ |
| *Br_5km* | -0.118*** | | | | | |
| | (0.011) | | | | | |
| *Br_10km* | | -0.155*** | | | | |
| | | (0.016) | | | | |
| *Br_15km* | | | -0.163*** | | | |
| | | | (0.021) | | | |
| *Br_20km* | | | | -0.166*** | | |
| | | | | (0.027) | | |
| *Br_25km* | | | | | -0.166*** | |
| | | | | | (0.034) | |
| *Br_30km* | | | | | | -0.151*** |
| | | | | | | (0.039) |
| CVs | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs | 406365 | 406365 | 406365 | 406365 | 406365 | 406365 |
| $R^2$ | 0.396 | 0.396 | 0.395 | 0.395 | 0.395 | 0.395 |

Note: *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively. County-level clustered standard errors are in parentheses. *Br_5km*, *Br_10km*, …, *Br_30km* is the number of commercial bank branches within the radius of 5, 10, …, and 30 kilometers near the firm, respectively.

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From the estimation outcomes, we can see that the coefficient estimates without the control variables are relatively larger, perhaps because of the overestimation of the estimated coefficients due to the omission of other factors that interfere. Furthermore, the coefficient estimates in columns (1)-(6) demonstrate that commercial bank expansion reduces firms' pollution emissions and that there is an "optimal geographical radius" for this effect. The estimated coefficient of *Br* is smallest at a radius of 5 km from the firm's center, -0.118. As the geographical radius increases, the maximum coefficient of *Br* for the influence of the commercial bank expansion on firms' pollution emissions is -0.166 at a radius of 20 km from the firm's center. This suppression effect gradually decreases to a coefficient of -0.151 for *Br* at a geographic radius set at 30 km. In general, the inhibitory effect of commercial bank expansion on corporate emissions increases and decreases with increasing geographical radius, demonstrating the importance of the "geographical factor" in studying the relationship between financial development and the environment. For rigor and to save space, we have focused on commercial bank expansion within a 5 km radius of the firm.

Our results are somewhat coherent with Khan et al. (2021) [54], who investigated the effect of financial development on $CO_2$ using an annual dataset of 88 developing countries and discovered that financial development reduces environmental pollution levels. In addition, our findings are congruent with those of Chen et al. (2021) [16], who conclude that financial development, as exemplified by the construction of regional financial institutions, has a positive influence on environmental improvements in the area. Notably, our results demonstrate the existence of an optimal geographical radius for the emission-suppressing effect of commercial bank expansion on firms. This demonstrates that firms whose distance from commercial bank branches is too great in the Chinese context are less likely to have their pollution emission behavior influenced by local financial development. The previous literature reveals that the positive association between financial development and environmental pollution (Adeel-Farooq et al., 2022) [14] is likely attributable to the use of macroaggregate indicators and the exclusion of the "geographic factor."

## Endogeneity Analysis

It is possible that commercial bank expansion and firms' pollution emissions are not exogenous, which means that the results of our baseline model may be influenced by endogeneity. For example, heavily polluting firms have higher investment levels, which may attract more commercial banks to set up near firms. In this subsection, we address the endogeneity issue using various methods, including the propensity score matching method (PSM), Difference-in-Differences method (DID), and instrumental variable method (IV).

### *Endogeneity Test- PSM Method*

Firms in areas of high and low commercial bank expansion may have different firm characteristics, thus confounding the estimation results in this paper. Although many firm characteristic variables have been included in our baseline regression model, there is still potential for bias in the estimation results. The PSM approach can relax the assumption of a functional form of the variable relationship by forming treatment and control groups similar to observable variables. Considering the possible problem of sample self-selection bias, drawing on L. Yu et al. (2022) [52], a PSM method is used in this paper to address this.

Column (1) of Table 3 presents the regression estimation results using the sample after performing 1:1 nearest neighbor matching. For robustness reasons, the core explanatory variable of the paper, *Br_5 km*, remains significantly negative at the 1% level, verifying the robustness of the paper's conclusion that the expansion of commercial bank branches reduces the level of firms' pollution emissions.

### *Endogeneity Test - DID Method*

For firms, the deregulation of bank branch establishment policy is an exogenous shock. Referring to Chen et al. (2023) [5], this paper adopts a DID model to examine the impact of commercial bank expansion on firms' pollution emissions again, using the "Opinions on the Adjustment of Market Access Policies for Small and Medium-sized Commercial Banks' Branches (for Trial Implementation)" (Policy No. 143) issued by the General Office of the former China Banking Regulatory Commission in April 2009 as a policy shock. In this paper, the DID model is set as follows:

$$\begin{aligned} SO2_{jkit} &= \phi_0 + \phi_1 Br_5km_{jkit} \\ &+ \phi_2 Br_5km_{jkit} * T_{jkit} * P_{jkit} \\ &+ \phi_3 T_{jkit} * P_{jkit} + \phi_4 \sum CV + \{FE\} + \varepsilon_{jkit} \end{aligned} \tag{5}$$

In Equation (5), $T_{jkit}$ is a dummy variable for the treatment group, and $T_{jkit}$ is assigned to 1 if no city commercial bank existed in city *K* before 2009 and 0 otherwise. $P_{jkit}$ is a policy shock variable assigned to 1 after 2009 and 0 otherwise. Other variables are set in line with Equation (1). The estimated values of the parameters reflect the impact of commercial bank expansion on firms' pollution emissions under the deregulated bank branch market access policy. Column (2) of Table 3 presents the regression results of the test using the DID methodology. The results of the DID model show that in the case of constructing a quasi-natural experiment using *Policy No. 143*, commercial bank expansion is indeed an important driver of the reduction in corporate pollution emissions.

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Table 3. Endogeneity tests: PSM, DID and IV methods.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | PSM | DID | IV1 | | IV2 | |
| | $SO_2$ | $SO_2$ | *Br_5km* | $SO_2$ | *Br_5km* | $SO_2$ |
| *Br_5km* | -0.121*** | -0.075*** | | -0.105*** | | -0.166*** |
| | (0.026) | (0.008) | | (0.005) | | (0.012) |
| *Br_5km*T*P* | | -0.114*** | | | | |
| | | (0.037) | | | | |
| *IV_1* | | | 0.077*** | | | |
| | | | (0.000) | | | |
| *IV_2* | | | | | 0.0964*** | |
| | | | | | (0.0004) | |
| *F-values* | | | 601.488 | | 272.828 | |
| *KP rk-LM* | | | | 88.24 | | 88.25 |
| | | | | [0.000] | | [0.00] |
| *KP rk-Wald F* | | | | 64.87 | | 64.87 |
| | | | | {16.38} | | {16.38} |
| | | | | 88.24 | | |
| CVs | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry | Yes | Yes | Yes | Yes | Yes | Yes |
| City | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs | 333282 | 406365 | 406365 | 406365 | 406365 | 406365 |
| $R^2$ | 0.506 | 0.375 | 0.126 | 0.053 | 0.081 | 0.025 |

Note: *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively. County-level clustered standard errors are in parentheses. Values in ( ) are robust standard errors, values in [ ] are p-values, and values in { } are critical values for the Stock-Yogo weak identification test at the 10% level.

*Endogeneity Test -IV Approach*

Taking into account the potential endogeneity problems resulting from reverse causality, we use a two-stage least squares (2SLS) instrumental variables approach to re-estimate the impact of commercial bank expansion on firms' pollution emissions.

The first instrumental variable (*IV_1*) used in this paper is constructed using geographical information and the number of regional commercial bank branches, specifically using the product of the geographical slope of the city where the firm is located and the number of commercial bank branches as an instrumental variable for commercial bank expansion. The reasons for using this instrumental variable are as follows: (1) The number of commercial banks around the firm is related to the number of commercial banks in the region, and the average slope of the area where the firm is located affects the location of commercial bank branches, satisfying the relevance of the instrumental variable. (2) Geographical slope is an exogenous geographical variable that can hardly directly affect the pollution emission level of firms, satisfying the exogeneity of the instrumental variable.

The second instrumental variable (*IV_2*) was constructed using historical information and Policy No. 143, using the product of the number of urban commercial bank branches in 1984 and the dummy variable for the year in which Policy No. 143 was implemented as the instrumental variable for commercial bank expansion. The reasons for using this instrumental variable are as follows: (1) As the number of urban bank branches in 1984 reflects the degree of financial development in different regions, China's economy was a planned economy at that time, so *IV_2* satisfies the exogeneity of the instrumental variable; (2) The implementation of Policy 143 in 2009 resulted in a significant increase in the number of bank branches. Therefore, *IV_1* positively

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correlates with the number of bank branches within a certain area around the company, satisfying the correlation of the instrumental variable.

The outcomes of the first-stage regressions are presented in columns (3) and (5) of Table 3. Both instrumental variables positively correlate with commercial bank expansion, and both F-values are significantly greater than 10. In columns (4) and (6) of the outcomes of the second-stage regression model, the KP rk LM test and the KP Wald F test rejected the null hypothesis that the instrumental variables are weak and underidentified, indicating a substantial correlation between the instrumental and explanatory variables. After accounting for endogeneity, the regression coefficients for *Br_5 km* are all statistically negative at the 1% level, indicating that the inhibitory effect of commercial bank expansion on firms' pollution emissions remains.

## Robustness Test

The baseline regression results suggest that commercial bank expansion reduces firms' pollution emissions. However, the robustness of the outcomes needs much further verification. To this end, the following procedures are used to conduct robustness testing.

(1) Change the measure of the explanatory variable. We replace the explanatory variables with the logarithm of soot emissions (*Dust*).

(2) Adding control variables. Greater industry competition (*HHI*) means a greater degree of monopoly in the industry, which is not conducive to market-generating technological advances and thus impacts environmental pollution (Jiang et al., 2014) [55]. In addition, a higher level of economic development (*GDP_p*) in a city tends to be more conducive to promoting the growth of green productivity in the region (Y. Wang et al., 2019) [56]. This paper, therefore, regresses the *HHI* and *GDP_p* into the baseline regression model.

(3) Regression using a sample of firms located near provincial boundaries (Lu et al., 2019) [57]. As topographical features may bring more convenient access, land prices and rental costs, they can provide a better business environment for firms to improve their performance and attract banks to set up new branches. As a result, our results may be biased by omitted variables. To alleviate this concern, this paper reuses the sample of firms located near provincial boundaries for the regressions.

(4) Excluding interference from other policies. The majority of environmental regulations in China are implemented at the provincial or municipal level; for instance, regulations controlling sulfur dioxide pollution since 1998 have been implemented at the prefectural level, as has the 2007 policy of increasing fines for pollutant emissions at the provincial level. Therefore, we control for the influence of these policies by controlling for the product of provincial fixed effects and year fixed effects and the product of prefecture-level city fixed effects and year fixed effects (L. Yu et al., 2022) [52]. In addition, in 2005, the Chinese State Council released the Decision on Implementing the Scientific Outlook on Development and Strengthening Environmental Protection, highlighting the strategic goal of protecting the environment. This policy may affect this paper's estimation of the relations between commercial bank expansion and firms' pollution emissions. Therefore, the regression equation includes the interaction term of the dummy variable P2005 with *Br_5km*.

(5) Consider the effects of the financial crisis. The 2008 financial crisis precipitated a global economic recession. Could the massive shock brought on by the financial crisis mitigate the effect of the expansion of commercial bank branches on firms' environmental emissions? To accomplish this, this paper defines a financial crisis dummy variable (*Crisis*) as having a value of 1 for the period 2008-2009 and a value of 0 otherwise and then incorporates the interaction term of *Crisis* with *Br_5km* into the regression equation.

The results of the robustness tests are shown in Table 4. The *Br_5km* coefficients are all significantly negative, showing the robustness of the regression results of the baseline model presented in this study. Notably, in column (3) of Table 4, the regression findings for the sample of firms close to the provincial border are displayed. The coefficient on *Br_5km* is still significantly negative, indicating that commercial bank expansion still discourages firms from polluting when the provincial border's geographical advantage is considered. Second, column (5) of Table 4 reports the estimated coefficients of *P2005*Br_5km*, which shows that the coefficient of the interaction term is still significantly negative at the 1% level, suggesting that the effect of the environmental regulation policy implemented in 2005 is significant and reduces the firms' polluting emissions, and the coefficient, *Br_5km*, is still significantly negative at the 1% level, which suggests that the expansion of the commercial bank's branches still reduces the firms' polluting emissions. In addition, the *Crisis*Br_5km* coefficient in column (7) is significantly positive, while the *Br_5km* coefficient remains negative. This indicates that the influence of the financial crisis significantly weakened the dampening effect of commercial bank expansion on firms' pollution emissions. The financial crisis brought a massive shock to the financial market, causing firms to face the risk of financial chain breakage, reducing their R&D expenditure on clean energy technologies and weakening the inhibiting effect of commercial bank expansion on firms' pollution emissions.

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Table 4. Robustness test.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | *Dust* | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ |
| *Br_5km* | -0.062*** | -0.115*** | -0.070** | -0.115*** | -0.116*** | -0.167*** | -0.188*** |
| | (0.003) | (0.010) | (0.031) | (0.010) | (0.010) | (0.005) | (0.006) |
| *HHI* | | 0.006*** | | | | | |
| | | (0.002) | | | | | |
| *GDP_p* | | -0.009* | | | | | |
| | | (0.005) | | | | | |
| *P2005*Br_5km* | | | | | | -0.141*** | |
| | | | | | | (0.016) | |
| *Crisis*Br_5km* | | | | | | | 0.046*** |
| | | | | | | | (0.009) |
| CVs | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| City | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Province*Year | No | No | No | Yes | No | No | No |
| City*Year | No | No | No | No | Yes | No | No |
| Obs | 310301 | 406365 | 14551 | 406365 | 406365 | 406365 | 406365 |
| $R^2$ | 0.393 | 0.444 | 0.497 | 0.440 | 0.451 | 0.224 | 0.224 |

Note: Column (1) shows the regression results with the explanatory variables replaced; Column (3) shows the regression results considering the omitted variable problem; Column (3) shows the regression results using the sample of firms near the provincial boundaries; Columns (3) and (4) show the regression results controlling for the province-with-year interaction fixed effects, and the prefectural city-with-year fixed effects, respectively; Column (5) is the regression results incorporating the policy dummy variable for the year 2005 with *Br_5km*; and Column (6) is the regression results incorporating the financial crisis with the interaction term with *Br_5km*.

## Heterogeneity Analysis at Regional, Industry and Firm Levels

The low-carbon city pilot policy and the degree of legal sophistication of the cities in which firms are located may lead to heterogeneous effects of commercial bank expansion on firms' pollution emissions. In addition, the characteristics of the industry in which the firm is located, such as the level of pollution and capital intensity of the industry and the ownership and size of the firm, may also lead to heterogeneity in the impact of commercial bank expansion on the pollution emissions of the firm.

Regarding regional heterogeneity, pilot cities with low-carbon city policies tend to have a higher degree of financial marketisation and usually have a cleaner industrial structure, which may weaken the dampening effect of commercial bank expansion on firms' pollution emissions. Firms located in areas with better legal environments are more likely to have greater lending capacity (Lee et al., 2021) [58], leading to the timely execution of loan contracts and a greater willingness on the part of banks to make lending decisions. This implies that commercial bank expansion is more likely to enable firms to obtain more external financing for technological improvements and to expand investment in pollution abatement, thereby reducing pollution emissions. Regarding sectoral heterogeneity, high-pollution industries have higher costs of pollution emissions and greater demand for environmental financing, so commercial bank expansion has a more significant impact on the pollution emissions of firms in high-pollution industries. Firms in high-capital-intensive industries usually invest in innovative projects at a high technological level (Sahaym et al., 2010) [59]. They are more motivated to undertake research and development for green projects, while low-capital-intensive industries rely more on the resources and labor required by the firm and have fewer research and development activities, so the impact of commercial bank expansion

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Table 5. Heterogeneity analysis at regional, industry and firm levels.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ | $SO_2$ |
| *Br_5km* | -0.129*** | -0.060*** | -0.089*** | -0.041*** | -0.122*** | -0.150*** |
| | (0.005) | (0.008) | (0.009) | (0.008) | (0.005) | (0.005) |
| *Br_5km*LC* | 0.128*** | | | | | |
| | (0.007) | | | | | |
| *Br_5km*Law* | | -0.009*** | | | | |
| | | (0.001) | | | | |
| *Br_5km*Ind_P* | | | -0.019*** | | | |
| | | | (0.005) | | | |
| *Br_5km*Ind_C* | | | | -0.156*** | | |
| | | | | (0.007) | | |
| *Br_5km*Scale* | | | | | 0.010** | |
| | | | | | (0.005) | |
| *Br_5km*SOE* | | | | | | 0.051*** |
| | | | | | | (0.005) |
| CVs | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry | Yes | Yes | Yes | Yes | Yes | Yes |
| City | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs | 406365 | 406365 | 406365 | 406365 | 406365 | 406365 |
| $R^2$ | 0.393 | 0.393 | 0.367 | 0.401 | 0.392 | 0.364 |

Note: *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively. County-level clustered standard errors are in parentheses. Subsequent tables are the same as this table.

on pollution emissions may be more significant for firms in high-capital-intensive industries. In terms of firm heterogeneity, commercial bank expansion may significantly impact the pollution emissions of small and medium-sized enterprises (SMEs), which have fewer fixed assets to pledge and are, therefore, more constrained by external financing. Similarly, state-owned enterprises (SOEs) are more likely to be biased by state-owned banks than nonstate-owned enterprises (non-SOEs) (Zhang et al., 2019) [60]. The pollution abatement effect of commercial bank expansion may be more pronounced among SOEs, as it increases the likelihood of firms accessing external finance and thus may significantly impact non-SOEs.

The findings of the heterogeneity test are presented in Table 5, columns (1) and (2), which display the results of the test at the regional level. We construct a dummy variable *LC*, which takes the value of 1 if the firm is located in a region identified by the low-carbon city pilot policy and 0 otherwise. Column (1) shows that commercial bank expansion has less impact on firms' pollution emissions in low-carbon pilot cities. *Law* is a subcomponent of the marketisation index constructed by Fan (2011) [61], an index of the development of market intermediaries and the legal environment. The greater the index, the more favorable the legal climate in the province where the firm is located. The outcomes in column (2) imply that the better the regional law, the higher the pollution abatement effect of commercial bank expansion.

The results of the industry-level heterogeneity analysis are displayed in columns 3 and 4. The dummy variable *Ind_P* is built based on the pollution attributes of the industry and is assigned the value 1 if the industry in which the firm operates is a highly polluting industry and the value 0 otherwise. In addition, a dummy variable *Ind_C* is created based on the industry's capital intensity, with a value of 1 if the industry in which the firm operates has a greater capital intensity than the industry average and 0 otherwise. The results in columns (3) and (4) suggest that for commercial banks, the pollution abatement effect of branch expansion is

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Table 6. Mechanism testing.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Technological progress | | | | | | Pollution abatement investment | | |
| | *Pat* | | *New* | | $SO_2$ | $SO_2$ | *RW* | *RS* | *RS_r* |
| | Low | High | Low | High | | | | | |
| *Br_5km* | 0.007 | 0.013*** | 0.080*** | 0.140*** | -0.179*** | -0.197*** | 0.010** | 0.022*** | 0.003** |
| | (0.010) | (0.005) | (0.009) | (0.020) | (0.005) | (0.006) | (0.005) | (0.006) | (0.001) |
| *Pat* | | | | | -0.300*** | | | | |
| | | | | | (0.018) | | | | |
| *New* | | | | | | -0.050*** | | | |
| | | | | | | (0.002) | | | |
| CVs | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Ind | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| City | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs | 192322 | 214043 | 153391 | 171044 | 406365 | 324435 | 227137 | 200062 | 203134 |
| Empirical *p*-value | 0.003*** | | 0.009*** | | - | | - | | |
| $R^2$ | 0.269 | 0.348 | 0.187 | 0.246 | 0.225 | 0.243 | 0.317 | 0.319 | 0.235 |

particularly significant in industries that are highly polluting and capital intensive.

The results of the heterogeneity test at the firm level can be seen in columns (5) and (6). The variable *Scale* is a binary variable that defines a firm as large when its size is greater than the average and takes the value of 1. In contrast, a firm smaller than the average is a small or medium-sized enterprise (SME) and takes a value of 0. In addition, *SOE* is a dummy variable representing state-owned enterprises (SOE), with a value of 1 if the enterprise is an SOE and 0 otherwise. As expected earlier, the interaction term coefficients in columns (5) and (6) suggest that the pollution abatement effect of commercial bank expansion is more significant for SMEs and non-SOEs.

## Mechanism Tests

The previous theoretical mechanism suggests that commercial bank expansion will promote technological progress and increase investment in pollution abatement, thereby reducing pollutant emissions. It is well documented that new product output and patent applications reflect firms' innovation outcomes (Liu and Buck, 2007) [49] and that improvements in the financing environment reduce firms' toxic emissions through the asset portfolio channel (Ren et al., 2022) [43]. Therefore, in this paper, we will test Eqs. (2), (3), and Equation (4) verify the technological progress channel and the pollution abatement investment channel. In addition, we ranked the degree of commercial bank expansion from low to high. Then we divided them into a low *Br_5km* group and a high *Br_5km* group to further test the existence of a technological progress channel.

Table 6 reports the results of the tests of the technological progress channel. Columns (1)-(4) show the effect of branch expansion on technological progress for the high and low groups of commercial banks, respectively. Bootstrap tests the significance of the differences between groups, and the p–values indicate that the groups are statistically significantly different. The results in columns (1)-(4) show that the coefficient on *Br_5km* is more significant at higher commercial bank expansion levels. This may be because technological innovation is a long-term process that is difficult to translate into commercial results quickly in the short term, involves certain risks, and requires stable financial support. Therefore, commercial bank expansion enhances the possibility of obtaining external financing for firms, increases their confidence in conducting technological R&D, stimulates them to expand their capital investment in technological R&D activities, and thus promotes technological progress. Columns (5) and (6) show that technological progress can reduce firms' pollution emissions when commercial bank expansion is controlled. This means that through technological innovation, firms will drive the use of green process technologies and promote green production. The regression results in columns (1)-(6) of Table 6 together show that the mechanism of technological progress is

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the primary channel through which commercial bank expansion suppresses firms' pollution emissions.

Columns (7)-(9) of Table 6 report the test results of the pollution abatement investment channel test. The coefficient of *Br_5km* in Column (7) is significantly positive, indicating that expanding commercial bank branches will increase firms' fixed investment in pollution abatement. The coefficient of *Br_5km* in Column (8) is significantly positive at 1% level, which indicates that the expansion of commercial bank branches will increase the variable cost of firms for pollution abatement. In addition, the coefficients of *Br_5km* in Column (8) are all significantly positive, and the results indicate that commercial bank expansion significantly increases the average efficiency of firms for pollution abatement. Overall, the results based on columns (7)-(9) of Table 6 show that commercial bank expansion increases firms' fixed and variable investment for pollution abatement, improves the efficiency of enterprises for abatement, and verifies the existence of pollution abatement investment channels.

## Discussion

A large body of literature has explored the factors influencing pollution emissions, but not enough attention has been given to commercial bank expansion. In this paper, we explore the intrinsic link between commercial bank expansion and firm emissions and analyze the underlying micro-level mechanisms in detail. In addition, we also conducted a heterogeneity analysis from the macro, meso and microscopic levels.

First, this paper contributes to the current debate on the relationship between financial development and environmental pollution, which has not been empirically unified, with studies identifying positive (Adeel-Farooq et al., 2022) [14], negative (Khan et al., 2020) [13] and no correlation (Bekhet et al., 2017) [29]. The findings of this paper suggest that commercial bank expansion significantly reduces firms' pollution emissions. A similar view is supported by the study of Chen et al. (2023) [5]. However, Shen et al. (2021) [62] contradict this paper by arguing that the functions of the financial sector can either straightforwardly finance environmentally friendly production procedures or finance pollution industries, which can lead to significant pollutant emissions. In addition, this paper innovatively finds that there is an optimal geographical radius for the disincentive effect of commercial bank expansion on firms' pollution emissions. In practical terms in China, the average area of a prefecture-level administrative unit is 27,000 square kilometers, which equates to a circle with an average radius of 92.7 kilometers, and there is a "threshold radius" for firms to access external finance, suggesting that firms may be too distant from banks in the same area to be influenced by them. Furthermore, the relative independence of China's regional financial systems makes it difficult for firms to obtain external financing from other cities. The contrary results of the previous literature may be due to measurement error issues arising from the use of macro aggregates, the omission of "geographical factors", and the neglect of the independence of financial systems in different regions.

Second, some literature has explored the impact of financial development on environmental pollution, but a micro-level analysis of the mechanisms is lacking. Technological innovation would influence environmental pollution, but they do not use data to test this empirically. In addition, Ren et al. (2022) [43] find that a firm's pollution abatement investment behaviur would reduce pollutant emissions. The paper builds on this to explore potential transmission mechanisms. This exploration extends the environmental consequences of banking sector development and provides a more valuable reference for the relationship between financial development and the environment. The results of the mechanism test suggest that commercial bank expansion will promote the technological progress of firms, prompting them to invest more in pollution reduction and ultimately reduce pollutant emissions. The results of this study support the view of Yu et al. (2022) [52]. The main reason for this finding is that commercial bank expansion increases firms' likelihood of accessing external financing, increasing their investment in technological upgrading and thereby reducing pollutant emissions. In addition, using high-tech and efficient equipment can increase productivity, and firms will invest more in pollution abatement to maximize profits, thus achieving productivity gains. Commercial bank expansion will help firms expand their investment in pollution abatement and ultimately reduce pollution emissions.

## Conclusions

### Research Findings

This paper adopts the web crawler method to obtain the distribution information of Chinese commercial bank institutions, combines the multidimensional fixed-effects model to deeply explore the effect and transmission mechanism of commercial bank expansion on firm pollution emission, and employs the IV method as well as DID method and other methods to demonstrate the robustness of the conclusions. This study provides theoretical guidance and empirical references for developing economies to deepen banking reforms and establish sustainable development systems to protect the environment. The main findings are summarized as follows.

(1) Commercial bank expansion reduces the firm's pollution emission, and there is an optimal "geographical radius" for this inhibiting effect. Specifically, the increase in the number of commercial bank branches within 20 km of the enterprise has the largest inhibitory

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effect on the enterprise's pollution emission and then decreases with the expansion of the geographical radius.

(2) The results of the transmission mechanism test show that the channel of technological progress and pollution abatement investment are important transmission mechanisms for commercial bank expansion to inhibit firm pollution emissions. Specifically, commercial bank expansion promotes the technological progress of firms, incentivizes firms to increase investment in pollution emission, promotes the use of green technologies and facilities by firms, and then reduces firm's pollution emissions.

(3) Heterogeneity analyses show that the pollution reduction effect of commercial bank expansion is more obvious in regions with perfect legal systems, high-pollution and high-capital-intensive industries, as well as in small and medium-sized enterprises and non-state-owned enterprises, while the pollution reduction effect of commercial bank expansion is smaller in low-carbon pilot cities.

## Practical Insights

On the basis of the above findings, policy implications are presented for optimizing the supply of financial resources and reducing environmental pollution.

First, developing countries should optimize the spatial distribution structure of banks, expand the coverage of the banking system, realize the multilayering of the banking system, ensure the reasonable distribution of credit resources, and alleviate the problem of uneven distribution of credit resources. The baseline results show that commercial bank expansion is conducive to reducing the level of firm pollution emissions, and the increase in the number of banks within 20 km of the enterprise's periphery has the largest inhibitory effect on firm pollution emissions. Therefore, when developing countries promote the marketisation of the banking industry, they need to pay attention to whether the distribution of commercial bank branches is reasonable in the spatial dimension and reduce the phenomenon of over-expansion and over-intensity so as to give greater play to the role of commercial banking institutions in improving the environmental protection and firm environmental performance.

Second, improve the banking system's ability to serve the real economy, encourage firms to invest in environmentally friendly projects, apply more green technologies and stimulate them to expand their investment in pollution reduction. The findings of the mechanism test demonstrate that commercial bank expansion will promote the technological progress of firms, stimulate them to invest more in pollution and emission reduction, and reduce their pollution emission levels. Therefore, when promoting structural reform on the supply side of finance, importance should be attached to the rational allocation of financial resources, providing credit support at a lower cost to firms that invest in environmentally sustainable projects and green technologies, urging them to expand their investment in pollution and emission reduction, making full use of the positive influence of the banking system on environmental protection, and avoiding the problem of imbalance in the distribution structure of credit resources.

Third, developing countries should rationally adjust the spatial distribution of banking institutions according to the characteristics of different regions, different industries and different enterprises so as to promote the efficient allocation of credit resources. The results of the heterogeneity test show that the expansion of bank branches has a greater impact on firm pollution emissions in regions with highly developed laws. Therefore, in order to give full play to the banking system to maximize the mitigation effect on environmental pollution, the regional legal system should be improved and optimized. In addition, the expansion of bank branches has a greater impact on pollution-intensive and capital-intensive industries, suggesting that attention should be paid to the supply of credit to pollution-intensive and capital-intensive industries as well as the allocation of credit and optimizing the access to credit for pollution-intensive and capital-intensive industries. Regarding enterprise size and ownership, the spatial allocation of bank credit resources should be more supportive of small and medium-sized enterprises and non-state-owned enterprises to realize greater environmental pollution mitigation effects.

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## Conflict of Interest

The authors declare no conflict of interest.

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