Cutting swaths in a jungle: The pressure of air pollution on firm entry

Abstract: Faced with the ongoing challenge of air pollution and the arduous task of reform and development of environmental protection, coordination of conservation and economic development is critical for sustainable practices world over. In this paper, we construct a theoretical model to deduce the impact mechanism of air pollution on firm entry and use regression discontinuity design (RDD) to conduct empirical analysis based on multiple sets of data at the individual, company, and regional levels in China. The estimation results indicate that air pollution inhibits firm entry, and the inhibitory effect is more obvious in areas with relatively low economic development levels, high public and government environmental concerns, and high expenditures on environmental protection. We examine the underlying channels and find that air pollution deters firm entry by affecting health depreciation, multidimensional labor supply, and firm risk. This study provides a theoretical basis and empirical support for China and other developing countries on how to pave the way toward green development through environmental governance and business startups.

Keywords: Air pollution; Firm entry; Regression discontinuity design (RDD); Environmental regulation

1. Introduction

Firm entry is essentially a problem regarding location selection, which can reflect the evolution trend of the spatial economic landscape (Seim, 2006). Firm entry is diffusely regarded as the core propulsive thrust of economic development and has become the key for countries to gain competitive advantage (Gourio et al., 2016). Specifically, new firms usually have new technologies, processes and products and higher productivity and stronger innovation capabilities (Hopenhayn, 1992). In accordance with the "creative destruction" theory, new firm entry will intensify competition among firms, leading to the gradual reduction, withdrawal or emigration of inefficient firms and ultimately optimizing the industrial structure and improving firm aging distribution, thereby injecting new vitality into the economy (Chen et al., 2020). In addition, firm entry will bring more trading opportunities to their upstream and downstream enterprises, helping to create a more resilient industrial chain and value chain (Blalock and Veloso, 2007). In summary, the positive effects of new firm entry have been universally recognized by scholars worldwide. Scholars attribute firm entry using factors such as infrastructure, human capital, and financing environment (Cetorelli and Strahan, 2006; Hjort and Poulsen, 2019). However, little research has focused on the impact of external environmental factors, including air pollution, on firm entry.

In fact, air pollution has become a high-profile environmental problem worldwide, and its negative effects now impact ecology, health and the economy. According to the World Health Organization (2022), the air that 99% of the world's population breathes is below the safety standard[1]. Low- and middle-income countries whose economies overly rely on fossil fuels suffer the most from air pollution. From "China's Ecological Environment Status Report", excluding the impact of sandstorms, 43.1% of cities at the prefectural level and above in China had poor air quality that was below the standard in 2021. According to the estimation of Yue et al. (2020), air pollution causes nearly one million deaths every year in China. In addition to health threats, air pollution has also resulted in enormous economic costs, including the outflow of high-quality talent (Chen et al., 2022), a significant decrease in labor productivity (Chang et al., 2019), increased uncertainty and potential risks for business operations (Chen et al., 2017), and surging rent-seeking opportunities (Candau and Dienesch, 2017). All of these costs directly or indirectly affect firm entry. Accordingly, the specific and core question we focus on is what impact air pollution will have on firm entry into a

[1] According to the "Global Air Quality Guidelines (2021)" (AQG 2021), 24-hour air quality guideline level (AQG level) of $PM_{2.5}$, PM_{10}, NO_2, SO_2, and CO_2 are 15 μg/m³, 45 μg/m³, 25 μg/m³, 40 μg/m³ and 4 mg/m³, respectively.

region.

In this study, we construct a theoretical model to clarify the mechanism of air pollution affecting firm entry and develop research hypotheses by analyzing the model. Second, using data at the county level in China, the firm entry effect of air pollution is empirically tested. We find that air pollution reduces newly registered firms, which is consistent with the implications of the theoretical model. After a series of robustness tests (e.g., instrumental variable test, bandwidth sensitivity test, placebo test, replacement of city-level data, replacement of air pollution indicators, nonparametric estimation, and fixed-effect model estimation), the basic conclusions do not change. Third, using multiple sets of data at the individual, firm, and regional levels, an empirical analysis is conducted for the mechanism of air pollution's impact on firm entry. The results indicate that air pollution inhibits firm entry by threatening the physical and physiological health of residents, impairing the quantity, quality and productivity of the labor force, and increasing firm risks. Fourth, there is remarkable heterogeneity in the impact of air pollution on firm entry. Specifically, for areas where the public and the government pay more attention to environmental quality, the cost of environmental protection is higher. Moreover, when the level of economic development is not high, the negative effect of air pollution on firm entry is greater.

The main contribution of this study is threefold. First, it is among the first to investigate the effect of air pollution on firm entry in a region using county-level data in China. Although many studies have tried to answer the key questions regarding the relationship between growth and the environment (Beckerman, 1992; Ziegler, 2021), few have taken firm entry as the breakthrough point. From the perspective of firm entry, it expands economists' cognition of the negative externalities and economic costs of air pollution and enriches research on climate economics. In addition, China's special institutional background enriches the research results and provides fresh ideas for government governance. Under China's political system, which places high priority on economic performance for the evaluation and promotion of officials, local government officials historically and routinely have an incentive to sacrifice the environment for economic development (Li and Zhou, 2005). Distorted outlooks on political achievements will inevitably lead to uncoordinated, unsynchronized and unbalanced economic development and environmental construction in some regions. However, this study provides evidence that strengthening environmental regulations is not at the cost of slower economic growth, and economic development and environmental protection could move forward hand in hand. Such results have important reference value for changing the mode of local environmental governance in China as well as in countries facing similar dilemmas of fostering economic growth and protecting the environment.

Second, this study is the first to use a causal inference framework to estimate the impact of air pollution on firm entry. In the study, the biggest challenge is the potential endogeneity issue between air pollution and regional firm entry, which may be caused by reverse causality and omitted variables. In this regard, using the quasinatural experiment of central heating north of the Qinling-Huai River boundary line (QHBL) in China, we have a rare opportunity to examine causal identification. Within the relatively close range on both sides of the QHBL, variables such as climate conditions, economic development levels, and population characteristics of counties will not change significantly. The only significant difference is whether the two sides of the QHBL are subject to central heating in winter, and coal-fired heating will lead to a differention in the air quality between the north and south of the boundary (Chen et al., 2013). Accordingly, we aggregated the data of 1.32 million newly registered firms in accordance with the industrial classification in 2991 counties in China and matched them with the $PM_{2.5}$ of each county. Afterward, the RDD method is employed to identify causality.

Third, the complexity and diversity of the influence mechanism in the Chinese context are emphasized. The literature rarely involves the underlying mechanism of air pollution affecting firm entry. Through theoretical modeling and empirical findings, we conduct a more detailed and in-depth examination of the influential mechanism from the three dimensions of health depreciation, multidimensional labor supply and firm risk. This theoretical and empirical evidence fills the research gap in the literature and enriches the understanding of the internal macro and micro mechanisms of the negative effects of air pollution on firm entry.

The remaining chapters of this article are arranged as follows: Section 2 reviews the relevant literature; Section 3 introduces the institutional background, establishes the theoretical model and proposes research hypotheses; Section 4 is the empirical design; Section 5 shows the empirical results and discussion; Section 6 is heterogeneity analysis; Section 7 displays the mechanism analysis and discussion; and Section 8 is the conclusion and policy recommendations.

2. Literature review

2.1 Multidimensional consequences of air pollution

Air pollution causes multidimensional consequences for individuals, firms and the economy, which have been widely investigated by scholars. One strand of literature studies the microscopic influence of air pollution on manpower capital. First, air pollution seriously damages the physical health of individuals, including increasing the prevalence of cardiovascular disease, stroke, lung cancer, and respiratory diseases (Landrigan, 2017; Al-Kindi et al., 2020); increasing the incidence of obesity (Deschenes et al., 2020); disrupting slumber quality (Heyes and Zhu, 2019); increasing infant and adult mortality (Currie et al., 2009; Yue et al., 2020); and reducing mean longevity (Ebenstein et al., 2017). Second, poor air quality also impairs individuals' physical health. Specifically, air pollution increases neuroinflammation and central nervous system disease prevalence (Block and Calderón-Garcidueñas, 2009), aggravates depression and anxiety symptoms in the elderly (Pun et al., 2017), impairs people's cognitive abilities (Zivin and Neidell, 2012), and multiplies the risk of suicide (Kim et al., 2010). Third, air quality affects productivity in specific occupations, including call center workers (Chang et al., 2019), footballers (Lichter et al., 2017), farm workers (Chang et al., 2016), and stock analysts (Li et al., 2020). In addition, air pollution also affects individuals' residential choices and immigration tendencies (Chen, et al., 2022; Pan, 2023), risk-taking (Klingen, 2022), happiness (Zheng et al., 2019), road safety (Sager, 2019) and student academic performance (Diette et al., 2000; Stafford, 2015).

The second strand of literature is about the microscopic effects of air pollution on firms. In the production link, air pollution promotes the outflow of high-quality executives and employees (Xue et al., 2021), reduces labor working hours (Hanna and Oliva, 2015), improves labor treatment (Wang et al., 2021), and reduces corporate productivity (Fu et al., 2021). In the circulation link, air pollution reduces visibility and increases transportation uncertainty, resulting in a lower inventory turnover rate and increased sales costs (Folmer and Howe, 1991). In the financing link, the depression and pessimism caused by air pollution lower the company's stock profit (Li and Peng, 2016). In general, the final market competitiveness of air pollution is weakened (Zhu and Xu, 2022). In general, air pollution will weaken the market competitiveness of firms (Zhu and Xu, 2022).

The third strand of literature investigated the macroeconomic effect of air pollution on the economy and society. First, poor air quality hinders economic development. Lanzi et al. (2018) contend that by 2060, the world economic cost of atmospheric pollution inaction will increase to 1% of GDP. Pandey et al. (2021) pointed out that in 2019, India's economic losses due to air pollution reached $36 billion. Second, air pollution has political costs. Yao et al. (2022) found that controlling PM2.5 emissions will increase the trust and satisfaction of Chinese citizens in local governments. Candau and Dienesch (2017) found that "pollution haven" has a certain connection with "corruption paradise". Furthermore, air pollution threatens global food security (Tai et al., 2014) and energy security (He, et al., 2020).

2.2 Influencing factors of firm entry

For the influencers of firm entry, prior studies have conducted extensive studies from the macro perspectives of economy, politics, and society and the micro perspective of entrepreneurial characteristics. Undoubtedly, the economy is the most critical factor affecting firm entry (Schultz, 1962). Related research has examined the entrepreneurial effects of economic factors such as fiscal subsidies and tax policies (Da et al., 2011; Pflüger and Südekum, 2013; Braunerhjelm and Eklund, 2014), financial market frictions (Ates and Saffie, 2021; Smirnyagin, 2022), industrial relatedness (Freedman and Kosová, 2012; Corradini and Vanino, 2022), labor costs (Belderbos et al., 2020), unemployment (Santarselli et al., 2009; Nikiforou et al., 2019) and energy prices (Patra, 2020).

Additionally, social factors are also important considerations for firm entry. Bettin et al. (2019) and Azoulay et al. (2022) applied datasets from Italy and the United States, respectively, to prove that immigrants are “job creators” rather than “job competitors”. Hopenhayn (2022) and Hopenhayn (2022) established a general equilibrium enterprise dynamic model and found that population growth increases the entrepreneurial rate and promotes younger firm distribution. Baptista et al. (2011) and Tsvetkova and Partridge (2021) pointed out that tertiary institutions promote enterprises entering into knowledge- and technology-intensive industries. Moreover, political factors, including political uncertainty and costly regulations (Klapper et al., 2006; Estrin and Prevezer, 2010; Bruno, 2013), are important factors that constitute barriers to firm entry. Furthermore, personal characteristics of entrepreneurs, such as cultural background (Erhardt and Haenni, 2022), age (Hammarstedt, 2004), education (Schulz et al., 2016; Hammarstedt, 2004), and managerial skills

(Amaral et al., 2011), are direct factors affecting firm entry.

2.3 Environment and firm entry

Compared with the widely studied internal factors such as economics, politics, society and entrepreneurial traits, the entrepreneurial effect of external factors such as the environment is less studied in theoretical research. With increasingly severe global ecological and environmental problems since the 21st century, the influence of the environment on firm entry has also begun to attract the attention of scholars. Shi and Zhang (2021) used a case study of Chinese manufacturing and found that the negative impact of extreme temperatures spreads to firm production, disrupts operational arrangements, increases operating costs, and thus affects firm dynamics. Dean and Brown (1995) used the data of new enterprises in 306 industries in America and proved that environmental regulations increased the capital requirements, approval difficulties and operating costs of new enterprises, thereby creating a series of barriers to entry. Based on more than 10 years of panel data, Helland and Matsuno (2003) verified that environmental costs increase the entry barriers for new firms in the market; in contrast, firms with the top 1/4 of Tobin's Q value obtained monopoly rents. Subsequently, Dardati (2016) also demonstrated from the perspective of pollution permits that environmental costs dampen the enthusiasm of new firms to enter.

In general, the above related literature lists the influence of temperature and environmental cost on firm entry. However, few studies have investigated the influences of air pollution on firm location decisions. Notably, the existing macrolevel research on firm entry is mainly based on provincial- or city-level statistical data. To this end, we use county-level data and the constructed theoretical model to explain practical issues and to deeply study the economic consequences of air pollution from the perspective of firm entry. In addition, an overall-based analysis cannot ignore underlying intergroup differences, and the effect of air pollution on firm entry may be heterogeneous in regions with different characteristics. We capture the heterogeneous impact of air pollution on firm entry from the perspectives of county economic development, environmental protection costs, and environmental concerns. These findings will help the government design differentiated policy measures and maximize the entrepreneurial driving effect of environmental regulatory policies.

3. Background and theoretical analysis

3.1 Background

Central heating is a heating method that transmits heat energy through heat network pipelines from a centralized heat source and supplies heat energy to the user's room. China’s central heating network is the largest in the world, and its fuel structure is dominated by coal (Ebenstein et al., 2017). Coal heating is cheaper than other heating methods, but when the coal-fired boiler is running, the concentrations of inhalable $PM_{2.5}$, SO2 and NO2 in the flue gas below the boiler increase significantly.

China's central heating policy began in the early 1950s. Considering complex reasons such as history, resource allocation, temperature, and energy availability, China takes the Qinling-Huai River line as the boundary. Central heating is implemented in winter in the areas north of the dividing line; south of the line, there is no central heating (Chen et al., 2017), as shown in Figure 1. The northern Qinling-Huai River line (that is, northern China) has a long winter, and the central heating area and heating duration are long. In 2020, heating energy consumption in northern China was 214 million TCE (tons of standard coal), accounting for 20% of the country's total building energy consumption, while carbon dioxide emissions from heating accounted for 25.2% of the country's total building emissions[2]. Additionally, the proportion of coal used for heating in northern China exceeds 80%[3], and burning coal releases many air pollutants. Moreover, the climate in northern China is dry, and there is little vegetation in winter, which is not conducive to the deposition and fixation of pollutants, exacerbating the air quality problem. In summary, the winter central heating policy in northern China and the natural climate in the north have jointly led to the obvious breakpoint of air pollution at the Qinling-Huai River line, which provides a rare opportunity for this paper to study the firm entry effect of air pollution.

[2] Data source: "China Building Energy Conservation Annual Development Research Report 2022"
[3] Data source: "China Building Energy Conservation Annual Development Research Report 2022"

Figure 1 Qinling-Huai River (central heating) dividing line

3.2 Theoretical analysis

We introduce a theoretical model for analyzing the mechanisms by which air pollution affects firm entry. From an economic perspective, firm entry is tightly related to innovation (Schumpeter and Backhaus, 2003), which is a main driver of economic growth. Firm entry, akin to opening up a new industry, can be regarded as a type of technological progress that is reflected in the expansion of the varieties of products (Dixit and Stiglitz, 1977).

Therefore, we refer to models with an expanding variety of products in economic growth theory to conduct our theoretical analysis. Our model combines the elements of Shi and Zhang (2021), Dixit and Stiglitz (1977), and Acemoglu et al. (2018). There are three types of agents. First, the final goods producer in a perfectly competitive market purchases intermediate input goods and combines them to produce the final product. Second, start-up companies hire laborers to produce intermediate goods, and once an intermediate good is produced, the start-up company gains market power and is able to earn profits. Third, households provide labor with unitary elasticity of supply.

3.2.1 The final goods producer

The final goods Y is a CES composite of a unit continuum of varieties, and Y is also the numeraire of the economy,

$$Y_t = \left(\int_0^1 y_{jt}^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}} \quad \varepsilon > 1 \tag{1}$$

y_{jt} is the purchase of the j^{th} type of specialized intermediate good. ε is the substitution elasticity, which is normally assumed to be larger than one (Chatterjee and Cooper, 2014; Jones and Tonetti, 2020), meaning a substitutable relationship among the existing intermediate goods. Eq. (1) implies that the marginal product of y_{jt} is given by

$$\frac{\partial Y_t}{\partial y_{jt}} = Y^{\frac{1}{\varepsilon}} y_{jt}^{\frac{-1}{\varepsilon}} \tag{2}$$

We normalize the price of final goods to be one. Then, the inverse demand function for y_{jt} is

$$p_{jt} = y_{jt}^{\frac{-1}{\varepsilon}} \tag{3}$$

3.2.2 The start-up company

The production function of each variety j is

$$y_{jt} = \phi_{PM2.5} A_{jt} l_{jt} \tag{4}$$

Labor l_{jt} is assumed to be the only input (Acemoglu et al. 2018; Bilbiie et al. 2012). A_{jt} is labor productivity. $\phi_{PM\,2.5}$ $(0 < \phi_{PM\,2.5} < 1)$ characterizes the negative effect of air pollution on labor productivity, which can be evidenced by many empirical studies (Chang et al., 2019).

Moreover, we assume the labor supply function with unitary elasticity to be

$$l_{jt} = \Psi_{PM2.5} \xi w_{jt} \tag{5}$$

where w_{jt} is the labor wage and ξ is the conversion coefficient between them. $\Psi_{PM\,2.5}$ $(0 < \Psi_{PM\,2.5} < 1)$ is the effect of air pollution on labor supply. According to previous studies (Aragon et al., 2017; Hanna and Oliva, 2015), air pollution has reduced the willingness of households to supply labor due to health concerns, and this effect is captured by parameter $\Psi_{PM\,2.5}$ in our model. Implying that the company needs to pay more to maintain the same amount of labor, or less labor, will be available for the same wage level.

Thus, start-up companies solve the following profit maximization problem:

$$max_{l_{jt},p_{jt}}\pi_{jt} = p_{jt}y_{jt} - w_{jt}l_{jt} \tag{6}$$

Inserting Eq. (3) and Eq. (5) into Eq. (6), profit can be rewritten as

$$\pi_{jt} = y_{jt}^{\frac{-1}{\varepsilon}} * y_{jt} - \frac{1}{\Psi_{PM2.5}\xi} * \left(\frac{y_{jt}}{\phi_{PM2.5}A_{jt}}\right)^2 \tag{7}$$

The company chooses output y_{jt} to maximize the profit; by derivation, the monopoly output y_{jt} and its price p_{jt} are obtained,

$$y_{jt} = \left[\frac{(\varepsilon - 1)\Psi_{PM2.5}\xi}{2\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon+1}} * \left(\phi_{PM2.5}A_{jt}\right)^{\frac{2\varepsilon}{\varepsilon+1}} \tag{8}$$

$$p_{jt} = \left[\frac{(\varepsilon - 1)\Psi_{PM2.5}\xi}{2\varepsilon}\right]^{\frac{-1}{\varepsilon+1}} * \left(\phi_{PM2.5}A_{jt}\right)^{\frac{-2}{\varepsilon+1}} \tag{9}$$

Then, the profit in each period is

$$\pi_{jt} = (\Psi_{PM2.5}\xi)^{\frac{\varepsilon-1}{\varepsilon+1}}(\phi_{PM2.5}A)^{\frac{2(\varepsilon-1)}{\varepsilon+1}}\left[\left(\frac{\varepsilon - 1}{2\varepsilon}\right)^{\frac{\varepsilon-1}{\varepsilon+1}} - \left(\frac{\varepsilon - 1}{2\varepsilon}\right)^{\frac{2\varepsilon}{\varepsilon+1}}\right] \tag{10}$$

The last part of Eq. (10) is positive since $\varepsilon > 1$; therefore, air pollution ($\Psi_{PM2.5}, \phi_{PM2.5}$) reduces the per-period profit a start-up company will gain if it enters the market.

3.2.3 Decision of a start-up company

Now let us see the decision of a start-up company regarding whether to join a market. Suppose that to enter the market, each entrant has to pay a fixed cost η_j; then, the net present profit from starting a company is

$$V_j = -\eta_j + \sum_{t=0}^{\infty}\frac{\pi_{jt}}{(1 + r)^t} = -\eta_j + \frac{\pi_{jt}}{r} \tag{11}$$

where r is the discount rate, or the rate of return required by investors. According to Heyes et al. (2016), the sporadic, unpredictable and highly volatile characteristics of air pollution are likely to increase a company's risk exposure. This means a higher risk premium, indicating a higher discount rate r. Suppose the fixed cost η_j for each product in the market follows a uniform distribution,

$\eta_j \in [a, b]$ and only if V_j is positive,

$$\eta_j < \frac{\pi_{jt}}{r} \tag{12}$$

will a firm decide to enter the market. Therefore, the possibility of starting an undertaking is

$$P_{enter} = \frac{\frac{\pi_{jt}}{r} - a}{b - a}, \quad a < \frac{\pi_{jt}}{r} < b \tag{13}$$

Air pollution will reduce P_{enter} by decreasing π_{jt}; see Eq. (10) and by increasing the discount rate r. Then, we have the following propositions with regard to how air pollution affects entrepreneurship.

Proposition 1: *Air pollution can hinder entrepreneurship by reducing labor productivity and limiting the available labor supply.*

Proposition 2: *Air pollution can hinder entrepreneurship by exposing companies to increased risks.*

4. Empirical strategy

4.1 Variables and data sources

1. Air pollution ($PM_{2.5}$). $PM_{2.5}$ is widely regarded as a typical index for measuring and controlling air pollution (Freeman et al., 2019). This study uses the annual average emission concentration of $PM_{2.5}$ published by the Socioeconomic Data and Applications Center (SEDAC) of Columbia University to measure air pollution. The reasons are as follows. First, among all representative pollutants, $PM_{2.5}$ is considered the most dangerous, as it settles in the lungs and causes serious respiratory problems. Second, the air pollution data released by China have problems such as a short time span, incomplete samples, and difficulty in unifying the caliber (Qin and Zhu, 2018). However, SEDAC uses satellite-mounted equipment to monitor and extract gridded data on $PM_{2.5}$, which is more comprehensive, objective, and accurate than ground observation data (Unfried et al., 2022). Third, China is one of the few countries in the world where coal is the main energy source (Bloch et al., 2015). Coal combustion emits a high number of pollutants such as SO_2, NO_2, CO_2 and smoke dust. $PM_{2.5}$ includes the pollutants directly produced by coal combustion and the particulate matter generated after secondary transformation of related pollutants. Therefore, $PM_{2.5}$ is a more comprehensive and accurate measurement of air pollution. In addition, we use PM_{10}, SO_2, NO_2 and

other air pollutants and AQI (air quality index) to replace independent variables for testing.

2. Firm entry (entry). The measurement indicators of firm entry mainly include the self-employment rate (Premand et al., 2016), the number of employees in individual and private enterprises (Hingtgen et al., 2015), the number of newly established enterprises, etc. (Shi et al., 2021). The first two measures tend to characterize remaining firms rather than new entrants. Therefore, referring to Shi et al. (2021), the number of newly registered firms is used to measure firm entry in each region. The data come from the "Aiqicha" database. The database is currently a relatively comprehensive and accurate information platform for Chinese firms (Guo et al., 2023), and it provides firm information including name, type, registered address, industry category, registered capital, establishment time, business scope, etc. During the sample period, the database covered firm information in 2,991 counties and 20 industries in China, with a total of 1,316,040 pieces of firm-related data. We aggregated the data at the county level. In addition, we integrate the data of newly registered firms to the city level for a robustness test.

3. Control variables. (1) Referring to the relevant classic literature (Covina and Slevin, 1991; Norbäck et al., 2014; Urbano et al., 2019) and considering the availability of data, we choose the control variables of county characteristics, including economic growth (GDP), social investment (asset), industrial structure (str), labor supply (employ), and openness (open). (2) In the robustness test section, city-level data are adopted for retesting, and the control variables include economic growth (GDP_city), industrial structure (str_city), labor supply (employ_city), and openness to foreign investment (fdi_city). Data sources are "China City Statistical Yearbook". (3) In the mechanism analysis, in addition to county-level data, microdata at the firm and individual levels are used. Among them, the control variables of firm characteristics include asset-liability ratio (debt), intangible assets (invisible_asset), total operating income (income) and major shareholder's shareholding ratio (shareholder). The data are from the CSMAR (China Stock Market & Accounting Research) database. Control variables at the individual level include whether married (marriage), working hours per week (labor), medical insurance (medical), endowment insurance (endowment), education, etc. The data come from the CHARLS (China Health and Retirement Longitudinal Study) database.

4. Other Variables. (1) In the robustness test, we selected the regional temperature inversion intensity as the IV for air pollution, including the temperature inversion intensity from the ground layer to the second layer (therminv2) and to the third layer (therminv3). The relevant data come

from the NASA MERRA2 satellite dataset. (2) Labor supply, resident health, and firm risk are mechanism variables. Labor supply includes labor quantity (employ), labor productivity (labor_productivity) and labor quality (labor_quality). Health indicators include physical health (ph) and mental health (mh). CRT and total_risk are used to indicate firm risk. The data come from the "China County Statistical Yearbook", CHARLS database and CSMAR database. (3) Heterogeneity variables include economic strength, environmental costs, and environmental concerns. Specifically, economic strength includes two indicators: whether it is a top 100 county (top_county) and per capita GDP level (pgdp). The data sources are the CCID Consulting Urban Economic Research Center and the "China County Statistical Yearbook", respectively. Environmental cost (environmental_cost) is a dummy variable constructed based on the discrepant impact of the environmental protection "fee-to-tax" policy. The specific process will be explained in detail later. Environmental concern includes public environmental concern (public_concern) and government environmental concern (government_concern). Table 1 is the definition of each variable.

Table 1 Variable definition

Variable	Variable definition
Panel A: air pollution	
$PM_{2.5}$	The $PM_{2.5}$ concentration value of each county extracted according to the satellite data (ug/m3), logarithmic form
PM_{10}	Annual average PM_{10} concentration value (ug/m3), logarithmic form
AQI	Air quality index, logarithmic form
SO_2	Annual average SO_2 concentration value, logarithmic form
NO_2	Annual average NO_2 concentration value, logarithmic form
Panel B: firm entry	
entry	Number of newly registered firms in each county (ten thousand)
entry_city	Number of newly registered firms in each city (millions)
Panel C: Control variables at the county level	
GDP	Economic growth: gross domestic product (trillion yuan)
asset	Social investment: social fixed capital investment (100 million yuan)
str	Industrial structure: added value of the tertiary industry, logarithm form
employ	Number of labor force: employee's quantity, logarithmic form
open	Openness: the total amount of foreign capital actually utilized in RMB, logarithmic form
internet	Informatization: number of mobile phone users (millions)
Panel D: Control variables at the city level	
GDP city	Economic growth: gross domestic product (10,000 yuan)
str_city	Industrial structure: added value of the tertiary industry (10,000 yuan)

employ_city	Number of labor force: employee's quantity (10,000 yuan)
fdi_city	Openness: the total amount of foreign capital actually utilized (10,000 dollars)
internet_city	Informatization: number of mobile phone users (10,000)
Panel E: Control variables at the firm level	
debt	Asset-liability ratio (%)
invisible_asset	Intangible assets (10,000 yuan)
income	total operating income (10,000 yuan)
shareholder	Shareholding ratio of major shareholders (%)
Panel F: Control variables at the individual level	
marriage	Married or not, 1=married; 0=unmarried
labor	Weekly working hours (hours)
medical	Whether you have medical insurance, 1=yes; 0=no
endowment	Whether you have endowment insurance, 1=yes; 0=no
education	Educated years (years)
Panel G: Other variables	
therminv2	Inversion intensity
therminv3	Inversion intensity
labor_productivity	Labor productivity: added value of relevant industries/Employees of relevant industrial at the end of the year
labor_quality	Labor quality: Average wage of on-the-job employees in urban (10,000 yuan)
ph	Physical health: Self-assessed health is not good, the assignment is 1, otherwise it is 0
mh	Mental health: depression tendency is assigned as 1, otherwise it is 0.
total_risk	Firm risk: measured by the annual standard deviation of daily stock returns
CRT	Firm risk: measured by the logarithmic value of the standard deviation of the annualized daily rate of return
top_county	Whether it belongs to the top 100 counties; 1=top 100 counties, 0=nontop 100 counties
pgdp	According to the tertiles, the per capita GDP is divided into three groups: high, medium and low
environmental_cost	Counties with high environmental protection costs are assigned a value of 1, otherwise 0
public_concern	Public environmental concern: Baidu smog search index
government_concern	Government environmental concern: the proportion of words related to the environment in the local government work report

5. In Table 2, Panel A reports the summary statistics of the variables used in the baseline regression. In addition, Panel B shows the mean values and differences of air pollution and firm entry in northern and southern China. Regardless of which air pollution indicators are used, county-

level or city-level data, the air pollution in the north is significantly worse than that in the south. Furthermore, the average value of newly registered firms in the southern counties is 4,100 and that in the north is 3,160. There are fewer entrepreneurial activities in northern China.

Table 2 Summary statistics of the main variables

Panel A					
Varname	Obs	Mean	Std. Dev.	Min	Max
$PM_{2.5}$	59451	3.644	0.583	0.006	4.988
entry	59451	0.368	0.665	0	44.37
GDP	53025	0.014	0.025	0.00002	0.927
asset	53025	98.54	176.7	0	7757
str	53025	12.21	1.480	6.792	17.36
employ	53025	9.916	0.948	4.025	14.45
fdi	52942	9.047	1.203	1.929	21.17
internet	53025	0.273	0.313	0	27.52

Panel B					
Varname	Mean			Mean-diff	T
	All sample	South	North		
$PM_{2.5}$	3.644	3.525	3.791	-0.266***	-56.830
AQI	4.368	4.278	4.484	-0.205***	-15.330
PM_{10}	4.328	4.191	4.506	-0.315***	-17.619
SO_2	2.849	2.610	3.159	-0.549***	-18.702
NO_2	3.374	3.291	3.481	-0.191***	-11.163
entry	0.368	0.410	0.316	0.094***	17.173
entry_city	0.478	0.505	0.444	0.061**	2.847

Notes: Mean-diff refers to the southern mean minus the northern mean; ***, **, * represent the statistical levels of 1%, 5%, and 10%, respectively (the same below).

4.2 Empirical method

Endogeneity is an inescapable estimation challenge. First, there are many confounding factors in the causal chain between air pollution and firm entry, including socioeconomic characteristics such as population density and individual characteristics such as residents' risk preference. Thus, omitted variables that cannot be directly observed will lead to estimation bias. Second, a nonnegligible reverse causality relationship exists. Firm entry may affect air pollution levels. For example, when entrepreneurial enterprises gather in one place, the industrial waste gas emissions in their production processes can lead to air pollution in the surrounding area (Dijkstra, 2022). To overcome the endogeneity bias in parameter estimation, following Chen et al. (2013), we adopt a fuzzy RDD model for causal estimation. The RDD model set in this study is shown below:

$$north_{it} = \begin{cases} 1, L_i \geq 0 \\ 0, L_i < 0 \end{cases} \quad (1)$$

$$entry_{it} = \delta_0 + \delta_1 north_{\mathrm{i}} + \delta_2 f(L_i) + \delta_3 X_{it} + \gamma_t + \rho_{\mathrm{i}} + \mathcal{E}_{it} \quad (2)$$

$$PM_{2.5it} = \alpha_0 + \alpha_1 north_{\mathrm{i}} + \alpha_2 f(L_{\mathrm{i}}) + \alpha_3 X_{it} + \gamma_t + \rho_{\mathrm{i}} + \mathcal{E}_{it} \quad (3)$$

$$entry_{it} = \beta_0 + \beta_1 PM_{2.5it} + \beta_2 f(L_{\mathrm{i}}) + \beta_3 X_{it} + \gamma_t + \rho_{\mathrm{i}} + \mathcal{E}_{it} \quad (4)$$

In the equation, i represents the county, t represents time; L_i is the forcing variable, which is the relative latitude difference between each county and QHBL; $f(L_{\mathrm{i}})$ is a polynomial adjustment function for the treatment variable; $north_{\mathrm{i}}$ is the treatment variable, which takes a value of 1 for counties north of QHBL and 0 otherwise; X_{it} represents control variables; γ_t and ρ_{i} represent year and county fixed effects, respectively; and $\mathcal{E}_{it}$ is the error term.

5. Empirical results and discussion

5.1 Baseline result

Before RDD estimation, we first observe whether the central heating policy leads to breakpoint changes in core variables. We first plotted the scatter distribution diagrams of $PM_{2.5}$ and firm entry on both sides of the QHBL and fitted the function curves corresponding to the scatter points based on a quadratic polynomial. The results are shown in Figure 1. $PM_{2.5}$ and the number of newly registered firms have obvious jumps at the boundary line. Among them, $PM_{2.5}$ has a discontinuous upward jump near the QHBL, indicating that the air pollution in the north is more serious than that in the south, and the central heating policy is one of the important reasons for the regional difference. At the same time, the number of newly registered firms increases significantly downward at the boundary line, indicating that there is less entrepreneurial activity in the north than in the south. Preliminary evidence suggests that a causal relationship between air pollution and firm entry may exist. Whether this causal relationship is statistically significant needs to be further verified through empirical analysis. Accordingly, we further used the RDD model to estimate the locally averaged treatment effect at the breakpoints.

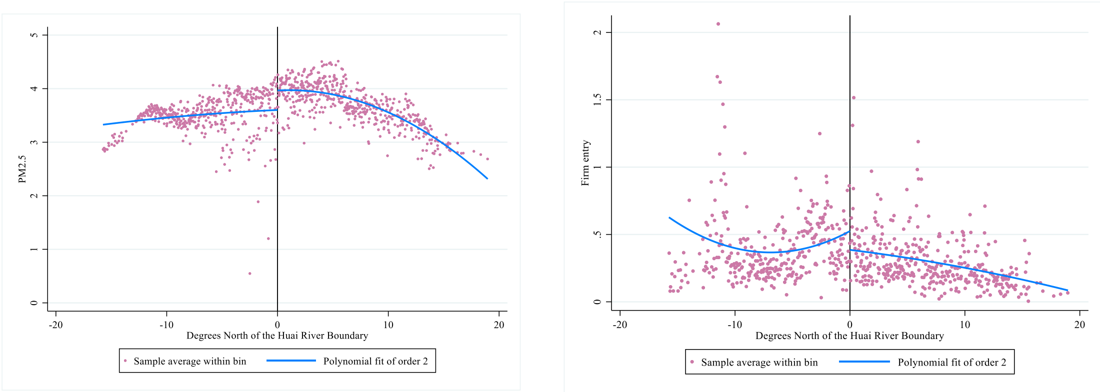


Figure 2 Breakpoint distribution of air pollution and firm entry at the Qinling-Huaihe boundary

The RDD estimation results are shown in Table 3. Panel A and Panel B are the regression results of Formula (2) and Formula (3) in the first stage. In Panel A and Panel B, the impacts of the dummy variable (north) on firm entry and air pollution are examined. We find that regardless of whether control variables are added or not, and regardless of whether the running variable is used in the linear or quadratic form, there are fewer newly registered firms in northern counties than in southern counties. Meanwhile, the average $PM_{2.5}$ concentration in the northern counties is approximately 0.429 μg/m^3 higher than that in the southern counties.

Panel C shows the second-stage regression results. Air pollution has a significant negative impact on firm entry in all counties in China. Specifically, for every 1% increase in the average concentration of $PM_{2.5}$, firm entry in each county will decrease by approximately 0.211%. The estimated results are basically consistent with theoretical expectations. For control variables, social investment (asset), economic growth (GDP), industrial structure (str), labor supply (employ), and openness (fdi) all have significant positive effects on firm entry. The explanations we provide are as follows: (1) With the continuous expansion of fixed asset investment, business environments such as transportation, information transmission and public facilities have also continued to improve, thereby stimulating entrepreneurial vitality in various regions (Papanek, 1962; Holtz-Eakin, 2000). (2) With economic growth, the living standards of the majority of consumers have also been greatly improved, and many people opt to start businesses. In addition, economic growth will continue to generate market demand, the expected rate of return of entrepreneurship will increase, and business risks will decrease, followed by the mobilization of entrepreneurial enthusiasm of market entities (Gourio et al., 2016). (3) An optimized industrial structure can provide entrepreneurial opportunities and resources, improve the entrepreneurial environment, and improve the level of regional entrepreneurship. For example, when the industrial structure is upgraded, outdated production capacity will be eliminated, thereby releasing a large number of economic factors and providing entrepreneurs with the capital or human resources needed to start a business (McMillan et al., 2014). (4) The impact of labor supply on firm entry is relatively direct. The more labor supply there is, the lower the price of labor. Cheap labor will lower the cost of firm entry. (5) The technology spillover of high-quality foreign capital can promote the improvement of the production efficiency of local enterprises, which in turn is conducive to firm entry (Aitken and Harrison, 1999; Bwalya, 2006; Abolhassani and Danakol, 2019).

Table 3 RDD estimation result

	(1)	(2)	(3)
Panel A:		**enp**	
north	-0.028***	-0.0568***	-0.0615***
	(-2.7109)	(-6.9180)	(-7.4040)
R^2	0.1273	0.4047	0.4063
Panel B:		**$PM_{2.5}$**	
north	0.528***	0.458***	0.429***
	(0.008)	(0.007)	(0.007)
R^2	0.123	0.437	0.485
Panel C: 2SLS		**enp**	
$PM_{2.5}$	-0.053***	-0.185***	-0.211***
	(0.018)	(0.016)	(0.018)
asset		0.0003***	0.0003***
		(0.000)	(0.000)
gdp		8.040***	7.934***
		(0.155)	(0.157)
str		0.062***	0.063***
		(0.004)	(0.005)
employ		0.104***	0.114***
		(0.005)	(0.005)
internet		0.099***	0.099***
		(0.008)	(0.008)
open		0.021***	0.019***
		(0.002)	(0.002)
Cons	0.334***	-1.095***	-1.064***
	(0.000)	(0.031)	(0.030)
N	59451	52921	52921
R^2	0.110	0.382	0.384
Polynomial in latitude	Linear	Linear	Quadratic
Fixed effect	Yes	Yes	Yes

Sta.err. in ().

5.2 RDD validity test

5.2.1 Unmanipulation test for forcing variable

In the context of this article, the QHBL was set based on the average geographical temperature in January, not for administrative or economic purposes (Chen et al., 2013). The setting of the boundary has "quasirandomness", so the latitude difference between the counties from the boundary is not under human control. Furthermore, we use the McCrary test to examine the density function continuity of the forcing variable (McCrary, 2008). The rationale for the McCrary test is that if individuals can absolutely manipulate the forcing variable above or below a certain threshold, then the density function of the forcing variable may jump around the breakpoint. Figure 2 shows the McCrary test results, where the abscissa axis represents the forcing variable; the vertical axis is the estimated value of the probability density; the blue solid line is the estimated probability density curve; and the blue dotted line represents the 95% confidence interval. In Figure 2, the forcing variable is very smooth near the cutoff point, without any jumping signs. Therefore, there is no evidence that the forcing variable is manipulated by humans.

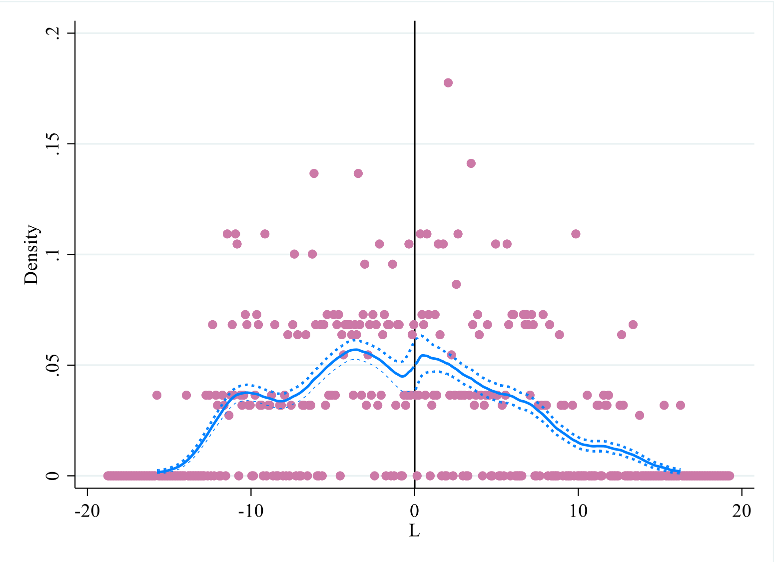
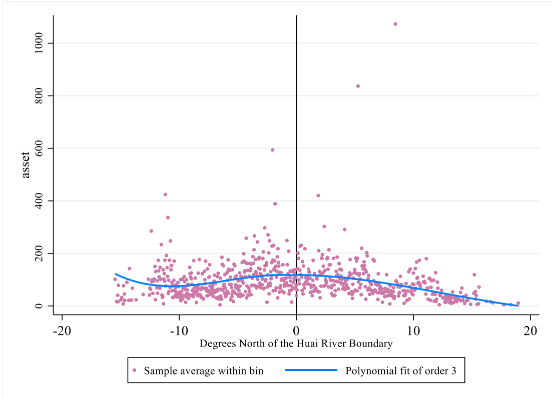


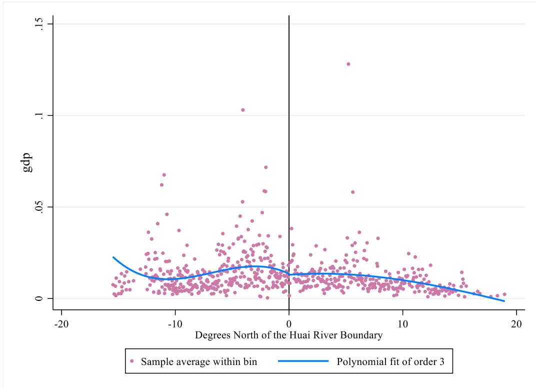
Figure 2 Unmanipulation test for forcing variable

5.2.2 Continuity test of control variables

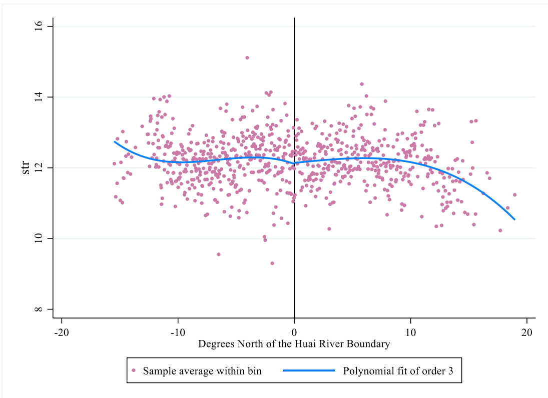
The other identifying assumption for the validity of RDD regression is that the observed control variables are continuous around breakpoints. The basic idea of this assumption is that the independent variable (air pollution) is the only factor that causes the dependent variable (firm entry) to jump at the breakpoint. If there is a significant jump in the control variable at the breakpoint, then the jump in firm entry at the breakpoint cannot be entirely attributed to the difference in air pollution. To this end, we plotted scatter distribution diagrams for the control variables: social investment (asset), economic growth (gdp), industrial structure (str), labor supply (employ), informatization (intenet) and openness (fdi). In Figure 3, there is no significant jump in these control variables near the QHBL, which meets the continuity requirement.



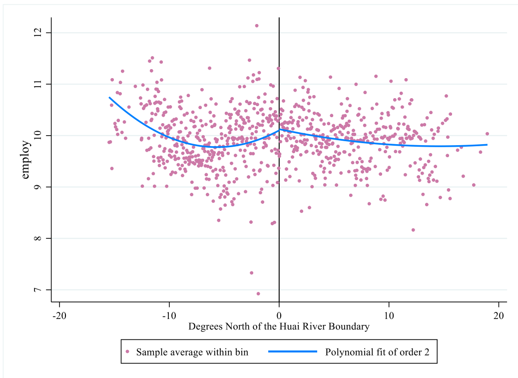
(a) asset



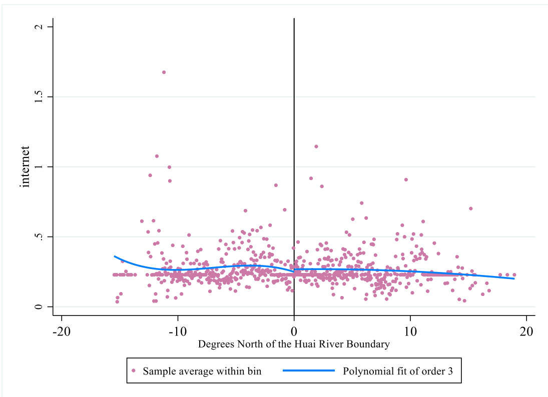
(b) gdp



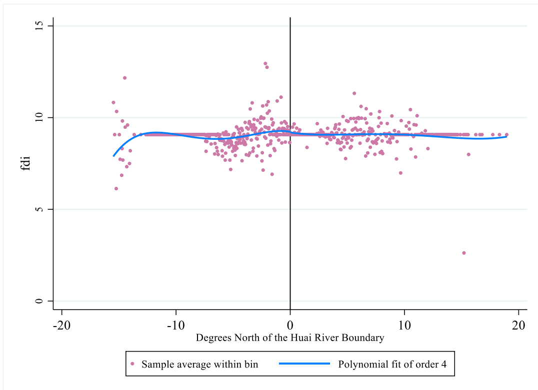
(c) str



(d) employ



(e) intenet



(f) fdi

Figure 3 Continuous test of control variables

5.3 Robustness test

5.3.1 Change bandwidth

The effectiveness and robustness of RDD estimation can be affected by bandwidth changes (Calonico et al., 2014). The smaller the bandwidth, the smaller the difference between the control variables, and the more unbiased the estimation result; however, the larger the sample loss, the less effective the regression result may be. Conversely, a larger bandwidth increases the sample size and improves the estimated efficiency but may also result in greater differences between control variables and biased estimates. Accordingly, we estimate the RDD estimation results under different bandwidths. In Columns (1)-(12) of Table 4, the bandwidths are 4°-15° (north−south symmetry), with an interval of 1°. Panel A and Panel B in Table 4 are the estimated results of Equation (3) and Equation (4), respectively. We find that regardless of the bandwidth used, the comprehensive effect of air pollution on firm entry is significantly negative. With an increase of 1% in $PM_{2.5}$ average concentration, the level of firm entry in each county decreases by approximately 0.128 and 0.316 percentage points, which does not vary much from the benchmark regression results.

Table 4 Change bandwidth

	(1)	(2)	(3)	(4)	(5)	(6)
Symmetric bandwidth	±4°	±5°	±6°	±7°	±8°	±9°
Panel A			**$PM_{2.5}$**			
North	0.231***	0.209***	0.277***	0.363***	0.392***	0.379***
	(0.014)	(0.012)	(0.011)	(0.010)	(0.009)	(0.009)
Panel B			**enp**			
$PM_{2.5}$	-0.128*	-0.316***	-0.175***	-0.180***	-0.203***	-0.220***
	(0.074)	(0.072)	(0.047)	(0.031)	(0.026)	(0.025)
R^2	0.386	0.350	0.369	0.374	0.372	0.371
Controls	VI	VI	VI	VI	VI	VI
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	21923	27264	31937	36062	40321	43639
	(7)	(8)	(9)	(10)	(11)	(12)
Symmetric bandwidth	±10°	±11°	±12°	±13°	±14°	±15°
Panel A			**$PM_{2.5}$**			
North	0.394***	0.403***	0.415***	0.427***	0.440***	0.442***
	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
Panel B			**enp**			

$PM_{2.5}$	-0.258***	-0.244***	-0.225***	-0.210***	-0.200***	-0.198***
	(0.023)	(0.021)	(0.019)	(0.019)	(0.018)	(0.017)
R^2	0.364	0.375	0.381	0.377	0.380	0.380
Controls	VI	VI	VI	VI	VI	VI
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	46621	49099	50695	51577	52039	52522

To provide a more intuitive understanding, we depicted the RDD estimation results for Equation (4) at different bandwidths. Figure 3 shows the estimated coefficients and their corresponding 95% confidence intervals for each bandwidth. The results show that the overall fluctuation range of the regression coefficient is small when the bandwidth is 6°-15°. It is further confirmed that the actual estimation results are not sensitive to the change in the bandwidth, and the overall regression results are very stable.

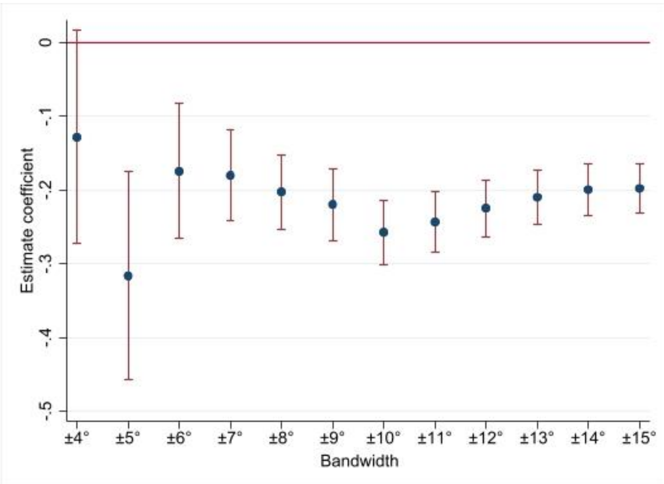


Figure 4 Bandwidth sensitivity

5.3.2 Placebo test

Following Ebenstein et al. (2017), we set up fake boundary lines to re-estimate the RDD model. The basic idea is that if the coefficient of the core variable is still significant after RDD estimation based on the fake boundary line, it means that the difference in firm entry in northern and southern China is not necessarily due to the difference in central heating policy in winter between the northern and southern QHBL. The approximate latitude of the QHBL is 32°N~34°N. Therefore, we selected four fake latitude breakpoints (29°N, 31°N, 35°N, 37°N latitude lines) in the north and south of the real breakpoint for RDD estimation. Columns (1)-(4) of Table 5 report the estimated results with latitude lines of 29°N, 31°N, 35°N, and 37°N as breakpoints. Obviously, under these fake breakpoints, the coefficients of air pollution are no longer significant, and the central heating policy on both sides of the real boundary line is indeed an important factor affecting firm entry.

Table 5 Placebo test results

	(1)	(2)	(3)	(4)
	29°N	31°N	35°N	37°N
$PM_{2.5}$	-0.037	-0.314	-0.325	-0.092
	(0.077)	(0.249)	(0.486)	(0.083)
Controls	VI	VI	VI	VI
Fixed effect	Yes	Yes	Yes	Yes
N	52921	52921	52921	52921

5.3.3 Nonparametric estimation

The bandwidth and polynomial order of RDD parameter estimation are provided in advance by researchers based on experience and the characteristics of research problems, which is somewhat subjective (Battistin and Rettore, 2008). To ensure the reliability of the basic conclusions, we re-estimate the regression using nonparametric estimation. Specifically, based on the optimal bandwidth selection methods of CER (coverage error rate) and MSE (mean squared error), the uniform kernel density function is used for nonparametric estimation. The results are shown in Table 6. In Columns (1) and (3), the first-stage estimation coefficients are significantly positive at the 1% level, indicating that the central heating policy leads to increased air pollution in northern China. The second-stage estimation results in Columns (2) and (4) indicate that the coefficient of $PM_{2.5}$ is significantly negative, once again confirming that counties with more severe air pollution have fewer newly registered firms.

Table 6 Nonparametric estimation results

Bandwidth selection	(1)	(2)	(3)	(4)
	Bandwidth: CER		Bandwidth: MSE	
	First-stage	Second-stage	First-stage	Second-stage
$PM_{2.5}$	0.151***	-0.749**	0.128***	-1.511***
	(0.015)	(0.356)	(0.013)	(0.498)
Controls	VI	VI	VI	VI
R^2	-	0.255	-	0.278
Controls	None	VI	VI	VI
Fixed effect	Yes	Yes	Yes	Yes
N	3654	3654	987	987

5.3.4 City-level estimates

The benchmark regression in this article uses county-level data. For robustness, we replace a set of city-level data and perform the regression again. The reasons for this practice are as follows. First, considering that central heating has not been fully realized in some counties in northern China, people living here basically rely on medium and small coal-fired boilers for heating in winter. At the same time, the heating of urban residents in China is basically well guaranteed. Second, there may be a certain degree of contingency in a single sample, and replacing the new sample can mitigate the overall sample selection bias. In this regard, we choose to replace the samples at the city level. In Table 7, regardless of which kernel estimation method is adopted and regardless of whether the linear, quadratic or cubic form of the forcing variable is used, the negative relationship between air pollution and firm entry still exists.

Table 7 City-level estimation results

	(1)	(2)	(3)	(4)	(5)	(6)
$PM_{2.5}$	-0.070***	-0.076***	-0.053***	-0.067***	-0.033**	-0.045***
	(0.013)	(0.013)	(0.015)	(0.025)	(0.016)	(0.017)
Controls	VI	VI	VI	VI	VI	VI
Fixed effect	Yes	Yes	Yes	No	Yes	Yes
Polynomial in latitude	Linear	Linear	Quadratic	Quadratic	Cubic	Cubic
Kernel	Triangular	Epanechnikov	Triangular	Epanechnikov	Triangular	Epanechnikov
N	1795	1795	1795	1795	1795	1795

5.3.5 Replacement of air pollution indicators

Coal combustion can produce various types of atmospheric pollutants, and different air pollutants may have heterogeneous effects on regional firm entry. Therefore, we use PM_{10}, AQI, SO_2, and NO_2 as alternative indicators of air pollution to conduct robustness tests. Since the country's air pollution substitute data are not available, we consider using the city's data in China to conduct RDD estimation. In Table 8, each air pollutant is not conducive to regional firm entry. In addition, among the three pollutants PM_{10}, SO_2, and NO_2, PM_{10} has the greatest negative effect on regional firm entry. Both PM_{10} and $PM_{2.5}$ are inhalable particulate matter. Particulate matter in the atmosphere not only comes from the direct emission of pollution sources but also from the reaction of gaseous precursors such as SO_2 and NO_x in the atmosphere to generate secondary particulate matter. Particulate matter is a comprehensive indicator of air pollution and contains harmful substances that are damaging to human health and atmospheric visibility (Zhou et al., 2017). Therefore, people take particulate pollution seriously (Liu et al., 2015), and its negative impact on regional firm entry is the most significant.

Table 8 Indicator replacement

	(1)	(2)	(3)	(4)
		enp		
PM_{10}	-0.838***			
	(0.338)			
AQI		-1.242*		
		(0.655)		
SO_2			-0.476*	
			(0.264)	
NO_2				-0.612***
				(0.195)
Controls	VI	VI	VI	VI
Fixed effect	Yes	Yes	Yes	Yes
Polynomial in latitude	Linear	Linear	Linear	Linear
N	1795	1795	1795	1795

5.3.6 Sample elimination in Beijing, Shanghai and Shenzhen

Beijing, Shanghai, and Shenzhen are superior to other regions in terms of high-quality human capital, policy support, R&D funds, and information environment, and their advantages in entrepreneurial resources are more obvious than other regions (Chang et al., 2017). The inclusion of these regions may bias the results. Therefore, the above regions were excluded from the sample. Table 9 shows the regression results after sample reselection. Columns (1)-(2) are the analysis of the entire sample range, and Columns (3)-(4) are the results within ±5° of the QHBL. Because the regression coefficient of $PM_{2.5}$ is always negative, our research conclusion is robust.

Table 9 Adjustment sample

	(1)	(2)	(3)	(4)
$PM_{2.5}$	-0.120***	-0.141***	-0.198***	-0.198***
	(0.016)	(0.017)	(0.066)	(0.066)
R^2	0.412	0.413	0.403	0.403
Controls	VI	VI	VI	VI
Fixed effect	Yes	Yes	Yes	Yes
Polynomial in latitude	Linear	Quadratic	Linear	Quadratic

Sample	Full	Full	±5°	±5°
N	52480	52480	26928	26928

5.3.7 Fixed effect model estimation

The RDD approach can only estimate local treatment effects. To obtain the global treatment effect, a fixed effect model is adopted to estimate the long-term average impact of air pollution on firm entry based on all county-level data from 2000 to 2020. The model is shown in Equation (5):

$$Enp_{it} = \theta_0 + \theta_1 PM_{2.5it} + +\theta_2 X_{it} + \gamma_t + \rho_i + \mathcal{E}_{it} \quad (5)$$

where $PM_{2.5}$ represents the annual average concentration of $PM_{2.5}$ emissions (10 ug/m3). The definitions of the remaining variables are consistent with Equation (4). The coefficient θ_1 is our focus. In Table 10. Columns (1)-(7) are the estimated results of gradually adding control variables. The coefficient of $PM_{2.5}$ is consistent with the RDD result, and the increase in air pollution level is accompanied by a decrease in firm entry.

Table 10 Fixed effect model estimation result

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$PM_{2.5}$	-0.055***	-0.034***	-0.028***	-0.029***	-0.029***	-0.028***	-0.028***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Cons	0.359***	0.265***	0.209***	1.206***	1.093***	1.093***	1.042***
	(0.017)	(0.017)	(0.016)	(0.073)	(0.091)	(0.091)	(0.093)
R^2	0.218	0.265	0.331	0.334	0.334	0.334	0.334
Controls	None	I	II	III	IV	V	VI
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	59451	53004	53004	53004	53004	53004	52921

5.3.8 IV estimations

To ensure the robustness of our conclusions, the IV method is used for re-estimation in this section. Referring to Deschenes et al. (2020) and Godzinski and Castillo (2021), the temperature inversion intensity in each region is used as the IV for air pollution, and 2SLS estimation is performed. Hot air is less dense and flows upward; cold air is denser and flows downward. The convection of cold air and hot air is conducive to the diffusion of air pollutants. However, in some cases, the temperature in the upper atmosphere is higher. This meteorological condition is called "temperature inversion". The occurrence of a temperature inversion is not conducive to air convection and hinders the diffusion of pollutants. Therefore, the temperature inversion phenomenon will affect the local air quality, and the correlation of IV is satisfied. In addition, temperature inversion is considered an exogenous shock of air pollution (Arceo et al., 2016), which is independent of socioeconomic activities, including firm entry. Therefore, the exogeneity of IV is also satisfied. The IV estimation model is as follows:

$$PM_{2.5} = \beta_0 + \beta_1 \text{therminv}_{it} + \theta_n X_{it} + region_i + year_t + \epsilon_{it} \tag{6}$$

$$enp_{it} = \gamma_0 + \gamma_1 \widehat{PM_{2.5}}_{it} + \varphi_n X_{it} + region_i + year_t + \vartheta_{it} \tag{7}$$

Here, Equation (6) and Equation (7) are the first-stage and the second-stage regression models, respectively. For temperature inversion data, the MERRA-2 meteorological database of the National Space Administration (NASA) provides temperature data of 42 atmospheric layers every 6 hours worldwide, with a grid accuracy of 50 km*60 km. Following Chen et al. (2017), the inverse temperature indicators therminv2 and therminv3 are used as IVs. $\widehat{PM_{2.5}}$ is the fitted value of PM2.5 estimated by Equation (6).

Table 11 reports the IV-2SLS results. From the first-stage regression results, the temperature inversion intensity is positively correlated with air pollution. In the second-stage regression results, the estimated coefficients are always significantly negative regardless of whether the IV is therminv2 or therminv3. The results remained robust when endogeneity was mitigated using the IV approach.

Table 11 IV estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	First-stage				Second-stage			
	$PM_{2.5}$				enp			
					therminv2		therminv3	
$\widehat{PM_{2.5}}$					-1.783***	-0.689***	-2.146***	-0.875***
					(0.212)	(0.163)	(0.235)	(0.183)
therminv2	0.187***	0.185***						
	(0.012)	(0.013)						
therminv3			0.165***	0.157***				
			(0.011)	(0.012)				
Cons	4.155***	3.537***	4.208***	3.595***	7.846***	2.280***	9.404***	2.962***
	(0.013)	(0.013)	(0.011)	(0.023)	(0.912)	(0.602)	(1.009)	(0.672)
Control variables	No	Yes	No	Yes	No	Yes	No	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	57226	50926	57226	50926	0.046	50926	57226	50926
Adj R^2	0.897	0.899	0.897	0.899	-	-	-	-

6. Heterogeneity analysis

6.1 Heterogeneity of county economic development

Counties with different economic development levels have differences in talent, technology, capital and industrial development, which affects their attractiveness to firms. In addition, for regions with relatively high levels of economic development, entrepreneurs may increase their tolerance to air pollution. In this regard, we further analyze the difference in the impact of air pollution on firm entry in regions with different economic development levels and examine the regional distribution effect of firms brought about by air pollution.

Two methods are adopted to classify the economic development level of each county. The first method is to divide the sample into top 100 counties and those not in the top 100 counties. For the top 100 counties, their primary condition is to pass the "double threshold" of regional GDP exceeding 80 billion yuan and general public budget revenue exceeding 2 billion yuan. The second method is to determine the top 1/3, middle 1/3 and bottom 1/3 counties with economic levels as high, middle and low economic levels, respectively, according to GDP per capita. Next, we unify the top 100 counties and areas with high per capita GDP as high-level economic development areas. Columns (1) and (5) in Table 12 belong to areas with high economic development levels, and the negative effects of air pollution in these areas are not obvious. The possible reasons are as follows: first, entrepreneurial activities cannot be carried out independently in a vacuum, and when making investment decisions for new businesses, they need to consider interactions with the outside world (Akron et al., 2020). Areas with high levels of economic development often have more entrepreneurial opportunities, more high-quality labor supply, more standardized systems, and more optimized business environments (Ma et al., 2023). These factors attract firms to enter and offset the adverse effects of air pollution. Second, areas with high levels of economic development have resource advantages, and registered firms in these regions are more likely to obtain high profits. Enticed by profits, entrepreneurs will reduce their sensitivity to air pollution and increase their tolerance. They may be willing to choose between actual and visible entrepreneurial opportunities, risk returns and potential and uncertain health risks in the future and, therefore choose to flood into areas with high economic development. Thus, under the combined effect, newly registered firms are further concentrated, which intensifies the unevenness of regional entrepreneurship.

Table 12 Heterogeneity of economic development level

	(1)	(2)	(3)	(4)	(5)
	Top 100 County		Per capita GDP		
	Yes	No	Low	Middle	High
$PM_{2.5}$	-0.975	-0.171***	-0.080***	-0.274***	-0.081
	(4.110)	(0.016)	(0.007)	(0.015)	(0.072)
Polynomial in latitude	Linear	Linear	Linear	Linear	Linear
Control variables	Yes	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes
N	2480	37836	17603	17668	17650

6.2 Heterogeneity of environmental protection cost

Entrepreneurs weigh risk costs and operating benefits when choosing a firm location. First, air pollution leads to increased health care costs and decreased productivity, which means that firms face higher investment risks and cost burdens (Zhang et al., 2023). Furthermore, if a region has stricter environmental regulations or higher environmental costs, it will increase the operating cost burden of new businesses in the area and lower the returns they obtain for each unit of risk taken (Zhu et al., 2021). Therefore, rational entrepreneurs will prefer to register their firms in areas with lower environmental protection costs.

To verify this idea, we use China's "Environmental tax reform" to differentiate environmental cost differences between regions. On January 1, 2018, China officially introduced an environmental protection tax, and the pollution discharge fee system that has been in operation for nearly 40 years has become historical (Zhou et al., 2021). Environmental tax more rigid and legally authoritative. Some provinces used the original pollution fee collection standards as the environmental tax standard, while 12 provinces (municipalities) raised the tax standard (Liu et al., 2022). Accordingly, we classify all counties that were not subject to an environmental tax before 2018 into the "low environmental cost" group and counties belonging to provinces with raised standards after 2018 into the "high environmental cost" group.

In Table 13, the coefficients of $PM_{2.5}$ are all positive. This proves that air pollution brings business risks and uncertainties to enterprises, which inhibits firm entry. More importantly, the regression coefficient of $PM_{2.5}$ in the "low environmental cost" group is significantly smaller than that in the "high environmental cost" group. It proves that firms tend to be established in areas with relatively low environmental standards, which is in line with the "pollution paradise hypothesis" or "industrial relocation hypothesis" (Candau and Dienesch, 2017).

Table 13 Heterogeneity of environmental protection costs

	(1)	(2)	(3)	(4)
	Low environmental protection cost		High environmental protection cost	
$PM_{2.5}$	-0.312***	-0.067***	-0.973**	-0.713*
	(0.034)	(0.016)	(0.459)	(0.383)
Polynomial in latitude	Linear	Linear	Linear	Linear
Control variables	No	Yes	No	Yes
Fixed effect	No	Yes	No	Yes
Latitude	±5°	±5°	±5°	±5°
N	13158	13158	996	996

6.3 Heterogeneity of environmental concern

Against the background of multi-subject co-governance, different public and government environmental concerns in each county may reduce or expand the distorting effect of air pollution on firm entry. With regard to public environmental concerns, first, with the intensification of environmental problems, the public's environmental demand and environmental public product preferences are increasing, which will lead to increased public attention to the ecological environment and related policies (Tu et al., 2019). In the era of digitalization and self-media, the public's high environmental concern will force firms to take the initiative to undertake environmental social responsibilities and invest more funds, manpower and material resources in environmental issues (Wang al., 2018). To a certain extent, the cost of cleaner production and pollution control of firms will increase, reducing firms' enthusiasm for entering the region. Second, in addition to political and media channels, the public can also express their environmental protection wishes and demands through capital market channels. According to the "deterrence effect" theory, the public will effectively respond to negative environmental events in the capital market (Carpentier and Suret, 2015). In regions with high public environmental awareness, investors are sensitive to information about environmental incidents. Once a company violates multiple environmental protection management regulations, the public will "vote with money" to protest and express their dissatisfaction (Lei and Shcherbakova, 2015). In this regard, firms in regions with high public environmental concern face limited financing channels and financial risks, reducing their attractiveness to the region. In Columns (1)-(4) of Table 14, after classifying the samples according to the degree of public environmental concern, for counties with high public environmental concerns, air pollution has a greater inhibitory effect on firm entry, and entrepreneurs are more susceptible to changes in air quality in areas with high public environmental concerns.

Government environmental concern represents the government's emphasis on the environment and is an important manifestation of the government's environmental governance philosophy. First, government attention is a scarce resource, and government attention needs to be allocated among the fields of economy, people's livelihood, and environmental protection (Gargan, 1981). There are differences in the investment and attention given by local governments in various fields. For regions with high government environmental attention, the government emphasizes environmental governance, imposes higher environmental constraints, conducts stricter environmental monitoring and inspection, and has higher execution of environmental policies. Accordingly, for firms in areas with high government environmental concerns, the cost of environmental protection is higher, which may have a negative effect of air pollution on the entry of firms. As shown in Columns (5)-(8) of Table 14, where the government pays more attention to the environment, firms are more likely to be affected by air quality.

Table 14 Heterogeneity of environmental concern

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Public environmental concern				Government environmental concern			
	Low	Low	High	High	Low	Low	High	High
$PM_{2.5}$	-0.166***	-0.132***	-0.636***	-0.390***	-0.086**	-0.022	-0.215***	-0.174***
	(0.032)	(0.033)	(0.188)	(0.189)	(0.038)	(0.031)	(0.051)	(0.051)
Polynomial in latitude	Linear	Linear	Linear	Linear	Linear	Linear	Linear	Linear
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
N	17075	17075	7059	7059	24669	24669	22521	22521

7. Mechanism analysis

The theoretical analysis in this article shows that air pollution can inhibit the entry of firms into an area. Therefore, how does air pollution affect firm entry? The following analysis is conducted from three perspectives: health depreciation, multidimensional labor supply, and firm risk.

7.1 Health depreciation

Air pollution will cause physical and psychological health depreciation and then affect the enthusiasm of firms to enter an area. The harm of air pollution to human physiological health is complex and diverse. First, according to the theories of environmental toxicology and environmental epidemiology, $PM_{2.5}$ can remain in the bronchi and lungs through respiration, which may cause respiratory system diseases (Groen and Hiltermann, 2019). When PM2.5 enters the bloodstream, it can cause endothelial dysfunction and induce blood system diseases (Wu et al., 2021). For susceptible populations, $PM_{2.5}$ can also cause fetal growth retardation and low birth weight (Pan, 2023), cognitive impairment in the elderly (He et al., 2020), and increase the risk of stroke, diabetes, hypertension, and lung cancer (Yue et al., 2020).

Air pollution harms mental health. First, poor air quality means a lower quality of life and a poor work environment, which can lead people to feel emotional, depressed and anxious (Pun et al., 2017), and some may have difficulty concentrating (Zivin and Neidell, 2013). Second, air pollution reduces outdoor social activities. Excessive time spent alone or indoors can induce feelings of loneliness and depression (Cao et al., 2013).

When air pollution causes physical and mental health depreciation, two concerns will hinder entrepreneurs from registering firms in polluted areas: on the one hand, entrepreneurs belong to the group senior managers in society, and usually this group has higher standards for air quality. Air pollution will harm the physical and mental health of entrepreneurs and their families; on the other hand, health depreciation will reduce labor productivity, resulting in the lower productivity of firms, and thus, products that are uncompetitive in the market.

Considering that the dependent variables in this section are all ordered variables, the Oprobit method is used for RDD estimation. The control variables at the individual level include married or not (marriage), working hours per week (labor), whether there is medical insurance (medical), whether there is endowment insurance (endowment) and years of education (education). From Columns (1)-(2) and Columns (3)-(4) in Table 15, air pollution causes depreciation of the physical health and mental health of individuals.

Table 15 Mechanism of health depreciation

	(1)	(2)	(3)	(4)
	Physical health		Mental health	
$PM_{2.5}$	1.040***	0.941***	1.091***	0.903***
	(0.131)	(0.138)	(0.167)	(0.182)

Control variables (City level)	Yes	Yes	Yes	Yes
Control variables (Individual level)	No	Yes	No	Yes
Fixed effect	Yes	Yes	Yes	Yes
Pseudo R2	0.0098	0.0230	0.0121	0.0319
N	8901	8901	8901	8901

7.2 Multidimensional labor supply

Theoretically, air pollution may cause multidimensional changes in labor supply, which may further affect the entry of firms in the region. (1) Air pollution reduces worker quantity. First, the air quality crisis will worsen people's living conditions and working environments, causing physical and mental health problems. For long-term health considerations, the labor force will "vote with feet" and move out of areas with severe air pollution (Banzhaf and Walsh, 2008; Pan, 2023). Second, poor air quality can easily damage the health of susceptible people and require family members to accompany them, which will indirectly reduce the labor force participation rate (Aragon et al., 2017). Furthermore, the cost of job vacancies and training of new employees increases. Therefore, the emigration and loss of the labor force will bring many non-operating expenses and then affect the enthusiasm for firm entry.

(2) Air pollution will lead to a decline in labor productivity. First, long-term exposure to polluted air can easily induce human respiratory, cardiopulmonary and other diseases (Fu et al., 2021), which in turn affect laborers' attendance performance and work efficiency (Zivin and Neidell, 2012). Second, air pollution greatly increases the risk of the cognitive decline of workers, affecting reaction time and concentration ability, which in turn impairs work efficiency (Chang et al., 2019). Furthermore, the decline in labor productivity means that it is difficult for firms to control labor costs, production processes and product quality, which affects firm entry.

(3) Air pollution will lower regional labor quality. The more educated, experienced, and productive group is more sensitive to air pollution (Chen et al., 2017). This may be attributed to the ability of these groups to raise the capital necessary to carry out spatial migration. These groups also have higher standards for air quality. Furthermore, the emigration of high-quality labor will weaken the motivation for firm entry.

To verify the above ideas, the RDD method is adopted to estimate the relationship between air pollution and labor quantity (employ), labor productivity (labor_productivity) and labor quality (labor_quality). The estimated results are shown in Table 16, where the dependent variables corresponding to Columns (1)-(5) are the labor force supply quantity of the secondary industry, the labor force supply quantity of the tertiary industry, the labor force productivity of the secondary industry, the labor force productivity of the tertiary industry, and the labor force quality. We find that the regression coefficients of $PM_{2.5}$ are all negative, confirming that air pollution leads to a reduction in the quantity, quality and productivity of labor supply, which in turn affects firm entry.

Table 16 Mechanism of labor supply, productivity and quality

	(1)	(2)	(3)	(4)	(5)
	Labor supply		Labor productivity		Labor quality
$PM_{2.5}$	-0.107***	-0.133***	-0.386***	-0.076***	-0.219**
	(0.017)	(0.011)	(0.048)	(0.015)	(0.096)
Control variables	Yes	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes
N	52921	52921	52914	52921	52921

7.3 Firm risk

Air pollution has a potential evolutionary effect on firm risk, which in turn affects firm entry. First, air pollution increases the operational risk of firms. Intensified air pollution may disrupt the production and operation process of firms. For example, reduced visibility can block traffic, leading to squeezed inventories and increased sales expenses (Chen et al., 2017). In addition, good air quality is a nonmonetary benefit for employees, so when the firm is located in a more polluted working environment, the firm needs to pay higher salaries to employees or managers (Wang et al., 2021). Second, air pollution increases the financial risk of firms. Financial institutions identify and evaluate the business risks of firms and then lend money. When the production risks brought by air pollution are shown in the performance indicators of firms, financial institutions will reduce loans to firms (Javadi and Masum, 2021). Third, air pollution increases the transformation risk of firms. Faced with the decline in air quality, command-based environmental regulations and market-based environmental regulations will force firms to undergo green transformation, which includes the elimination of outdated equipment and techniques, the use of low-carbon cutting-edge technologies, and the addition of environmentally friendly, energy-saving and sewage equipment, bringing firms a series of transformation costs. Furthermore, the higher the potential risk faced by the firm, the higher the expected return required by investors in the market for the firm, which will reduce the entrepreneurial income and thus weaken a firm's enthusiasm to enter.

Referring to Bernile et al. (2018), based on stock transaction data, we use the standard deviation of the annualized rate of return and the standard deviation of individual stock returns to measure firm risk, which includes three calibers: daily, weekly and monthly. Among them, the dependent variables corresponding to Columns (1)-(3) in Table 17 are the standard deviations of individual stock returns on a daily, weekly and monthly basis; Columns (4)-(6) correspond to dependent variables that are daily and weekly and the monthly standard deviation of the annualized rate of return. The larger the value of this indicator, the more uncertain factors the firm faces and the higher the firm risk. We find that after adding control variables at the county and firm levels, the coefficient of $PM_{2.5}$ is always significantly positive, which verifies that air pollution will increase firm risk and thus inhibit firm entry.

Table 17 Mechanism of enterprise risk

	(1)	(2)	(3)	(4)	(5)	(6)
	risk_day	risk_week	risk_month	CRT_day	CRT_week	CRT_month
$PM_{2.5}$	1.932^{***}	0.419^{*}	1.763^{*}	0.894^{**}	0.343^{**}	1.636^{*}
	(0.658)	(0.230)	(0.927)	(0.359)	(0.200)	(0.857)
Control variables (County level)	Yes	Yes	Yes	Yes	Yes	Yes
Control variables (firm level)	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	13147	13124	13023	13147	13124	13023

8. Conclusions and policy implications

The article collected multiple sets of data at the county, city, firm, and individual levels, matching them with air pollution data. The impact and heterogeneity of air pollution on firm entry were analyzed through the RDD method, and the potential impact mechanism was examined from micro and macro perspectives. The results are as follows. First, air pollution significantly inhibits regional entrepreneurial initiative. After multiple robustness tests, such as model replacement estimation, bandwidth sensitivity test, placebo test, nonparametric estimation, sample replacement, replacement of air pollution indicators, and IV estimation, the results remain significant. Second, for counties with high environmental protection costs, high public and government environmental attention, and weak economic strength, the negative effects of air pollution on firm entry are more apparent. Third, the possible mechanism for air pollution affecting firm entry is theoretically explained, and combined with the RDD method for testing, we find that air pollution can affect entrepreneurial activities through channels such as affecting multidimensional labor supply, health depreciation, and firm risk. This study proposes a multidimensional linkage mechanism and strategy for the promotion of environmental governance and entrepreneurial activity from multiple perspectives and provides a decision-making reference for the central and local governments to formulate relevant policies.

First, air pollution has a negative impact on individuals, enterprises, and regional economies, while investment in environmental governance can bring environmental bonuses, economic bonuses, and social bonuses. Local governments should fully realize that the functions of environmental protection and economic development do not conflict, effectively implement the concept of green development, formulate reasonable environmental protection policies, and strengthen environmental governance capabilities. Specifically, clean heating should be actively and steadily promoted in northern China, clean heating methods should be developed according to local conditions, and the efficiency of heating networks should be vigorously improved. The top priority of the current environmental protection work in various places should be to deepen the prevention and control of air pollution with a focus on $PM_{2.5}$ prevention and control, integrate ecological and environmental science and technology resources, and increase investment in basic research and applied research.

Local governments should recognize that environmental protection and economic development functions are not conflicting, thus enabling them to implement the concept of green development, formulate reasonable environmental protection policies, and strengthen environmental governance capabilities. Specifically, actively and steadily promoting clean heating in northern China, developing clean heating methods according to local conditions, and vigorously improving the efficiency of heat networks should be the top priorities of current environmental protection work in various regions, focusing on the prevention and control of PM2.5 as the key to deepening atmospheric pollution prevention and control. In addition, localities should integrate ecological and environmental science and technology resources and increase investment in basic and applied research.

Second, air pollution presents a series of hidden costs and uncertain risks to firms. Local governments should aim to attract firms and highlight their advantages in high-quality ecological environments when working to attract investment. The strategy of large-scale tax, land, and labor cost concessions commonly used in the past to attract firms presents a vicious competition between regions. In the new development stage, local governments can consider new ways to attract firms from non-economic perspectives such as ecological environment construction and air quality compensation. This "ecological environment-based investment promotion" can simultaneously meet the multi-dimensional needs of entrepreneurs, including health, labor supply, and sustainable development.

Third, air quality intensifies the spatial agglomeration of firms. Heterogeneity analysis shows that in areas with a fairly high level of economic development, entrepreneurs will reduce their sensitivity to air pollution in that area, while air pollution in areas with average economic development levels significantly inhibits the entry of firms. For this reason, to attract firms to regions with relatively stunted economic development, they must further promote the initiatives for prevention and control of air pollution, follow the road of green development, and avoid the metaphorical detour of "pollution first and then governance". Otherwise, the gap in economic development between regions will be widened once again.

References

Abolhassani, M., & Danakol, S. H. (2019). Wage and competition channels of foreign direct investment and new firm entry. Small Business Economics, 53, 935-960.

Acemoglu, D., Akcigit, U., Alp, H., Bloom, N., & Kerr, W. (2018). Innovation, reallocation, and growth. American Economic Review, 108(11), 3450-91.

Aitken, B. J., & Harrison, A. E. (1999). Do domestic firms benefit from direct foreign investment? Evidence from Venezuela. American Economic Review, 89(3), 605-618.

Akron, S., Demir, E., Díez-Esteban, J. M., & García-Gómez, C. D. (2020). Economic policy uncertainty and corporate investment: Evidence from the US hospitality industry. Tourism Management, 77, 104019.

Al-Kindi, S. G., Brook, R. D., Biswal, S., & Rajagopalan, S. (2020). Environmental determinants of cardiovascular disease: lessons learned from air pollution. Nature Reviews Cardiology, 17(10), 656-672.

Amaral, A. M., Baptista, R., & Lima, F. (2011). Serial entrepreneurship: impact of human capital on time to re-entry. Small Business Economics, 37, 1-21.

Aragon, F. M., Miranda, J. J., & Oliva, P. (2017). Particulate matter and labor supply: The role of caregiving and non-linearities. Journal of Environmental Economics and Management, 86, 295-309.

Arceo, E., Hanna, R., & Oliva, P. (2016). Does the effect of pollution on infant mortality differ between developing and developed countries? Evidence from Mexico City. The Economic Journal, 126(591), 257-280.

Ates, S. T., & Saffie, F. E. (2021). Fewer but better: Sudden stops, firm entry, and financial selection. American Economic Journal: Macroeconomics, 13(3), 304-56.

Azoulay, P., Jones, B. F., Kim, J. D., & Miranda, J. (2022). Immigration and entrepreneurship in the United States. American Economic Review: Insights, 4(1), 71-88.

Banzhaf, H. S., & Walsh, R. P. (2008). Do people vote with their feet? An empirical test of Tiebout's mechanism. American Economic Review, 98(3), 843-863.

Baptista, R., Lima, F., & Mendonça, J. (2011). Establishment of higher education institutions and new firm entry. Research Policy, 40(5), 751-760.

Battistin, E., & Rettore, E. (2008). Ineligibles and eligible non-participants as a double comparison group in regression-discontinuity designs. Journal of Econometrics, 142(2), 715-730.

Beckerman, W. (1992). Economic growth and the environment: Whose growth? Whose environment?. World Development, 20(4), 481-496.

Belderbos, R., Tong, T. W., & Wu, S. (2020). Portfolio configuration and foreign entry decisions: A juxtaposition of real options and risk diversification theories. Strategic Management Journal, 41(7), 1191-1209.

Bernile, G., Bhagwat, V., & Yonker, S. (2018). Board diversity, firm risk, and corporate policies. Journal of Financial Economics, 127(3), 588-612.

Bettin, G., Bianchi, P., Nicolli, F., Ramaciotti, L., & Rizzo, U. (2019). Migration, ethnic concentration and firm entry: evidence from Italian regions. Regional Studies, 53(1), 55-66.

Bilbiie, F. O., Ghironi, F., & Melitz, M. J. (2012). Endogenous entry, product variety, and business cycles. Journal of Political Economy, 120(2), 304-345.

Blalock, G., & Veloso, F. M. (2007). Imports, productivity growth, and supply chain learning. World Development, 35(7), 1134-1151.

Bloch, H., Rafiq, S., & Salim, R. (2015). Economic growth with coal, oil and renewable energy consumption in China: Prospects for fuel substitution. Economic Modelling, 44, 104-115.

Block, M. L., & Calderón-Garcidueñas, L. (2009). Air pollution: mechanisms of neuroinflammation and CNS disease. Trends in Neurosciences, 32(9), 506-516.

Braunerhjelm, P., & Eklund, J. E. (2014). Taxes, tax administrative burdens and new firm formation. Kyklos, 67(1), 1-11.

Bruno, R. L., Bytchkova, M., & Estrin, S. (2013). Institutional determinants of new firm entry in Russia: A cross-regional analysis. Review of Economics and Statistics, 95(5), 1740-1749.

Bwalya, S. M. (2006). Foreign direct investment and technology spillovers: Evidence from panel data analysis of manufacturing firms in Zambia. Journal of Development Economics, 81(2), 514-526.

Calonico, S., Cattaneo, M. D., & Titiunik, R. (2014). Robust nonparametric confidence intervals for regression-discontinuity designs. Econometrica, 82(6), 2295-2326.

Candau, F., & Dienesch, E. (2017). Pollution haven and corruption paradise. Journal of Environmental Economics and Management, 85, 171-192.

Cao, Z., Zhou, J., Li, M., Huang, J., & Dou, D. (2023). Urbanites' mental health undermined by air pollution. Nature Sustainability, 1-9.

Carpentier, C., & Suret, J. M. (2015). Stock market and deterrence effect: A mid-run analysis of major environmental and non-environmental accidents. Journal of Environmental Economics and Management, 71, 1-18.

Cetorelli, N., & Strahan, P. E. (2006). Finance as a barrier to entry: Bank competition and industry structure in local US markets. The Journal of Finance, 61(1), 437-461.

Chang, K., Pei, P., Zhang, C., & Wu, X. (2017). Exploring the price dynamics of CO2 emissions allowances in China's emissions trading scheme pilots. Energy Economics, 67, 213-223.

Chang, T. Y., Graff Zivin, J., Gross, T., & Neidell, M. (2019). The effect of pollution on worker productivity: evidence from call center workers in China. American Economic Journal: Applied Economics, 11(1), 151-72.

Chang, T., Graff Zivin, J., Gross, T., & Neidell, M. (2016). Particulate pollution and the productivity of pear packers. American Economic Journal: Economic Policy, 8(3), 141-169.

Chatterjee, S., & Cooper, R. (2014). Entry and exit, product variety, and the business cycle. Economic Inquiry, 52(4), 1466-1484.

Chen, S., Mao, H., & Feng, Z. (2020). Political uncertainty and firm entry: Evidence from Chinese manufacturing industries. Journal of Business Research, 120, 16-30.

Chen, S., Mao, H., & Feng, Z. (2020). Political uncertainty and firm entry: Evidence from Chinese manufacturing industries. Journal of Business Research, 120, 16-30.

Chen, S., Oliva, P., & Zhang, P. (2022). The effect of air pollution on migration: evidence from China. Journal of Development Economics, 156, 102833.

Chen, Y., Ebenstein, A., Greenstone, M., & Li, H. (2013). Evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River policy. Proceedings of the National Academy of Sciences, 110(32), 12936-12941.

Corradini, C., & Vanino, E. (2022). Path dependency, regional variety and the dynamics of new firm creation in rooted and pioneering industries. Journal of Economic Geography, 22(3), 631-651.

Covin, J. G., & Slevin, D. P. (1991). A conceptual model of entrepreneurship as firm behavior. Entrepreneurship Theory and Practice, 16(1), 7-26.

Currie, J., Neidell, M., & Schmieder, J. F. (2009). Air pollution and infant health: Lessons from New Jersey. Journal of Health Economics, 28(3), 688-703.

Da Rin, M., Di Giacomo, M., & Sembenelli, A. (2011). Entrepreneurship, firm entry, and the taxation of corporate income: Evidence from Europe. Journal of Public Economics, 95(9-10), 1048-1066.

Dardati, E. (2016). Pollution permit systems and firm dynamics: how does the allocation scheme matter?. International Economic Review, 57(1), 305-328.

Dean, T. J., & Brown, R. L. (1995). Pollution regulation as a barrier to new firm entry: Initial evidence and implications for future research. Academy of Management Journal, 38(1), 288-303.

Deschenes, O., Wang, H., Wang, S., & Zhang, P. (2020). The effect of air pollution on body weight and obesity: Evidence from China. Journal of Development Economics, 145, 102461.

Diette, G. B., Markson, L., Skinner, E. A., Nguyen, T. T., Algatt-Bergstrom, P., & Wu, A. W. (2000). Nocturnal asthma in children affects school attendance, school performance, and parents' work attendance. Archives of Pediatrics & Adolescent Medicine, 154(9), 923-928.

Dijkstra, H. (2022). Entrepreneurs are key assets to systemically address marine plastic pollution. Nature Reviews Earth & Environment, 3(11), 720-721.

Dixit, A. K., Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. The American Economic Review, 67(3), 297-308.

Ebenstein, A., Fan, M., Greenstone, M., He, G., & Zhou, M. (2017). New evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River Policy.

Proceedings of the National Academy of Sciences, 114(39), 10384-10389.

Erhardt, K., & Haenni, S. (2022). The Cultural Roots of Firm Entry, Exit and Growth. The Economic Journal, 132(648), 2767-2814.

Estrin, S., & Prevezer, M. (2010). A survey on institutions and new firm entry: How and why do entry rates differ in emerging markets?. Economic Systems, 34(3), 289-308.

Folmer, H., & Howe, C. W. (1991). Environmental problems and policy in the single European market. Environmental and Resource Economics, 1, 17-41.

Freedman, M. L., & Kosová, R. (2012). Agglomeration, product heterogeneity and firm entry. Journal of Economic Geography, 12(3), 601-626.

Freeman, R., Liang, W., Song, R., & Timmins, C. (2019). Willingness to pay for clean air in China. Journal of Environmental Economics and Management, 94, 188-216.

Fu, S., Viard, V. B., & Zhang, P. (2021). Air pollution and manufacturing firm productivity: Nationwide estimates for China. The Economic Journal, 131(640), 3241-3273.

Fu, S., Viard, V. B., & Zhang, P. (2021). Air pollution and manufacturing firm productivity: Nationwide estimates for China. The Economic Journal, 131(640), 3241-3273.

Gargan, J. J. (1981). Consideration of local government capacity. Public Administration Review, 41(6), 649-658.

Godzinski, A., & Castillo, M. S. (2021). Disentangling the effects of air pollutants with many instruments. Journal of Environmental Economics and Management, 109, 102489.

Gourio, F., Messer, T., & Siemer, M. (2016). Firm entry and macroeconomic dynamics: a state-level analysis. American Economic Review, 106(5), 214-218.

Gourio, F., Messer, T., & Siemer, M. (2016). Firm entry and macroeconomic dynamics: a state-level analysis. American Economic Review, 106(5), 214-218.

Groen, H. J., & Hiltermann, T. J. N. (2019). Air pollution and adenocarcinoma in never-smokers. Journal of Thoracic Oncology, 14(5), 761-763.

Guo, M., Kuai, Y., & Liu, X. (2020). Stock market response to environmental policies: Evidence from heavily polluting firms in China. Economic Modelling, 86, 306-316.

Guo, S., Lin, G., & Ouyang, A. Y. (2023). Are pro-SME credit policies effective? Evidence from shadow banking in China. Economic Modelling, 119, 106115.

Hammarstedt, M. (2004). Self-employment among immigrants in Sweden–an analysis of intragroup differences. Small Business Economics, 23, 115-126.

Hanna, R., & Oliva, P. (2015). The effect of pollution on labor supply: Evidence from a natural experiment in Mexico City. Journal of Public Economics, 122, 68-79.

Hanna, R., Oliva, P. (2015). The effect of pollution on labor supply: Evidence from a natural experiment in Mexico City. Journal of Public Economics, 122, 68-79.

He, G., Liu, T., & Zhou, M. (2020). Straw burning, PM2. 5, and death: Evidence from China. Journal of Development Economics, 145, 102468.

He, J., Liu, H., & Salvo, A. (2019). Severe air pollution and labor productivity: Evidence from industrial towns in China. American Economic Journal: Applied Economics, 11(1), 173-201.

He, P., Liang, J., Qiu, Y., Li, Q., & Xing, B. (2020). Increase in domestic electricity consumption from particulate air pollution. Nature Energy, 5(12), 985-995.

Helland, E., & Matsuno, M. (2003). Pollution abatement as a barrier to entry. Journal of Regulatory Economics, 24(2), 243-259.

Heyes, A., & Zhu, M. (2019). Air pollution as a cause of sleeplessness: Social media evidence from a panel of Chinese cities. Journal of Environmental Economics and Management, 98, 102247.

Heyes, A., Neidell, M., & Saberian, S. (2016). The effect of air pollution on investor behavior: Evidence from the S&P 500 (No. w22753). National Bureau of Economic Research.

Hingtgen, N., Kline, C., Fernandes, L., & McGehee, N. G. (2015). Cuba in transition: Tourism industry perceptions of entrepreneurial change. Tourism Management, 50, 184-193.

Hjort, J., & Poulsen, J. (2019). The arrival of fast internet and employment in Africa. American Economic Review, 109(3), 1032-79.

Holtz-Eakin, D. (2000). Public policy toward entrepreneurship. Small Business Economics, 15, 283-291.

Hopenhayn, H., Neira, J., & Singhania, R. (2022). From population growth to firm demographics: Implications for concentration, entrepreneurship and the labor share. Econometrica, 90(4), 1879-1914.

Hopenhayn, H., Neira, J., & Singhania, R. (2022). From population growth to firm demographics: Implications for concentration, entrepreneurship and the labor share. Econometrica, 90(4), 1879-1914.

Hupenhayn, H. A., (1992). Entry, Exit, and Firm Dynamics in Long Run Equilibrium. Econometrica, 60(5), 1127.

Javadi, S., & Masum, A. A. (2021). The impact of climate change on the cost of bank loans.

Journal of Corporate Finance, 69, 102019.

Jepsen, C., Mueser, P., & Troske, K. (2016). Labor market returns to the GED using regression discontinuity analysis. Journal of Political Economy, 124(3), 621-649.

Jones, C. I., & Tonetti, C. (2020). Nonrivalry and the Economics of Data. American Economic Review, 110(9), 2819-58.

Klapper, L., Laeven, L., & Rajan, R. (2006). Entry regulation as a barrier to entrepreneurship. Journal of Financial Economics, 82(3), 591-629.

Klingen, J., & van Ommeren, J. (2022). Risk-Taking and Air Pollution: Evidence from Chess. Environmental and Resource Economics, 81(1), 73-93.

Landrigan, P. J. (2017). Air pollution and health. The Lancet Public Health, 2(1), e4-e5.

Lanzi, E., Dellink, R., & Chateau, J. (2018). The sectoral and regional economic consequences of outdoor air pollution to 2060. Energy Economics, 71, 89-113.

Lee, D. S., & Lemieux, T. (2010). Regression discontinuity designs in economics. Journal of Economic Literature, 48(2), 281-355.

Lei, Z., & Shcherbakova, A. V. (2015). Revealing climate change opinions through investment behavior: Evidence from Fukushima. Journal of Environmental Economics and Management, 70, 92-108.

Li, C. K., Luo, J. H., & Soderstrom, N. S. (2020). Air pollution and analyst information production. Journal of Corporate Finance, 60, 101536.

Li, H., & Zhou, L. A. (2005). Political turnover and economic performance: the incentive role of personnel control in China. Journal of Public Economics, 89(9-10), 1743-1762.

Li, Q., & Peng, C. H. (2016). The stock market effect of air pollution: evidence from China. Applied Economics, 48(36), 3442-3461.

Lichter, A., Pestel, N., & Sommer, E. (2017). Productivity effects of air pollution: Evidence from professional soccer. Labour Economics, 48, 54-66.

Liu, C., Hsu, P. C., Lee, H. W., Ye, M., Zheng, G., Liu, N., ... & Cui, Y. (2015). Transparent air filter for high-efficiency PM2. 5 capture. Nature Communications, 6(1), 6205.

Liu, G., Yang, Z., Zhang, F., & Zhang, N. (2022). Environmental tax reform and environmental investment: A quasi-natural experiment based on China's Environmental Protection Tax Law. Energy Economics, 109, 106000.

Ma, T., Cao, X., & Zhao, H. (2023). Development zone policy and high-quality economic growth: quasi-natural experimental evidence from China. Regional Studies, 57(3), 590-605.

McCrary, J. (2008). Manipulation of the running variable in the regression discontinuity design: A density test. Journal of Econometrics, 142(2), 698-714.

McMillan, M., Rodrik, D., & Verduzco-Gallo, Í. (2014). Globalization, structural change, and productivity growth, with an update on Africa. World Development, 63, 11-32.

Nikiforou, A., Dencker, J. C., & Gruber, M. (2019). Necessity entrepreneurship and industry choice in new firm creation. Strategic Management Journal, 40(13), 2165-2190.

Norbäck, P. J., Persson, L., & Douhan, R. (2014). Entrepreneurship policy and globalization. Journal of Development Economics, 110, 22-38.

Pan, S. (2023). Health, air pollution, and location choice. Journal of Environmental Economics and Management, 102794.

Pandey, A., Brauer, M., Cropper, M. L., Balakrishnan, K., Mathur, P., Dey, S., ... & Dandona, L. (2021). Health and economic impact of air pollution in the states of India: the Global Burden of Disease Study 2019. The Lancet Planetary Health, 5(1), e25-e38.

Papanek, G. F. (1962). The development of entrepreneurship. The American Economic Review, 52(2), 46-58.

Patra, S. (2020). Energy in a model of firm entry. Macroeconomic Dynamics, 24(2), 231-254.

Pflüger, M., & Südekum, J. (2013). Subsidizing firm entry in open economies. Journal of Public Economics, 97, 258-271.

Premand, P., Brodmann, S., Almeida, R., Grun, R., & Barouni, M. (2016). Entrepreneurship education and entry into self-employment among university graduates. World Development, 77, 311-327.

Pun, V. C., Manjourides, J., & Suh, H. (2017). Association of ambient air pollution with depressive and anxiety symptoms in older adults: results from the NSHAP study. Environmental Health Perspectives, 125(3), 342-348.

Qin, Y., & Zhu, H. (2018). Run away? Air pollution and emigration interests in China. Journal of Population Economics, 31(1), 235-266.

Sager, L. (2019). Estimating the effect of air pollution on road safety using atmospheric temperature inversions. Journal of Environmental Economics and Management, 98, 102250.

Santarselli, E., Carree, M., & Verheul, I. (2009). Unemployment and firm entry and exit: an update on a controversial relationship. Regional Studies, 43(8), 1061-1073.

Schultz, T. W. (1962). Reflections on investment in man. Journal of Political Economy, 70(5, Part 2), 1-8.

Schulz, M., Urbig, D., & Procher, V. (2016). Hybrid entrepreneurship and public policy: The case of firm entry deregulation. Journal of Business Venturing, 31(3), 272-286.

Schumpeter, J., Backhaus, U. (2003). The theory of economic development (pp. 61-116). Springer, Boston, MA.

Seim, K. (2006). An empirical model of firm entry with endogenous product-type choices. The RAND Journal of Economics, 37(3), 619-640.

Shi, X., & Zhang, X. (2021). Extreme temperature and firm dynamics: the case of Chinese manufacturing. Available at SSRN, 3981739.

Shi, X., Xi, T., Zhang, X., & Zhang, Y. (2021). "Moving Umbrella": Bureaucratic transfers and the comovement of interregional investments in China. Journal of Development Economics, 153, 102717.

Shi, X., Zhang, X. (2021). Extreme temperature and firm dynamics: the case of chinese manufacturing. Available at SSRN, 3981739.

Smirnyagin, V. (2022). Returns to scale, firm entry, and the business cycle. Journal of Monetary Economics.

Stafford, T. M. (2015). Indoor air quality and academic performance. Journal of Environmental Economics and Management, 70, 34-50.

Tai, A. P., Martin, M. V., & Heald, C. L. (2014). Threat to future global food security from climate change and ozone air pollution. Nature Climate Change, 4(9), 817-821.

Tsvetkova, A., & Partridge, M. (2021). Knowledge-based service economy and firm entry: an alternative to the knowledge spillover theory of entrepreneurship. Small Business Economics, 56, 637-657.

Tu, Z., Hu, T., & Shen, R. (2019). Evaluating public participation impact on environmental protection and ecological efficiency in China: Evidence from PITI disclosure. China Economic Review, 55, 111-123.

Unfried, K., Kis-Katos, K., & Poser, T. (2022). Water scarcity and social conflict. Journal of Environmental Economics and Management, 113, 102633.

Urbano, D., Aparicio, S., & Audretsch, D. (2019). Twenty-five years of research on institutions, entrepreneurship, and economic growth: what has been learned?. Small Business Economics, 53, 21-49.

Wang, L., Dai, Y., & Kong, D. (2021). Air pollution and employee treatment. Journal of Corporate Finance, 70, 102067.

Wang, R., Wijen, F., & Heugens, P. P. (2018). Government's green grip: Multifaceted state influence on corporate environmental actions in China. Strategic Management Journal, 39(2), 403-428.

World Health Organization, 2022. WHO Air Quality Database 2022. Available from: https://www.who.int/data/gho/data/themes/airpollution/who-air-quality-database.

Wu, Y., Yang, X., Wang, H., Jia, G., & Wang, T. (2021). Relationship between ambient $PM_{2.5}$ exposure and blood cadmium level in children under 14 years in Beijing, China. Journal of Hazardous Materials, 403, 123871.

Xue, S., Zhang, B., & Zhao, X. (2021). Brain drain: The impact of air pollution on firm performance. Journal of Environmental Economics and Management, 110, 102546.

Yao, Y., Li, X., Smyth, R., & Zhang, L. (2022). Air pollution and political trust in local government: Evidence from China. Journal of Environmental Economics and Management, 115, 102724.

Yue, H., He, C., Huang, Q., Yin, D., & Bryan, B. A. (2020). Stronger policy required to substantially reduce deaths from $PM_{2.5}$ pollution in China. Nature Communications, 11(1), 1462.

Zhang, X., Ou, X., Yang, X., Qi, T., Nam, K. M., Zhang, D., & Zhang, X. (2017). Socioeconomic burden of air pollution in China: Province-level analysis based on energy economic model. Energy Economics, 68, 478-489.

Zheng, S., Wang, J., Sun, C., Zhang, X., & Kahn, M. E. (2019). Air pollution lowers Chinese urbanites’ expressed happiness on social media. Nature Human Behaviour, 3(3), 237-243.

Zhou, D., Qiu, Y., & Wang, M. (2021). Does environmental regulation promote enterprise profitability? Evidence from the implementation of China's newly revised Environmental Protection Law. Economic Modelling, 102, 105585.

Zhou, L., Tian, X., & Zhou, Z. (2017). The effects of environmental provisions in RTAs on $PM_{2.5}$ air pollution. Applied Economics, 49(27), 2630-2641.

Zhu, J., & Xu, J. (2022). Air pollution control and enterprise competitiveness–A re-examination based on China's Clean Air Action. Journal of Environmental Management, 312, 114968.

Zhu, X., Zuo, X., & Li, H. (2021). The dual effects of heterogeneous environmental regulation on the technological innovation of Chinese steel enterprises—Based on a high-dimensional fixed effects model. Ecological Economics, 188, 107113.

Ziegler, A. (2021). New Ecological Paradigm meets behavioral economics: On the relationship between environmental values and economic preferences. Journal of Environmental Economics and Management, 109, 102516.

Zivin, J. G., & Neidell, M. (2012). The impact of pollution on worker productivity. American Economic Review, 102(7), 3652-3673.

Zivin, J. G., & Neidell, M. (2013). Environment, Health, and Human Capital. Journal of Economic Literature, 51(3), 689.