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Air Pollution and Entrepreneurship*

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Abstract

We examine the causal effect of air pollution on an individual's propensity for entrepreneurship in China. Our preferred model, which employs an instrumental variable approach to address endogeneity arising from sorting into entrepreneurship and locational choices, suggests that exposure to higher intensity of air pollution lowers one's proclivity for entrepreneurship. A one standard deviation increase in air pollution leads to a 21.2% decrease in the propensity for entrepreneurship. We also find that self-efficacy is a channel in the relationship between air pollution and entrepreneurship. In addition, education moderates the relationship between air pollution and self-efficacy.

KEYWORDS

Air pollution; Entrepreneurship; China

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1. Introduction

Nine out of ten people worldwide are exposed to a high concentration of air pollutants (World Health Organization, 2018). Both outdoor (ambient) and indoor (household) air pollution can damage physical health (Ghanem, 2018), mental health and cognition (Zhang et al., 2017; Isen et al., 2017). Nevertheless, the negative impact of outdoor air pollution is the most challenging to address (Hu et al., 2019). An extensive body of epidemiological literature shows that outdoor air pollution exposure leads to adverse health consequences, while several recent studies in economics find that air pollution also affects productivity and human capital accumulation by impacting the functioning of the human body and brain. These effects, in turn, influence emotional status, memory, cognition, physical endurance, concentration, and absenteeism (Currie et al., 2009; Evans and Jacobs, 1981; Zivin and Neidell, 2013). The resulting loss in the human capital accumulated often manifests in a higher frequency of poor and biased decisions, as observed among students and employees (Chang et al., 2016, 2019; Stafford, 2015).

It, however, remains unclear if air pollution negatively influences ongoing decision-making activities such as those regularly carried out by entrepreneurs (defined by all types of entrepreneurs, i.e., both self-employed individuals and business owners) as part of their work¹. Yet this topic is important as entrepreneurs' decisions affect not only their companies' success but also local employment, investment, trade and economic growth. As air pollution diminishes individual performance and productivity, it may also prevent the rise of entrepreneurship since this requires a sustained level of sound decision-making and performance. Moreover, people with entrepreneurial aspirations but live in highly polluted areas may give up their preferred employment choice or migrate to less polluted to start their businesses. Although there is macro-level evidence on the harmful effects of air pollution on entrepreneurial activities, in-depth

¹ Previous literature defines entrepreneurs as those who work for themselves in non-agricultural sectors, as opposed to those who work for others in non-agricultural sectors or who work in agricultural sectors (Steinmetz and Wright, 1989). It includes Schumpeterian entrepreneurs and managerial business owners. Schumpeterian entrepreneurs are innovative high-growth entrepreneurs. And Schumpeterian entrepreneurship is an important pillar for economic development and might bring dramatic technological breakthroughs and revolutionize an entire industry (Block et al., 2017).

investigation by using micro-data is needed to confirm the relationship between air pollution and personal entrepreneurial behaviors (Zhao et al., 2022). It is also worth investigating the mechanisms if air pollution does affect entrepreneurial activities.

We address these questions by using the data collected by the China Health and Retirement Longitudinal Study (CHARLS), combined with data on air pollution, thermal inversions and weather conditions sourced from the National Aeronautics and Space Administration (NASA) and city-level information from the *China City Statistical Yearbooks* and the *China Statistical Yearbooks*.

We find that those who experience more severe air pollution are less likely to start a business. In the correlation between air pollution and entrepreneurial decisions, we find that self-efficacy is a channel, consistently with the hypothesis that would-be entrepreneurs are doubtful about their personal abilities if they live in a highly polluted area. The results contribute evidence that air pollution is not only a health hazard but an economic problem, as it affects productivity and entrepreneurship.

The rest of the paper is organized as follows. In the next section, we begin by reviewing the relevant literature on air pollution and entrepreneurship to develop the framework and derive a set of testable hypotheses. We explain the methodology in Section 3 and report the empirical results in Section 4. In the last section, we discuss the main implications of our findings for research and policy.

2. Literature Review

Our analysis builds on established evidence that people exposed to air pollution tend to have lower productivity, a higher probability of physical and mental health issues relative to people who are not (Chen, 2018). Given such evidence, we advance the hypothesis that prospective entrepreneurs located in highly polluted areas make a conscious decision about whether and if so where to engage in entrepreneurial activities. Such decision, in turn, relies on their individual-level characteristics (such as physical health, self-efficacy and self-rated social

status²). We hence posit that individuals with entrepreneurial aspirations are less willing to start a business if they live in a highly polluted area. We also posit that a person's level of education—representing their level of cognition before entering the labor market—may play a pivotal role in undertaking such choice, in that it affects self-efficacy and thereby influences the inclination to pursue entrepreneurship. In addition to individual-level influences, high levels of air pollution may also affect the city-level characteristics, thus providing an unfavorable business environment for aspirational entrepreneurs.

2.1 Air Pollution and Productivity

Exposure to air pollution puts individuals at a disadvantage in terms of productivity. The relevant literature suggests that the productivity of manual workers such as fruit packers (Chang et al., 2016), those with white-collar jobs such as call-center workers (Chang et al., 2019), and workers with complex professional jobs such as investors and judges (Kahn and Li, 2019; Meyer and Pagel, 2017) are adversely affected by air pollution. The performance of people in high-pressure situations, such as athletes (Lichter et al., 2017), referees (Archsmith et al., 2018) and chess players (Künn et al., 2019), has also been found to be negatively impacted by air pollution. In the long run, one consequence of air pollution harming productivity is a reduction in local economic development. Our study is consistent with the literature that found exposures to air pollutants increase the risk of productivity loss. If air pollution negatively affects productivity, the entrepreneurial productivity of time devoted to businesses will decrease. To the best of our knowledge, the studies have not directly assessed the outcomes of air pollution on entrepreneurial choices using detailed individual-level information. And we contribute to the substantive evidence of the socio-economic toll of air pollution by looking at the new insights regarding the correlation between air pollution and entrepreneurship. The preceding discussion leads us to hypothesize:

² Self-efficacy is people's belief in their ability to achieve something (Bandura, 1977). Individuals' human capital, such as their physical and mental abilities, are the seeds that could help enhance self-efficacy (Zuhir et al., 2019). Note that, due to data limitations, we focus on self-efficacy instead of entrepreneurial self-efficacy.

2.2 Air Pollution and Entrepreneurship: The Mediating Role of Personal Characteristics

First, air pollution is one of the crucial factors that lead to diseases. For example, nitrogen dioxide and carbon monoxide are closely linked to pneumonia, chronic obstructive pulmonary infections, asthma and metabolic disorders (Fang et al., 2012; Gehring et al., 2013; Vella et al., 2015). Air pollution also causes deaths. According to global estimates, total pollution's impact is on par with that of smoking and more significant than that of war, terrorism, drugs and alcohol (Fuller et al., 2022).³

Good health conditions might be an important determinant of productivity and decision-making, especially for people who bear almost all of the risks and make most of the business decisions (Chao et al., 2010). Individuals in good health may have much time to think about complex entrepreneurship issues and believe they have enough energy to prepare for businesses and deal with challenges in entrepreneurship development. Because of these reasons, individuals with poor physical health will be unlikely to have enough physical ability, focus and time to start a business. The reduction in physical ability caused by poor physical health might negatively correlate with entrepreneurship. The lack of time to prepare for creating a new venture and self-directed suspicion (i.e., doubt about one's physical ability) lead to low self-evaluations and weak entrepreneurial orientation.

Second, subjective perception factors include self-efficacy and self-rated social status. According to investor sentiment theory, air pollution leads to negative emotions and expectations, and these cause people to make cognitive errors, auditors to make inaccurate professional judgments and investors to change trading behaviors (Ailshire et al., 2017; Song and Song, 2018; Wu et al., 2018).⁴

³ In 2019, air pollution remained responsible for 6.7 million deaths, accounting for approximately 74.4% of the total number of deaths caused by pollution worldwide (Fuller et al., 2022).

⁴ Moreover, air pollution may reduce individuals' self-efficacy by damaging cognitive performance. People with prolonged exposure to air pollution tend to exhibit low school test scores and weak working memory (Ebenstein et al., 2016; Shier et al., 2019; Vahedi, 2020). Taking the correlation between cognitive ability and learning efficacy into account (Burgoyne et al., 2016), weak cognition among potential entrepreneurs may lead to poor learning performance when preparing for entrepreneurship. For potential entrepreneurs, insufficient accumulation of

Entrepreneurs might have a strong internal locus of control and a high level of entrepreneurial self-efficacy. And self-efficacy might be related to entrepreneurial self-efficacy. Personal performance is a basis of self-efficacy. It will shape and estimate self-efficacy. The sense of self-efficacy will also predict performance. People with high self-efficacy will have a high intrinsic interest in tasks and tend to expand their effort and show persistence in front of obstacles. Recent studies also point out that self-efficacy enables people to have high self-motivation, positive expectations, low perceived discrepancy and increased effort allocation, which will help people to enact entrepreneurial intentions (Gielnik et al., 2020).

Moreover, some researchers argue that social status is an essential socioeconomic factor in creating entrepreneurs. Individuals' social capital, such as personal networks, could promote entrepreneurship (Kwon et al., 2013). In the Chinese context, many studies have shown the positive impact of social networks (i.e., individuals' social capital) on entrepreneurship, as social networks can help potential entrepreneurs obtain financing (Barnett et al., 2019).

Although studies in entrepreneurship focus on the individual-level determinants of becoming entrepreneurs, they do not look at the environmental circumstances of these individuals. By exploring the impact of air pollution on entrepreneurship through personal characteristics, we could understand how human behaviors change in response to the environment.

2.3 Air Pollution and Entrepreneurship: The Mediating Role of City Characteristics

Air pollution might increase criminal activities and could be harmful to the local economy. Increasing literature suggests that high air pollution is associated with high crime rates since it might increase mental health problems such as aggression, impulsivity and anxiety. Types of criminal activities include cybercrimes, violent and unpremeditated crimes (Herrnstadt et al., 2021; Kuo and Putra, 2021). If air pollution increases crime rates, it will negatively affect local

relevant skills and experiences before starting businesses may reduce their perceived self-efficacy in starting a business, as experiences are generally the critical components for successful companies.

economic development and, ultimately, make it unlikely to provide a favorable business environment.

China's economic reform in 1978 (i.e., the introduction of Reform and Opening-Up policies) by removing or lowering institutional barriers to market entry led to booming entrepreneurship. In alternative words, economic development could bring benefits to the performance of enterprises (He et al., 2019; Kwon et al., 2013). If crime rates increase and the local economic growth rates decrease, entrepreneurial activities will also be negatively affected. Also, highly polluted areas have high migration rates of highly educated and skilled workers (Chen et al., 2022; Qin and Zhu, 2018), which might affect the labor supply. In recent studies, only scarce attempts have been made to provide evidence on how city-level attributes impact individual-level outcomes under exposure to air pollution. And we contribute to the understudied macro-level perspective on the determinants of personal entrepreneurial choices.

2.4 Impact of Air Pollution on Entrepreneurship through Subjective Perception Factors: The Moderating Role of Education

Considering that a high education level may represent advantages in the labor market, such as high cognition, family background and opportunities, education level could act as a moderator of the correlation between air pollution and subjective perception factors. First, education is an input in the human capital production function and an essential element for overall skills (e.g., managerial, decision-making and new specialized knowledge) accumulation in the future. Individuals with lower education levels may be less efficient in skills development and problem-solving than people with higher education levels (Gustavsson, 2006). Second, the higher the initial level of cognition, the higher the sense of efficacy and self-esteem, which may increase individuals' perception of opportunities and ability to assess their business success in a certain sector. Thirdly, high education levels might signal high general capability. The possibility of entrepreneurship for more capable individuals may be higher than for their less-educated counterparts. Education level might impact self-perceived factors, and the exploration of the

mediated moderation role of education might be helpful in examining how people respond to air pollution differently.

3. Method

3.1 Data Analysis

We adopt the linear probability model to test the impact of air pollution on entrepreneurial choices. And we use a causal mediation analysis framework in instrumental-variable regressions to assess the effects of air pollution on entrepreneurship, mediated by personal and city characteristics. We group respondents by education level to test for heterogeneity. Our mediation approach is based on estimations of three regressions of the same sample (Baron and Kenny, 1987). First, we regress the entrepreneurship on air pollution. Second, we regress the mediator on air pollution. And finally, we regress the entrepreneurship on both mediator and air pollution. There is an indirect effect of air pollution on entrepreneurship if the results of the first and second regressions are significant, and the result of the mediator is significant in the third regression. Furthermore, there is a partial mediation (i.e., complementary mediation) if the coefficient of air pollution in the third regression is less than the first regression and significant. There is a full mediation (i.e., indirect-only mediation) if the air pollution in the third regression is not significant. And there is a suppressor effect (i.e., competitive mediation) if the coefficient of air pollution in the third regression is equal to or larger than the first regression and significant.

In the regressions, we include city fixed effects, month fixed effects and year fixed effects to control for the time-invariant factors of city, month and year, respectively. Robust standard errors are clustered at the household-level to adjust for heteroskedasticity and accommodate within-household autocorrelation over time (some households are observed twice due to the inclusion of both husband and wife responses).

Finally, we address the endogeneity problem in the model by using an instrumental variable. In this study, endogeneity mainly occurs because entrepreneurship and pollution-related factors cannot be fully controlled. For example, compared to other places, large cities might have lower

levels of entrepreneurship (due to severe air pollution) or higher levels (due to higher development, more entrepreneurial talent, and more measures to protect against air pollution, such as the promotion of electric vehicles and the installation of air purifiers in public places).

We follow the recent studies on air pollution to construct an instrumental variable using thermal inversions (He et al., 2019; Liu and Salvo, 2018; Qin et al., 2019). Thermal inversions can only affect air pollution when the pollutants exist, and thermal-inversion-induced air pollution will affect entrepreneurship through the original air pollution. Thus, we use values for temperature inversions in the atmosphere, wind speed, wind direction, and the number of stagnation days (i.e., days with positive thermal inversion values) in the regression predicting PM2.5. Moreover, we adopt the fitted value of PM2.5 in the first-stage regression in our analysis. Considering that the relationship between thermal inversions and air pollution might be non-linear, we use their squared terms in robustness checks. The instrumental variable is exogenous as the temperature inversions, wind speed, and wind direction in the atmosphere are natural phenomena and may exacerbate the level of air pollution.

3.2 Limitations and Suggestions for Future Analysis

First, we focus only on the impact of air pollution on the decision to become an entrepreneur, yet the measures taken by established companies to deal with air pollution and the subsequent consequences might also be valuable topics for further study. Following the existing literature, air pollution and corporate measures may also have a causal relationship. Specifically, when the level of air pollution increases, companies may adopt environmentally friendly techniques to improve their environmental management under the influence of corporate responsibility or government policies, and these actions may decrease the concentrations of air pollutants.

Second, although we adopt PM2.5 as an independent variable, other environmental factors may also impact entrepreneurship, and their effects are unclear. As other environmental factors may have different impacts on productivity, we assume that they may also have different effects

on entrepreneurship. For example, temperature and productivity have an inverted U-shaped relationship (i.e., the extreme temperature will have a significant adverse impact on human-capital accumulation) (Zivin and Neidell, 2014), and this might be due to the adaptation effects of humans.

Third, we investigate that air pollution might negatively affect people's proclivity to become entrepreneurs through several channels. Future research could focus on the mediating roles of other social factors (e.g., childhood adversity, domestic violence and inequality) and provide a comprehensive view of the impact of air pollution on general entrepreneurship.

Fourth, researchers could try to identify further long-term effects of air pollution on entrepreneurship. Future work could distinguish between the cumulative effects of air pollution and the human body's habituation effects on air pollutants. By looking at multiple lags of air pollution and the impacts of early-stage exposure on different phases of the life cycle, we could understand how to mitigate air pollution's harmful impacts in the long run.

Finally, both firm formation rates and firm dissolution rates could represent entrepreneurship; future research could address our study's limitations by using firm-level data and measuring the impact of air pollution on business failures.

3.3 Sample

Participants in the study were urban Chinese included in the CHARLS. The CHARLS dataset we utilize was initiated by Peking University in China in 2011. The CHARLS was conducted in 2011, 2013, 2015 and 2018 and included 28 provinces in the sample. Moreover, the researchers of the CHARLS utilized systematic probability proportional to size sampling with implicit stratification by administrative boundary and socioeconomic status. Then, they obtained a multi-stage probability sample. Finally, the CHARLS's baseline survey contains 10,257 households in 150 counties and consists of information on adults, families and communities. The CHARLS datasets provide city-level geographical information.

Compared with other surveys, the CHARLS have more detailed geographic information, a longer follow-up period, a larger sample size, and more variables that reflect middle-aged individuals and the elders' characteristics⁵. We use CHARLS data from 2011, 2013, 2015 and 2018 to create a city-level dataset, adopting cross-sectional data so that all interviewees were surveyed at least once.⁶ Our working sample contains 10,362 adults, with a total of 19,089 data points.

We obtained air pollution data from the NASA Socioeconomic Data and Applications Center at Columbia University.⁷ This satellite-derived data are used to measure the annual global surface concentrations of ground-level PM_{2.5} ($\mu\text{g}/\text{m}^3$). The dataset has a high grid cell resolution of 0.01 degrees (latitude) \times 0.01 degrees (longitude) (Van Donkelaar et al., 2016, 2018). And the data confirm the significant variations of PM_{2.5} concentrations across cities in our dataset: the mean and standard deviation of the PM_{2.5} concentrations in the sample are 53.264 $\mu\text{g}/\text{m}^3$ and 21.233 $\mu\text{g}/\text{m}^3$, respectively.

3.4 Measures

All the measures in the survey were constructed in Chinese, and CHARLS provides official English versions of the questionnaires and datasets on its website. The data from the Yearbooks are also provided in the original Chinese and official English versions. To assure the accuracy and consistency of the air pollution and weather condition data, we adopted data only from NASA in the United States, which provides data in English.

The survey questions changed slightly from year to year. We match the variables according to their original meaning or response options. If the answer options have different ranges or scales, we indicate this in the item descriptions below.

⁵ For example, for the self-efficacy variable in the CFPS, we need to eliminate the error due to scale mismatch and increase comparability across years.

⁶ We also use panel data to test the hypotheses, and the results are robust.

⁷ The data can be found at: <https://beta.sedac.ciesin.columbia.edu/data/set/sdei-global-annual-gwr-pm2-5-modis-misr-seawifs-aod-v4-gl-03>.

Entrepreneurship. We focus on people who are employed or self-employed. They have different skills and experiences and work in various sectors and industries. They might be, for example, physical laborers, salespersons, equipment or machinery operators, doctors, or leaders of enterprises. Although these people have divergent skills and experiences, most of them could invest in businesses if they had entrepreneurial intentions. This is because individuals with enough financial or social capital can make decisions to enter or exit the market in many industries under the permission of relevant regulations. We attempt to reduce the bias in the estimations by excluding people who worked in agriculture (i.e., casual agricultural workers and those who do agricultural work for their families or other families). Although agrarian workers might also be affected by air pollution, the reasons for and conditions of their entrepreneurial decisions might differ from those in the non-agricultural labor force. Thus, our study focuses on non-agricultural individuals.

We measured individuals' entrepreneurial actions using the adults' primary job type reported in the surveys.⁸ After excluding agricultural workers, we created a dichotomous variable representing an individual's entrepreneurial behavior; the variable is coded as one if the individual started a new venture and as zero if the individual worked at a company owned by someone else.

Air pollution. We used PM2.5 to measure air quality and matched it at the city-level with the CHARLS data. This is a reasonable measure of air pollutants because the fine particulate matter of 2.5 micrometers or smaller is more harmful to people's physical health than larger and more extensive particulate matter.

Thermal-inversion-induced air pollution. Following previous studies on air pollution, we use atmospheric thermal inversions to adjust the measurement error and solve the endogenous problem of air pollution arising from sorting, avoidance behaviors and the relationship between

⁸ Job types include entrepreneurship, waged jobs and agriculture work.

air pollution and economic activities. Specifically, air pollutants are not randomly assigned. Individuals may try to avoid exposure to air pollution. And areas with high economic growth tend to have high levels of air pollution. Yet, they will provide a favorable living environment, mitigating the negative impact of air pollution on human beings (Jans et al., 2018).⁹

We calculate the temperature differences from 1,000 to 850 hPa and adopt the predicted PM2.5 based on temperature differences as an instrumental variable for air pollution in the analysis. The first-stage specifications are as follows:

$$PM_{2.5,t,j} = PM_fit_{2.5,t,j} + X_{t,j} + \varepsilon_{t,j}, \quad (1)$$

$$PM_fit_{2.5,t} = \sum_0^t \sum_0^j \gamma_{1,t,j} InverValue_{t,j} + \sum_0^t \sum_0^j \sum_0^l \gamma_{2,t,j,l} WS_{t,j,l} + \sum_0^t \sum_0^j \sum_0^l \gamma_{3,t,j,l} WD_{t,j,l} + \sum_0^t \sum_0^j \sum_0^l \gamma_{4,t,j,l} InverDay_{t,j,l} + \varepsilon_{t,j}, \quad (2)$$

In Equation (1) and Equation (2), where $PM_fit_{2.5,t}$ represents the fitted value of PM2.5 at time t in city j . In Equation (1), $PM_{2.5,t}$ is PM2.5 at time t in city j , and X_t is the set of control variables. As for Equation (2), $InverValue_{t,j}$ is the value of thermal inversions at time t in city j ; $WS_{t,j,l}$, $WD_{t,j,l}$, and $InverDay_{t,j,l}$ denote wind speed, wind direction, and the number of occurrences of temperature inversions at time t in city j at layer l , respectively. The data source is the Modern-Era Retrospective Analysis for Research and Applications version 2 project, which

⁹ Thermal inversions occur in three ways. They are generated on clear nights when the ground and the air touching the ground are cooled faster than the higher air layers. This is because the Earth's infrared emissions warm the higher layers of the atmosphere (radiation inversions). Vertical air movement causes a cold air layer to descend through a hot air layer (subsidence inversions). Moreover, when layers of air at different temperatures move horizontally, a layer of cold air develops below a layer of hot air (advection inversions; Jacobson, 2002).

provides historical atmospheric climate records.¹⁰ And we aggregate the 6-hourly data to yearly mean data.¹¹

Channels. We utilize a dichotomous variable, whether the respondents visited the hospital last month to reflect their physical health status. And we adopt individuals' self-efficacy and self-rated social status as mechanisms through which air pollution affects entrepreneurship. The survey interviewers asked adults how frequently they had felt bothered by things that don't usually bother them during the past week. We converted the scales of the variable and constructed a dummy variable represents adults' self-efficacy (low self-efficacy = 0, high self-efficacy = 1). Moreover, the interviewers asked adults, "Overall, how would you rate your own standard of living? Is it very high, relatively high, average, relatively poor or poor?" After converting the scales of answers, constructed responses ranged from 1 (poor) to 5 (very high), with higher values as a proxy of higher social status. Furthermore, we calculate the city's criminal activity by using the number of people arrested for violent crimes by the procuratorate per ten thousand people calculated from the data in People's Procuratorate work reports¹².

Controls. The survey includes many questions on individuals' characteristics that could be covariates. Including these variables could eliminate bias in the estimation because they may impact ambient air pollution and entrepreneurial decisions, but they cannot be influenced by air pollution and entrepreneurship. The control variables at the individual-level are age, age squared, sex (female = 0, male = 1), education level (below high school = 0, equal to or above high

¹⁰ The data can be accessed at https://disc.sci.gsfc.nasa.gov/datasets/M2I6NPANA_5.12.4/summary?keywords=M2I6NPANA.

Also, some researchers use thermal inversions data from National Oceanic and Atmospheric Administration (NOAA) (He et al., 2019), which are slightly different from the data we use. The NOAA atmospheric temperature at standard pressure points (e.g., 1,000 hPa) or other detailed pressure points (e.g., 999 hPa) is easily accessed. However, the NASA data we obtained only directly show the average temperature in standard pressure points, while the data at other pressure points need to be further calculated. Considering that the previous literature mainly focuses on the differences between layers of standard pressure points, we do not pay attention to other pressure points in this study.

¹¹ Wind can transport air pollution. Researchers have found that the variation of meteorological parameters, such as wind speed and direction, can cause pollutant dispersion (Verma and Desai, 2008). Studies have also confirmed that PM_{2.5} and other pollutants can traverse considerable distances (Deryugina et al., 2019).

¹² Many cities in our sample does not provide criminal activities data in official websites.

school = 1), whether the individual migrated to other provinces (non-migrant = 0, migrant = 1), hukou status (rural = 0, urban = 1), marital status (never married = 1, separated, divorced, widowed = 2, married with spouse present, or married but not living with spouse temporarily for reasons such as work = 3), number of people living in this household, financial status compared to the average family in the same area before the age of 17 years old, health condition compared to other children of same age before the age of 16 years old, whether covered by public medical insurance and non-entrepreneurial status (entrepreneurial = 0, non-entrepreneurial = 1).¹³ City attributes include the real gross domestic product (GDP) per capita (1978 = 100) and population density, as reported in the *China City Statistical Yearbook*.¹⁴ Furthermore, in the heterogeneity test, we use education level. Considering that weather could significantly affect individual performance, we collected weather information from NASA.¹⁵ The weather control variable is surface-level temperature, precipitation and wind speed.¹⁶ We also control for a dummy variable to measure if there are large variations among the counties within the same city (no = 0, yes = 1).

4. Results

 Insert Table 1 about here

The descriptive statistics for the variables of all samples, educated individuals and less-educated individuals are presented in Table 1.¹⁷ In the data from all samples, about 23.0% of participants are entrepreneurs, and most of them are less educated. 15.1% of individuals went to

¹³ To explore the impact of air pollution on general entrepreneurship, we view the people who have no employees in firms as non-entrepreneurs in the analysis. We would downward bias the results if including this group of people. Due to data limitations, we do not contain other types of non-entrepreneurial people. Non-entrepreneurial people might be those who work in government, computer science or finance, entrepreneurs with simple physical work, and individuals with many years of schooling.

¹⁴ The GDP deflator was calculated by nominal and real GDP, which are sourced from the *China Statistical Yearbook*.

¹⁵ For surface-level temperature, the spatial grid is 0.25 degrees (latitude) \times 0.25 degrees (longitude), and the data frequency is every three hours. The data were gathered from the NASA Global Land Data Assimilation System: https://disc.sci.gsfc.nasa.gov/datasets/GLDAS_NOAH025_3H_2.1/summary?keywords=GLDAS_NOAH025_3H.2.1.

¹⁶ Weather data were gathered via <http://daac.gsfc.nasa.gov/>. Note that precipitation might reduce the occurrences of thermal inversions and closely correlates with relative humidity.

¹⁷ The analysis was conducted using STATA (version 16.0 MP).

the hospital last month. The average self-efficacy for adults is 0.605 (SD = 0.489), and the average self-rated social status is 2.439 (SD = 0.779); both means are similar to the median values. The average number of people arrested for violent crimes by the procuratorate per ten thousand people is 7.727. Of the interviewees, 67.0% are male, 20.0% attended high school or above, 8.8% migrated from other provinces, 27.3% have non-agricultural hukou and 5.6% are coded as non-entrepreneurial. Moreover, the data indicate that the levels of air pollution vary greatly across cities, and the average annual mean PM2.5, 53.264 μgm^{-3} , is largely higher than the primary annual mean National Ambient Air Quality Standard of 12 μgm^{-3} set by the United States Environmental Protection Agency.¹⁸

To compare the impact of air pollution on entrepreneurial actions by education level, we report the summary statistics after grouping respondents by their level of education. We also conducted a univariate test, again segregating interviewees by education level, to identify any differences between the two groups. The results show that the group differences are significant (the Welch's t-statistic of entrepreneurship and PM2.5 are 11.768 and -5.992, respectively). Table 1 indicates that the distributions of entrepreneurship and air pollution across education levels are very similar to the distributions in all samples. Yet, considering that descriptive statistics do not fully capture the relationship between air pollution and entrepreneurial behaviors, and the relationship might change when including the micro-level and macro-level controls, we explore our research questions through further empirical analysis.

 Insert Table 2 about here

Table 2 reveals the results of the estimation using a linear probability model and a two-stage least squares regression. Column (1) in Table 2 presents the results of the linear probability

¹⁸ We could find the air quality standard on the website: <https://www.epa.gov/criteria-air-pollutants/naaqs-table>.

model. The findings indicate that the impact of air pollution on entrepreneurship is not significant. However, based on the above discussion, we suspect that the estimation of the linear probability model is biased, so we use an instrumental variable to construct a two-stage least squares regression. As reported in column (2), the results indicate that an increase in the growth rate of PM2.5 corresponds to a decrease in entrepreneurship. Specifically, a one unit increase in PM2.5 concentrations will reduce the propensity for entrepreneurship by 0.010 units, equivalent to -21.2% of one standard deviation increase in air pollution. Furthermore, the instrument's *t*-statistic is larger than the threshold of 3.43 (Lee et al., 2020), indicating that there are no weak instrument variable problems and our usage of the two-stage least squares regression is reasonable. Thus, the results fully support that air pollution hinders the emergence of entrepreneurship.

 Insert Table 3 about here

As we assume that there are channels through which air pollution affects entrepreneurship, we regress entrepreneurship on PM2.5 with physical health, self-efficacy, self-rated social status and crime rates and present the results of the mediated models in Table 3. We report only the results for the critical variables due to space limitations. All columns include the controls for the individual and city attributes and include city, month and year fixed effects. The results in Panel B of Table 3 show that air pollution is significantly negatively related to self-efficacy (the coefficient is -0.130), whereas the results in Panel A, Panel C and Panel D of Table 3 represent the impact of air pollution on physical health, self-rated social status and crime rates are not significant. Also, after controlling for air pollution, the indirect effects of self-efficacy (the coefficient is -0.032) are significant and negative. The indirect effects of self-efficacy show the impact of air pollution on entrepreneurship is partly suppressed by self-efficacy. The possible reason for the slightly suppressive effect of self-efficacy is that higher self-efficacy might lead to

lower performance of entrepreneurs. Although people believe in their own ability to perform specific tasks, they might not expect to achieve positive outcomes. And those with high self-efficacy might be overconfident and experienced environmental dynamism (i.e., a high rate of unpredicted change occurring in a specific industry), which makes individuals ambiguous and have errors in judgment and decision-making (Hmieleski and Baron, 2008). The Kleibergen-Paap F -statistic¹⁹ for the excluded instruments in the first-stage regression of air pollution on entrepreneurship as well as for air pollution and the self-efficacy is above 10, which proves there are no weak instrument issues. Overall, the results suggest that air pollution affects entrepreneurship through the channel of self-efficacy.

Insert Table 4 about here

Air pollution may have different effects on entrepreneurs with different backgrounds. Considering that education level may affect people's ways of thinking and work performance and that subjective perception factors may also play mediated roles in these relationships, we conducted a moderated mediation analysis. We focus on self-efficacy rather than self-rated social status since it significantly impacts the relationship between air pollution and entrepreneurship. In column (1) of Table 4, we find that the impact of air pollution on self-efficacy is harmful and significant for less-educated individuals (the coefficient is 0.003). Hence, the heterogeneity effects provide support for the moderate mediation role of education in the relationship between air pollution and entrepreneurship. In the regression, we exclude those who have aged above or equal to 55 years old to eliminate the bias caused by legal retirement age (i.e., 60 years old for males, 55 years old for female civil servants and 50 years old for other female workers). In

¹⁹ We obtain Kleibergen-Paap F -statistic to test for the weak-instruments problem. The null hypothesis is that the independent variable is weakly identified because it is subject to unacceptably large bias. And the rule of thumb is that if it exceeds 10, we could say that the instruments are not weak, and the correlations between the independent variable and instruments are not small. In addition, it is valid in non-independent and identically distributed (non-i.i.d.) cases (we could use robust standard errors to address non-i.i.d errors) (Kleibergen and Paap, 2006).

addition, we found the effect is significant for females below 55 years old whereas not significant for males below 60 years old, which shows that females' self-efficacy is negatively influenced by air pollution, and they are more vulnerable if experiencing severe air pollution than males. Yet, according to the results in Table 4, we cannot conclude that education might be helpful for the generation of entrepreneurship for middle-aged and elderly prospective entrepreneurs.

In Table A1 of robustness checks, we report the results of the long-term impact of air pollution on entrepreneurship. We found that the average air pollution in previous years is positively correlated with entrepreneurship. The possible reason for the increase in entrepreneurship might be the individuals' adaptation to the long-term air pollution and the encouragement of entrepreneurial behavior of the government.

Indoor air pollution harms cognitive abilities (Vahedi, 2020), and it has various adverse effects on different cognitive functions (Burgoyne et al., 2016). It also harms work performance (Satish et al., 2012), which is evident in underdeveloped areas (Soppelsa et al., 2021). Considering indoor air pollution might affect entrepreneurship, we conduct robustness checks to check if the impact of outdoor air pollution will change after controlling for indoor air pollution. The results in Table A2 confirm the consistency of the findings in Table 2.

We conduct a sub-group analysis to measure the impact of air pollution in cities with different economic performances. The results in Table A3 represent that the negative impact is not significant in the cities with top or bottom 10% economic status, whereas significant in the cities after excluding these cities. The cities with the top 10% economic status might have comprehensive protection actions to help people escape from the negative impact of air pollution, which might lead to the nonsignificant effect of air pollution on entrepreneurship. For example, schools and firms in large metropolitan areas might be likely to provide air purifiers in indoor spaces. And the cities with the bottom 10% economic status are not likely to have a favorable business environment; thus, the level of air pollution and entrepreneurship might not change over the years.

We divide the sample into urban and rural areas since the types of activities, development opportunities and business environment might be different for urban entrepreneurs and their rural counterparts. The results are presented in Table A4 and show a negative and significant impact on entrepreneurs living in urban areas, which suggests that the urban population might experience more negative effects from air pollution than rural residents.

We use an alternative measure of air pollution, distance-weighted PM_{2.5}, to estimate the impact of air pollution on entrepreneurship in Table A5. The results are negative and significant, which confirms the robustness of our results.

Air pollution might affect human beings in a number of other ways. High air pollution is associated with a large number of economic activities or limited environmental regulations in the short run, which might attract outside investment (especially in high pollution industries). In the Chinese context, the increase in air pollution in the short term might generate a production effect (i.e., imply production expansion) (Liu et al., 2020). And the pollution haven hypothesis suggests air pollution is associated with an increase in the number of manufacturing firms from foreign countries. This hypothesis is confirmed in recent Chinese studies that pollution-intensive industries tend to relocate to places with less stringent environmental regulations, especially for industries with strong mobility (i.e., relocate across regions at a low cost and in a short time) (Dou and Han, 2019). These social factors might reduce the willingness to become entrepreneurs and mediate the correlation between air pollution and entrepreneurship. We use outside investment scores from components of the Index of Regional Innovation and Entrepreneurship in China²⁰ and number of industrial firms per ten thousand people from the *China City Statistical Yearbook* to represent outside investment and industrial activity, respectively. The results in Table

²⁰ This data are calculated by Center for Enterprise Research of Peking University. The website is <https://doi.org/10.18170/DVN/NJIVQB>.

A6 prove that air pollution might impact personal entrepreneurial intention through outside investment and industrial activity.²¹

Since the non-entrepreneurial population might have less willingness to start businesses, we test whether the results remain the same if we exclude the non-entrepreneurial population in Table A7. The results suggest the negative effect of air pollution on entrepreneurship still exists.

Considering migrants might experience mixed effects from air pollution (i.e., on the one hand, compared to their life in origin, migrants might experience a lower level of air pollution, have higher productivity and obtain better opportunities in the destinations they moved to; on the other hand, in the destination areas, they might have fewer financial and nonfinancial resources for starting businesses), we measure the impact of air pollution and entrepreneurship after excluding migrants from the sample. The negative and statistically significant coefficient in Table A8 also empirically supports our main results.

To test whether our results are sensitive to alternative samples, we estimate the main regression by using alternative samples. First, we exclude 2018 in our sample, considering air quality becomes better after a series of environmental regulations and it may influence our results. Results in Table A9 suggest that our previous findings are consistent and environmental policy might underestimate the negative impact of air pollution slightly. Second, we adopt the sample of the same age group of China Family Panel Studies (CFPS) and the results are not significant. The possible reason is that the target sample of the survey is the general population, not only middle-aged and elderly people in China. The lack of observations for this group of people might lead to biased results. Also, due to data limitations, we cannot control for similar financial and health status in childhood by utilizing CFPS data.

We further check the personal income of people pre- and post-choice of becoming an entrepreneur. We present the summary statistics on income after excluding people with the same

²¹ Note that there might be a mutual relationship between air pollution and industrial activity, which might underestimate the positive impact of air pollution on city industrial activity.

job status in the survey and zero income. We also exclude people who are entrepreneurs before they are workers to eliminate the effect of business failures and the possibility of side work. The results in Table A10 report that those who are entrepreneurs tend to have a relatively higher income than workers, which suggests that being an entrepreneur might be helpful in improving individuals' well-being.

We attempt to plot the trends in entrepreneurship and air pollution and see if they are negatively correlated without the control of other confounders. As shown in Fig. A1, the yearly average entrepreneurial probability increases after 2011 but decreased after 2013. And the trend in air pollution decreases steadily between 2011 and 2018, with a reduction of nearly 21.494 $\mu\text{g}/\text{m}^3$. The trends of entrepreneurial probability and air pollution show a positive correlation between these variables after 2013. The findings mitigate the concern that the correlation between air pollution and entrepreneurship is negative and might give biased relationships.

5. Discussion

5.1 Theoretical Implications

Our study makes a number of contributions to the environment and human-capital literature. First, the research on human resilience might suggest that air pollution will have some positive impact. Most people are inherently resilient and have the capacity to become resilient. These abilities will contribute to adaptation or recovery responses when people face extreme stressors or traumatic life events (Abramson et al., 2015). Specifically, in some Chinese cities with high pollution industries, air pollution might be similar to environmental disasters, or they can be correlated; when people are exposed to severe air pollution, they may want to start businesses to alleviate the loss and help others reduce the harm (i.e., they feel a sense of social responsibility). However, we find that the harmful impact caused by air pollution on general entrepreneurship is more significant than its positive effects on green entrepreneurship. The impact of toxic airborne particles may differ from that of general environmental adversity, such as earthquakes and tsunamis.

Second, while many studies have shown that air pollution negatively impacts the performance or productivity of workers, we know very little about air pollution's effects on entrepreneurs. Therefore, our research supplements the literature on the impact of air pollution on human behaviors.

Third, our results on how air pollution influences self-efficacy and city attributes are consistent with existing research on air pollution issues, contributing to this literature.

Finally, we provide evidence that policymakers need to be alerted to the important role of education in the negative impact of air pollution and self-efficacy. People with low education levels might experience more air pollution's adverse effects since they might have lower levels of cognition or social support, and thus, they will have lower self-efficacy compared to their high-educated counterparts. Low self-efficacy constitutes an individual's low cognitive estimate of capabilities when performing job tasks, although it might not be related to being an entrepreneur; thus, some favorable jobs will no longer become an attractive career option for them. And having skills related to an individual's work might be helpful for personal success. The government could help less-educated people to counteract the negative impact by encouraging them to attend classes, training and apply for support from the government. All jobs are equally important in society. And we care about whether people can live equally without paying an extra price for clean air. These practices will help them to master experiences, improve social connections, enhance self-belief and, ultimately, help them to realize their full potential and greatest possibilities vocationally.

5.2 Practical Implications

Our study has several policy implications. First, the significant negative impact of air pollution on individuals' entrepreneurial decisions should be considered when encouraging entrepreneurship and providing support to people who live in highly polluted areas. To reduce large health costs and productivity loss caused by air pollution, governments need to control air pollutant emissions, especially in cities with high air pollution levels. For instance, governments

could install air quality monitors and use mobile technologies to increase environmental awareness. And policy makers need to be alerted to weather factors in relation to air pollution, such as thermal inversions, wind speed, and wind direction. The results on the mediating role of subjective perception factors suggest that air pollution may take a heavier toll on self-efficacy. In addition to addressing air pollution issues, policy makers might need to figure out how to enhance people's psychological capital. Feasible measures include developing mental health care services in clinics and hospitals, establishing community psychological consultation rooms nationwide (i.e., places to provide convenient private consultation services about mental issues) and ensuring the provision of high-quality education (Chen et al., 2018). These practices could be helpful for the improvement and construction of self-confidence. Second, although the Chinese government has already been focusing for decades on environmental protection and sustainability, there may be differences in enforcement across prosperous urbanized areas and impoverished inland areas (van Rooij et al., 2017). Some cities in China might need to address air pollution issues in an efficient manner, as our findings highlight the potential continuous impact of air pollution. Finally, the results of our moderation analysis further prove the importance of education. According to our findings, the nine-year compulsory education policy benefits the Chinese urban population. Although the negative impact of air pollution on self-efficacy might decrease for the new generations of China, we cannot ignore the broad negative outcomes of air pollution.

6. Conclusion

This study suggests that air pollution adversely affects the creation of businesses. And self-efficacy might be a channel through which air pollution affects entrepreneurship. After grouping respondents, we show that in terms of self-efficacy, less-educated individuals and females are more vulnerable to air pollution than their more-educated counterparts. The significant effects of air pollution on entrepreneurship are consistent with this strand in the productivity literature. Prior studies have investigated the productivity outcomes of individuals in responding to both

concurrent and prolonged severe air pollution (He et al., 2019). As these studies emphasize that demographic variables are essential information (Qin et al., 2019), we considered heterogeneity and uncovered the adverse effects of air pollution on the self-efficacy of people with low levels of education. Furthermore, from a managerial perspective, potential entrepreneurs need to pay attention to air pollution issues and individual-level characteristics and city-level attributes resulting from air pollution. And less-educated people might need to seek additional help or resources, such as training classes, to overcome the negative impact of air pollution. We should find methods to tackle air pollution issues due to the negative externalities of air pollution. Our results will convince policy makers of these externalities and the costs of air pollution in different dimensions of productivity and life course choices. Supporting policies are needed in reducing air pollution and encouraging education and the publicity of these information (i.e., let people understand what they were doing and what they need to do next).

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Table 1
Descriptive Statistics

	All adults		Less educated		More Educated		Welch's t-statistic
	Mean	SD	Mean	SD	Mean	SD	
Entrepreneurship (yes = 1)	0.230	0.421	0.246	0.431	0.165	0.371	11.768***
PM2.5 ($\mu\text{g}/\text{m}^3$)	53.264	21.233	52.793	20.972	55.167	22.142	-5.992***
Thermal-inversion-induced fitted PM2.5 ($\mu\text{g}/\text{m}^3$)	53.496	9.705	53.394	9.628	53.907	10.001	-2.860***
Physical health	0.151	0.358	0.153	0.360	0.146	0.353	1.025*
Self-efficacy	0.605	0.489	0.601	0.490	0.624	0.485	-2.613***
Self-rated social status	2.439	0.779	2.416	0.788	2.515	0.741	-4.522***
City's crime rates	7.727	7.344	7.738	7.218	7.684	7.871	0.262
Age	54.161	6.858	54.450	7.174	53.011	5.271	13.908***
Male (yes = 1)	0.670	0.470	0.657	0.475	0.720	0.449	-7.691***
High school or above (yes = 1)	0.200	0.400	0.000	0.000	1.000	0.000	n.a.
Migrated to other provinces (yes = 1)	0.088	0.283	0.086	0.280	0.096	0.294	-1.838**
Non-agricultural hukou (yes = 1)	0.273	0.445	0.181	0.385	0.606	0.489	-49.292***
Marital status	2.982	0.133	2.983	0.130	2.979	0.145	1.637*
Household size	3.315	1.485	3.347	1.508	3.186	1.381	6.318***
Financial status in childhood	2.538	0.963	2.477	0.960	2.817	0.928	-17.469***
Health status in childhood	3.403	0.993	3.394	1.000	3.445	0.956	-2.543**
Have public medical insurance (yes=1)	0.944	0.230	0.943	0.232	0.949	0.221	-1.352*
Non-entrepreneurial (yes = 1)	0.056	0.229	0.060	0.238	0.036	0.187	6.683***
Real gross domestic product per capita (thousand yuan)	8.385	5.349	8.330	5.326	8.602	5.434	-2.776***
Population density (per km^2)	512.521	319.370	520.037	314.171	482.603	337.720	6.211***
Ground-level temperature ($^{\circ}\text{C}$)	15.547	4.854	15.807	4.680	14.514	5.370	13.643***
Ground-level rainfall ($10^6 \text{ kg}/\text{m}^2\cdot\text{s}$)	34.414	16.638	35.073	16.672	31.776	16.238	11.165***
Ground-level wind speed (m/s)	3.376	2.263	3.340	2.283	3.520	2.175	-4.539***
High variance of PM2.5 within city (yes=1)	0.110	0.313	0.101	0.301	0.146	0.354	-7.331***

Notes: SD = standard deviation. The sample only includes entrepreneurs and workers. We assume that our unpaired data do not have equal variances, and we present Welch's *t*-statistic (less educated–educated). Physical health denotes at least one hospital visit last month (yes = 1).

* $p < .10$

** $p < .05$

*** $p < .01$

Table 2

The Impact of Air Pollution on Entrepreneurship

Dependent variable	(1) Entrepreneurship		(2) Entrepreneurship	
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.001	(0.001)	-0.010**	(0.005)
Age	-0.035***	(0.009)	-0.034***	(0.009)
Age squared	0.000***	(0.000)	0.000***	(0.000)
Male (yes = 1)	-0.031***	(0.008)	-0.031***	(0.008)
High school or above (yes = 1)	-0.054***	(0.012)	-0.051***	(0.012)
Migrated to other provinces (yes = 1)	-0.009	(0.019)	-0.007	(0.019)
Non-agricultural hukou (yes = 1)	0.006	(0.014)	0.007	(0.014)
Marital status	0.025	(0.031)	0.029	(0.032)
Household size	0.002	(0.003)	0.002	(0.003)
Financial status in childhood	0.008*	(0.005)	0.008*	(0.005)
Health status in childhood	0.001	(0.004)	0.001	(0.004)
Have public medical insurance (yes=1)	-0.045**	(0.019)	-0.046**	(0.019)
Non-entrepreneurial (yes = 1)	0.945***	(0.007)	0.947***	(0.007)
Real gross domestic product per capita (thousand yuan)	0.001	(0.002)	-0.003	(0.002)
Population density (per km^2)	0.000	(0.000)	0.000	(0.000)
Ground-level temperature ($^{\circ}\text{C}$)	0.016**	(0.006)	0.021***	(0.007)
Ground-level rainfall ($10^3 \text{ kg}/\text{m}^2\cdot\text{s}$)	0.113	(0.713)	0.141	(0.724)
Ground-level wind speed (m/s)	-0.018**	(0.008)	-0.017**	(0.008)
High variance of PM2.5 within city (yes=1)	0.045***	(0.016)	0.116***	(0.040)
Constants	0.918***	(0.289)		
City fixed effects	YES		YES	
Month fixed effects	YES		YES	
Year fixed effects	YES		YES	
Observations	12946		12946	
Clusters	5074		5074	
Methodology	LPM		2SLS	
t-statistic (instrument)	n.a.		13.95	
Kleibergen-Paap rk Wald F-statistic (instrument)	n.a.		194.630	

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Table 3

The Impact of Air Pollution on Entrepreneurship: Mediation Effects of Personal and City Characteristics

Panel A. Physical health

Dependent variable	(1) Entrepreneurship	(2) Physical health	(3) Entrepreneurship
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.010** (0.005)	0.006 (0.005)	-0.010** (0.005)
Physical health			0.006 (0.010)
Control variables	YES	YES	YES
City fixed effects	YES	YES	YES
Month fixed effects	YES	YES	YES
Year fixed effects	YES	YES	YES
Observations	12946	12946	12946
Clusters	5074	5074	5074
Methodology	2SLS	2SLS	2SLS
t-statistic (instrument)	13.95	13.95	13.94
Kleibergen-Paap rk Wald F-statistic (instrument)	194.630	194.630	194.392

Panel B. Self-efficacy

Dependent variable	(1) Entrepreneurship	(2) Self-efficacy	(3) Entrepreneurship
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.009624** (0.005)	-0.013** (0.006)	-0.010035** (0.005)
Self-efficacy			-0.032*** (0.007)
Control variables	YES	YES	YES
City fixed effects	YES	YES	YES
Month fixed effects	YES	YES	YES
Year fixed effects	YES	YES	YES
Observations	12946	12946	12946
Clusters	5074	5074	5074
Methodology	2SLS	2SLS	2SLS
t-statistic (instrument)	13.95	13.95	13.98
Kleibergen-Paap rk Wald F-statistic (instrument)	194.630	194.630	195.349

Panel C. Self-rated social status

	(1)		(2)		(3)	
Dependent variable	Entrepreneurship		Self-rated social status		Entrepreneurship	
PM2.5 ($\mu\text{g}/\text{m}^3$)	0.140	(0.286)	-0.219	(0.516)	0.144	(0.277)
Self-rated social status					0.021	(0.063)
Control variables	YES		YES		YES	
City fixed effects	YES		YES		YES	
Month fixed effects	YES		YES		YES	
Year fixed effects	YES		YES		YES	
Observations	5172		5172		5172	
Clusters	3101		3101		3101	
Methodology	2SLS		2SLS		2SLS	
t-statistic (instrument)	0.70		0.70		0.73	
Kleibergen-Paap rk Wald F-statistic (instrument)	0.489		0.489		0.533	

Panel D. City's crime rates

	(1)		(2)		(3)	
Dependent variable	Entrepreneurship		City's crime rates		Entrepreneurship	
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.116	(0.324)	-3.235	(7.925)	-0.276	(1.702)
City's crime rates					-0.049	(0.310)
Control variables	YES		YES		YES	
City fixed effects	YES		YES		YES	
Month fixed effects	YES		YES		YES	
Year fixed effects	YES		YES		YES	
Observations	6075		6075		6075	
Clusters	3204		3204		3204	
Methodology	2SLS		2SLS		2SLS	
t-statistic (instrument)	0.41		0.41		0.17	
Kleibergen-Paap rk Wald F-statistic (instrument)	0.167		0.167		0.028	

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Table 4

The Impact of Air Pollution on Entrepreneurship: Moderated Mediation Effect of Education

Dependent variable	(1) Self-efficacy	(2) Self-efficacy	(3) Self-efficacy
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.017** (0.008)	-0.018 (0.013)	-0.015* (0.008)
PM2.5 * Education level	0.003* (0.001)	0.006** (0.003)	-0.001 (0.001)
City fixed effects	YES	YES	YES
Month fixed effects	YES	YES	YES
Year fixed effects	YES	YES	YES
Observations	7018	2625	6563
Clusters	2967	1583	3273
Methodology	2SLS	2SLS	2SLS
t-statistic (instrument)	10.67	7.51	11.90
Kleibergen-Paap rk Wald F-statistic (instrument)	60.958	31.129	71.742
Sample	Age<55	Female, age<55	Male, age<60

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Appendix

Table A1

Robustness Checks: The Long-term Impact of Air Pollution on Entrepreneurship

Dependent variable	(1) Entrepreneurship	(2) Entrepreneurship	(3) Entrepreneurship	(4) Entrepreneurship	(5) Entrepreneurship
Average PM2.5 ($\mu\text{g}/\text{m}^3$) in previous years	0.001* (0.001)	0.002* (0.001)	0.002** (0.001)	0.004** (0.001)	0.005** (0.002)
Control variables	YES	YES	YES	YES	YES
City fixed effects	YES	YES	YES	YES	YES
Month fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
Observations	12946	12946	12946	12946	12946
Clusters	5074	5074	5074	5074	5074
Methodology	LPM	LPM	LPM	LPM	LPM
Previous years	2016-2017	2015-2017	2014-2017	2013-2017	2008-2017

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Table A2

Robustness Checks: Controlling for Indoor Air Pollution Measures

Dependent variable	(1) Entrepreneurship	(2) Entrepreneurship	(3) Entrepreneurship
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.009* (0.005)	-0.010** (0.005)	-0.011* (0.006)
Indoor air pollution from smoking behaviors	-0.032*** (0.010)		
Indoor air pollution from spouse's smoking behaviors		-0.019 (0.013)	
Indoor air pollution from cooking fuel			-0.059*** (0.012)
Control variables	YES	YES	YES
City fixed effects	YES	YES	YES
Month fixed effects	YES	YES	YES
Year fixed effects	YES	YES	YES
Observations	11837	11922	9287
Clusters	4903	4830	4589
Methodology	2SLS	2SLS	2SLS
t-statistic (instrument)	13.64	13.64	10.71
Kleibergen-Paap rk Wald F-statistic (instrument)	185.976	186.127	114.620

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Table A3

Robustness Checks: Sub-group Analysis according to Economic Performance

Dependent variable	(1)		(2)		(3)	
	Entrepreneurship		Entrepreneurship		Entrepreneurship	
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.015	(0.019)	0.015	(0.011)	-0.029***	(0.010)
Control variables	YES		YES		YES	
City fixed effects	YES		YES		YES	
Month fixed effects	YES		YES		YES	
Year fixed effects	YES		YES		YES	
Observations	835		1803		10308	
Clusters	479		776		4178	
Methodology	2SLS		2SLS		2SLS	
t-statistic (instrument)	3.79		7.52		7.46	
Kleibergen Paap rk wald F-statistic (instrument)	14.339		56.524		55.643	
Sample	Bottom 10% economic status		Top 10% economic status		Exclude Top and Bottom 10% economic status	

Notes: Robust standard errors are clustered by household and reported in parentheses.* $p < .10$ ** $p < .05$ *** $p < .01$

Table A4

Robustness Checks: Sub-group Analysis according to Urban-Rural Area Type

Dependent variable	(1)		(2)	
	Entrepreneurship		Entrepreneurship	
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.006	(0.007)	-0.011*	(0.006)
Control variables	YES		YES	
City fixed effects	YES		YES	
Month fixed effects	YES		YES	
Year fixed effects	YES		YES	
Observations	6987		5959	
Clusters	2931		2143	
Methodology	2SLS		2SLS	
t-statistic (instrument)	9.85		9.51	
Kleibergen Paap rk wald F-statistic (instrument)	96.945		90.441	
Sample	Rural area		Urban area	

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Table A5

Robustness Checks: Alternative Measure of Air Pollution

Dependent variable	(1) Entrepreneurship
Distance-weighted PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.021** (0.010)
Control variables	YES
City fixed effects	YES
Month fixed effects	YES
Year fixed effects	YES
Observations	12946
Clusters	5074
Methodology	2SLS
t-statistic (instrument)	8.05
Kleibergen-Paap rk Wald F-statistic (instrument)	64.758

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Table A6

Robustness Checks: Potential Mediation Effects of City Characteristics

Panel A. City's outside investment

	(1)		(2)		(3)	
Dependent variable	Entrepreneurship		City's outside investment		Entrepreneurship	
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.010**	(0.005)	0.274***	(0.062)	-0.009**	(0.004)
City's outside investment					-0.003***	(0.001)
Control variables	YES		YES		YES	
City fixed effects	YES		YES		YES	
Month fixed effects	YES		YES		YES	
Year fixed effects	YES		YES		YES	
Observations	12946		12946		12946	
Clusters	5074		5074		5074	
Methodology	2SLS		2SLS		2SLS	
t-statistic (instrument)	13.95		13.95		13.92	
Kleibergen-Paap rk Wald F-statistic (instrument)	194.630		194.630		193.734	

Panel B. City's industrial activity

	(1)		(2)		(3)	
Dependent variable	Entrepreneurship		City's industrial activity		Entrepreneurship	
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.012**	(0.005)	0.028***	(0.003)	-0.011**	(0.005)
City's industrial activity					-0.038***	(0.009)
Control variables	YES		YES		YES	
City fixed effects	YES		YES		YES	
Month fixed effects	YES		YES		YES	
Year fixed effects	YES		YES		YES	
Observations	12571		12571		12571	
Clusters	4898		4898		4898	
Methodology	2SLS		2SLS		2SLS	
t-statistic (instrument)	13.43		13.43		13.37	
Kleibergen-Paap rk Wald F-statistic (instrument)	180.363		180.363		178.860	

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$ ** $p < .05$

*** $p < .01$

Table A7

Robustness Checks: Excluding Non-entrepreneurial Population

Dependent variable	(1)	
	Entrepreneurship	
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.009**	(0.004)
Control variables	YES	
City fixed effects	YES	
Month fixed effects	YES	
Year fixed effects	YES	
Observations	12226	
Clusters	4955	
Methodology	2SLS	
t-statistic (instrument)	14.78	
Kleibergen-Paap rk Wald F-statistic (instrument)	218.491	
Sample	Exclude non-entrepreneurial population	

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Table A8

Robustness Checks: Excluding Migrants

Dependent variable	(1) Entrepreneurship
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.008* (0.005)
Control variables	YES
City fixed effects	YES
Month fixed effects	YES
Year fixed effects	YES
Observations	12240
Clusters	4816
Methodology	2SLS
t-statistic (instrument)	13.53
Kleibergen-Paap rk Wald F-statistic (instrument)	183.098
Sample	Exclude migrants

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Table A9

Robustness Checks: Alternative Sample

Dependent variable	(1)		(2)	
	Entrepreneurship		Entrepreneurship	
PM2.5 ($\mu\text{g}/\text{m}^3$)	-0.011**	(0.006)	0.002	(0.010)
Control variables	YES		YES	
City fixed effects	YES		YES	
Month fixed effects	YES		YES	
Year fixed effects	YES		YES	
Observations	9720		9086	
Clusters	4292		3453	
Methodology	2SLS		2SLS	
t-statistic (instrument)	12.19		5.95	
Kleibergen-Paap rk Wald F-statistic (instrument)	148.632		35.427	
Sample	Exclude 2018		Same age group in CFPS	

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

Table A10

Robustness Checks: Summary Statistics on Income Pre- and Post-choice of being an Entrepreneur

	All adults		Workers		Entrepreneurs		Welch's t-statistic
	Mean	SD	Mean	SD	Mean	SD	
Personal income (thousand yuan)	19.564	16.716	19.155	14.143	20.027	19.261	-0.436

Notes: Robust standard errors are clustered by household and reported in parentheses.

* $p < .10$

** $p < .05$

*** $p < .01$

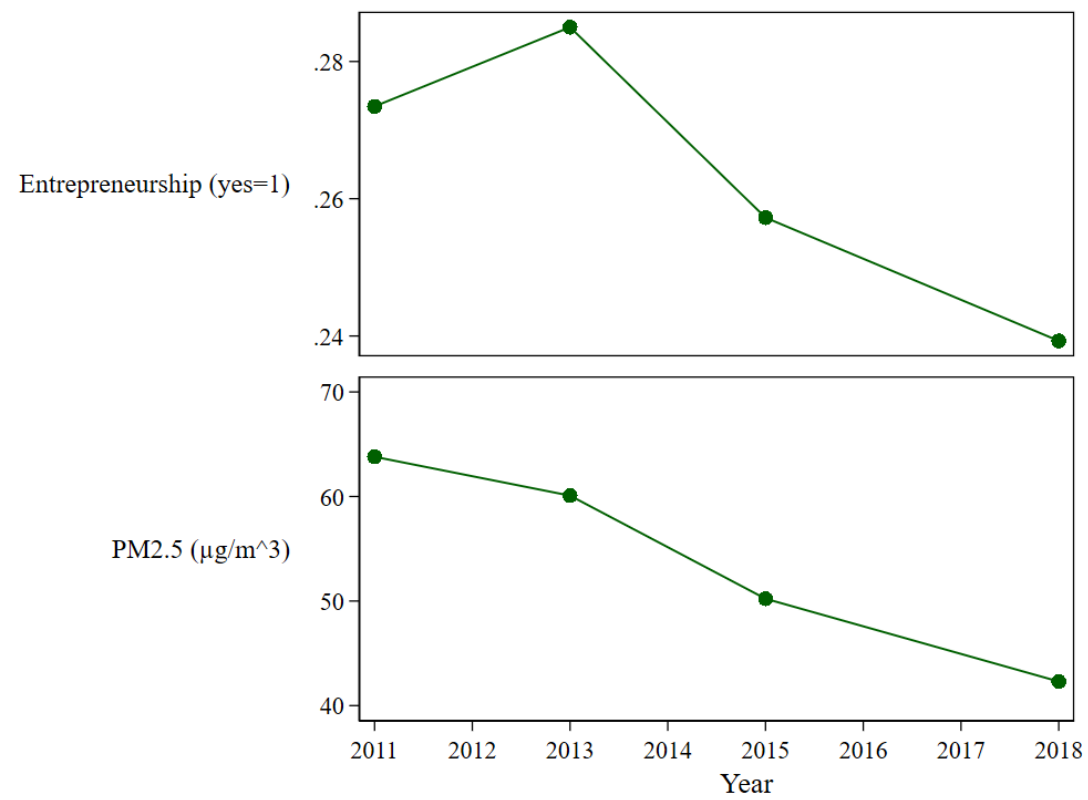


Fig. A1 Trends in Annual Mean Air Pollution and Entrepreneurship