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## AIR POLLUTION AND INVESTORS' BEHAVIOR

### A Review of Recent Literature

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#### Introduction

Air pollution is broadly recognized as a synthesis of gases and matter that have adverse effects on the health of living beings. These gases include carbon compounds, such as carbon monoxide (CO); nitrogen compounds, such as nitrogen dioxide ( $\text{NO}_2$ ); sulfur compounds, such as sulfur dioxide ( $\text{SO}_2$ ); volatile organic compounds (VOCs); ozone ( $\text{O}_3$ ); and particulate matter (PM), such as 2.5- $\mu\text{m}$  PM ( $\text{PM}_{2.5}$ ) and 10- $\mu\text{m}$  PM ( $\text{PM}_{10}$ ) (Brunekreef & Holgate, 2002; Kampa & Castanas, 2008). According to the World Health Organization, air pollution is “the biggest environmental risk to health” (World Health Organization, 2016) and caused seven million deaths globally in 2016 (World Health Organization, 2018).

The social relevance of air pollution has been the subject of extensive research. In the green finance area, numerous research focuses on how investment affects air pollution. Studies have found a linear relationship between investment and air pollution. For example, firm outward foreign direct investment (OFDI) is negatively related to air pollution (Zhou & Li, 2021), while foreign direct investment (FDI) increases air pollution (Huynh & Hoang, 2019; S. Liu & Zhang, 2022; Omri & Bel Hadj, 2020). Green investment can alleviate air pollution through emission reduction (Mngumi et al., 2022), energy conservation (Ren et al., 2022), and reducing the PM 2.5 concentration (Zeng et al., 2022). Scholars have also found a nonlinear relationship between investment and air pollution. For example, urban traffic infrastructure investment decreases air pollution in the short run but increases air pollution in the long run (Sun et al., 2018), and investment in real estate has an inverted-U shape effect on air pollution (Chen & Lee, 2020). Although how investment affects air pollution is well studied, research has paid little attention to the direct effect of air pollution on investments.

Extant research on how air pollution affects investment mainly focuses on three aspects: performance, financial instrument preferences, and willingness to trade.

First, the effects of air pollution on investors' performance have been assessed. Investing is a mentally taxing activity prone to investors' cognitive biases. Numerous studies have found that air pollution impairs people's cognitive functions and leads to depression, anxiety, and other mental disorders (Calderón-Garcidueñas et al., 2008; Hsieh et al., 1991; Lercher et al., 1995; Rautio et al., 2018; Schwarz & Clore, 1983; Weuve et al., 2012). Thus, investors exposed to air pollution may make inferior investment decisions.

Second, the effects of air pollution on investors' financial instrument preferences have been examined. For example, the market value of green bonds has grown substantially, from less than US \$10 billion in 2005 to more than US \$913.2 billion in 2020 (DBS Bank, 2021). This may be because deterioration in air quality encourages investors' interest in green finance, which aids the development of the green financial market.

Finally, research has also focused on how air pollution affects investors' willingness to trade. One significant factor influencing investors' trading decisions is risk aversion (Cohn et al., 1975; Dow & Werlang, 1992; Eckel & Grossman, 2008). Studies have shown that air pollution increases cortisol concentrations in the body, increasing individuals' levels of risk aversion (Rosenblitt et al., 2001; Tomei et al., 2003). Thus, compared with investors not exposed to air pollution, investors exposed to air pollution may be less likely to make investments due to their increased levels of risk aversion.

Although these studies have focused on how air pollution affects investor behavior, no comprehensive literature review has been conducted. These studies have performed empirical tests on a wide range of financial markets, including the stock market, the bond market, and the poverty market, and have obtained diverse findings. Therefore, there is a need for a review to synthesize these results and provide a coherent framework for future research and implication for the green financial market.

Our review reveals that the relationship between air pollution and investors' performance has been the focus of most studies, which have suggested that air pollution has a significantly negative effect on investor performance. However, studies have obtained mixed results on whether individual investors are more susceptible to the negative effects of air pollution than institutional investors. Similarly, studies of investors' preferences have suggested that air pollution increases investors' holdings of portfolios related to consumption but have obtained mixed results on investors' preferences for green financial instruments. Some studies have argued that air pollution induces investors to invest in green funds and less in polluting firms, while others have found that air pollution has a statistically insignificant effect on investors' preferences for green financial instruments. Studies on the effects of air pollution on investors' willingness to trade have also reported inconclusive results. Studies have generally found that air pollution decreased investors' desire to trade, but some studies have reported that air pollution induces excessive trading by increasing investors' confidence. The findings of our review suggest that since air pollution may to some extent push investors towards green financial instruments, it is important to take air pollution into consideration when promoting green financial instruments to achieve better synergy. In addition, it also implies that investors believe green finance could address environmental issues.

The remainder of this chapter proceeds as follows. The second section discusses the methods used to identify the relevant studies. The third section provides a statistical summary of the studies identified and presents the relevant findings. The chapter ends with a concluding section that offers suggestions for future research.

## **Methodology**

In this section, we detail the approach used to identify the relevant studies. The first part describes the two stages of our search – an initial search and a reference search – and our search criteria. The second part elaborates on the main information we extracted from our search.

### ***Initial Search***

Following prior research (Zhang et al., 2019), we searched for studies in Scopus, which can generate highly relevant results and is commonly used for literature reviews in the field of business.

We first used keywords to identify studies, namely “air pollution” and “investor behaviors.” To ensure our results were comprehensive, we also used technical terms that describe air pollution, such as “SO<sub>2</sub>,” “NO<sub>2</sub>,” and “PM 2.5,” together with several synonyms for air pollution, such as “air quality,” “air condition,” and “air polluting,” as our first batch of keywords.

Carbon dioxide (“CO<sub>2</sub>”) is one of the primary causes of climate change (Solomon et al., 2009) but is not a source of air pollution by definition (Brunekreef & Holgate, 2002; Kampa & Castanas, 2008). We did not include carbon dioxide (“CO<sub>2</sub>”) in this search, as our main focus was on the relationship between air pollution and investor behavior; we used “invest,” “investor,” “investing,” and “investment” as our second batch of keywords.

We searched these keywords in Scopus for an all-time span and filtered the results to include only studies published in peer-reviewed journals in the field of business and economics. This search yielded 466 studies. We examined the titles and abstracts of every study and excluded articles that contained our keywords but whose themes were irrelevant to our topic. For example, some studies contained the keywords “air pollution” and “investment” but investigated “how investment reduced air pollution,” which was not our concern. Therefore, we ceded these articles and retained articles closely relevant to our topic. This afforded a set of 23 studies.

Our search code was as follows:

```
(TITLE-ABS-KEY("air pollution" OR "air condition" OR "air quality" OR "air polluting" OR "polluted air" OR "particulate matter" OR "PM 2.5" OR "PM 10" OR "volatile organic compounds" OR "VOCs" OR "carbon monoxide" OR "ozone" OR "O3" OR "nitrogen dioxide" OR "NO2" OR "sulfur dioxide" OR "SO2") AND TITLE-ABS-KEY("investor" OR "invest" OR "investing" OR "investment")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ECON"))
```

### ***Reference Search***

We next checked the reference list of each study selected in our initial search, and other studies that cited each study to identify any omissions. We performed this process iteratively until the results reached saturation.

After these two stages of searching, our final set consisted of 25 studies. We then used a spreadsheet to code their critical information: title, author, year of publication, methods, data source, variables, mechanism, main results, and the publishing journal.

## **Results**

Here, we first provide a basic overview of the literature, such as distributions of publications, the main mechanisms and types of investors examined, and the outcomes. We then synthesized the studies that have focused on how air pollution affects investor performance, their preferences for green financial instruments, and their willingness to trade.

### ***Basic Overview***

In this section, we summarize our set of studies and classify them according to their main findings. We provide detailed information for each study in Table A1 in the Appendix.

#### *Time Trend*

Figure 30.1 gives the number of studies published each year. The earliest study we identified was published in 2011. The number of published studies has increased since then and reached a

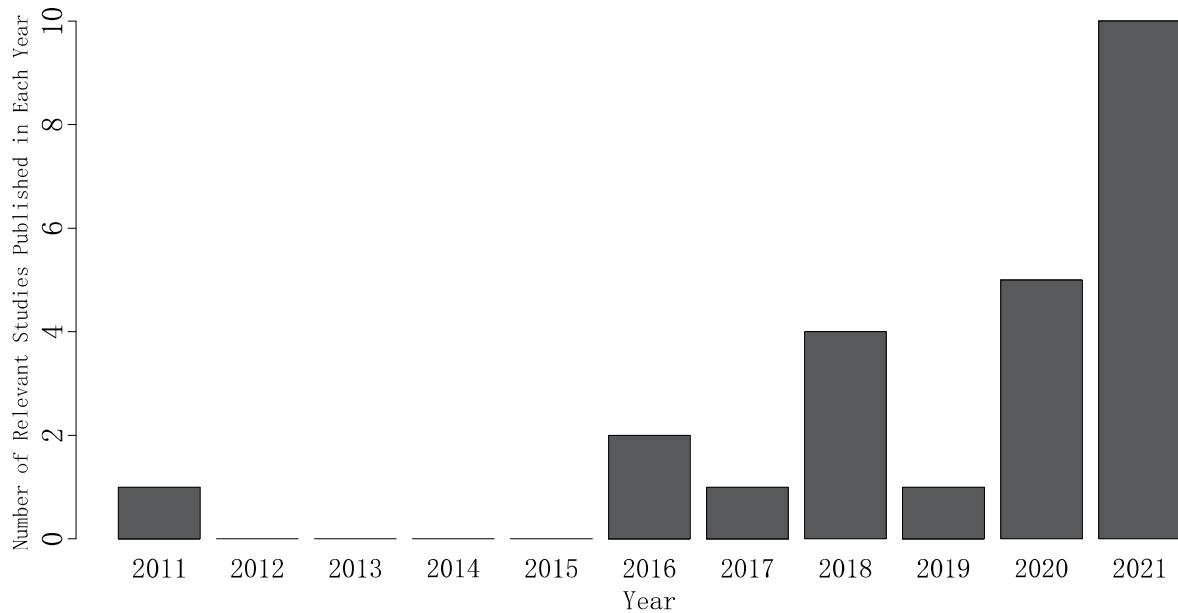


Figure 30.1 Number of relevant studies published in each year

maximum in 2021, which saw ten studies published. This confirms that air pollution has drawn increasing scholarly attention in recent years.

#### Publishing Journals

We found that the 25 studies were evenly distributed across 19 journals. *Applied Economics* and the *Journal of Cleaner Production* have each published three studies. *Finance Research Letters* and the *Pacific Basin Finance Journal* have each published two studies. Only two studies that have focused

Table 30.1 Number of relevant studies published in each journal

Journal	Count
Applied Economics	3
Journal of Cleaner Production	3
Finance Research Letters	2
Pacific Basin Finance Journal	2
Emerging Markets Review	1
Energy Policy	1
Environmental Science and Pollution Research	1
Frontiers in Public Health	1
International Review of Economics and Finance	1
Journal of Asset Management	1
Journal of Behavioral and Experimental Finance	1
Journal of Economic Psychology	1
Journal of Empirical Finance	1
Journal of Financial Economics	1
Journal of Financial Markets	1
Management Science	1
Real Estate Economics	1
Research in International Business and Finance	1
Sustainability (Switzerland)	1
<b>Total</b>	<b>25</b>

Table 30.2 Distribution of research context in each year

Year	China	Italy	United States
2011	0	0	1
2016	1	1	0
2017	1	0	0
2018	4	0	0
2019	1	0	0
2020	5	0	0
2021	9	0	1
Total	21	1	2

on how air pollution affects investors' behavior were from top journals; one was published in the *Journal of Financial Economics* (Li et al., 2021), and the other was published in *Management Science* (Huang et al., 2020).

#### *Research Contexts*

Most studies have been based in China; however, two focused on the United States, and one focused on Italy. The first study, from 2011, focused on US investors and air quality in New York City (Levy & Yagil, 2011), and similar studies were then conducted in China and Italy in 2016 (Lepori, 2016; Li & Peng, 2016). From 2017 to 2021, 20 studies focused on China, and only one focused on the United States (Muntifering, 2021). China is a developing country with more severe air pollution than most developed countries and has two exchange centers and numerous active investors in Shanghai and Shenzhen. Thus, China is a suitable context in which to investigate the relationship between air pollution and investors' behavior.

#### *Types of Investors*

Institutional and individual investors differ in various aspects. Institutional investors are typically professionals in large organizations such as banks, funds, unions, or insurance companies. Institutional investors generally have more experience and skill than individual investors, and therefore the former may be less affected by air pollution than the latter. However, the findings of studies on this aspect are inconsistent. We next classify the studies according to their main findings.

#### *Measures of Air Pollution*

Most studies that have focused on China have used the Air Quality Index (AQI) to measure air pollution. The AQI was initially provided by the Ministry of Environmental Protection of the People's Republic of China (MEPC), which was succeeded by the Ministry of Ecology and Environment of the People's Republic of China (MEEPRC) in 2018. AQI measures air pollution levels in terms of the concentrations of noxious gases, namely CO, O<sub>3</sub>, NO<sub>2</sub>, and SO<sub>2</sub>, and the concentrations of PM<sub>2.5</sub> and PM<sub>10</sub>. A grading scale of 0 to 500 is applied, with a higher score representing poorer air quality.

We identified three studies that constructed the national daily AQI of China. Two used provincial AQI data provided by the MEPC and then weighted these data by the number of stock accounts in each province (Liu et al., 2021a) or multiplied these data by the trading ratios of the

provincial capitals (Gao et al., 2020). An et al. (2018) calculated the average AQI of major trading cities in China to construct measures of China's national air pollution.

In 12 studies that assessed investors' perceptions, city-level daily AQI data were used to measure the air pollution levels in all Chinese cities. These studies obtained data from the MEPC (Ding et al., 2021; Guo et al., 2021; Huang et al., 2020; Huang & Du, 2022; Li et al., 2021; Teng & He, 2020; Wu et al., 2018a, 2020), city-level environmental protection bureaus (Zhang et al., 2021), the World Air Quality Index website (Jo et al., 2022), the Chinese Air Quality Study Platform website (Wu & Lu, 2020), and all Chinese monitoring stations (Han et al., 2021).

Air pollution in specific Chinese cities was examined in ten studies. These included daily AQI data for Shanghai (He & Liu, 2018; Liu et al., 2021b; Su et al., 2019) and Shenzhen (Jiang et al., 2021) obtained from the MEPC, and hourly AQI data for Beijing obtained from the website of the US Department of State Air Quality Monitoring Program (Zhang et al., 2017). Other studies used daily AQI data for 16 major Chinese cities (those with populations of over eight million) (Li & Peng, 2016) or the maximum daily AQIs of heavily polluted cities each December during the sample period (Wu et al., 2018b) obtained from the MEPC. Some studies measured air pollution levels using the New York City daily AQI data from the US Federal Environmental Protection Agency (EPA) (Muntifering, 2021) or the daily AQI data of the four main US stock exchanges (the New York Stock Exchange (NYSE), the American Stock Exchange (NASDAQ), and the Philadelphia stock exchange (PHLX)) retrieved from AirData websites (Levy & Yagil, 2011). The daily AQI data reported by three monitoring stations were also used to measure the ambient air pollution level in Milan (Lepori, 2016).

### ***The Mechanism by Which Air Pollution Affects Investors***

Most of the studies have focused on the psychological or physiological effects of air pollution on investors. Air pollution can have negative psychological effects on investors' moods, leading to depression, anxiety, and negative sentiment. The physiological effects consist of changes to the body's cortisol concentrations.

Psychological effects have been the focus of 15 studies in our set (An et al., 2018; Ding et al., 2021; Gao et al., 2020; Huang et al., 2020; Huang & Du, 2022; Jiang et al., 2021; Jo et al., 2022; Levy & Yagil, 2011; Li et al., 2021; Muntifering, 2021; Teng & He, 2020; Wu et al., 2018a,b; Wu & Lu, 2020; Zhang et al., 2021). One study considered only physiological effects (Guo et al., 2021), and nine examined both physiological and psychological effects (Han et al., 2021; He & Liu, 2018; Lepori, 2016; Li & Peng, 2016; Liu et al., 2021a,b; Su et al., 2019; Wu et al., 2020; Zhang et al., 2017).

Those that considered the psychological effects of air pollution on investor behavior mainly focused on investors' moods and cognitive functions. Research into mental health has suggested that exposure to air pollution can depress mood and impair cognitive function (Calderón-Garcidueñas et al., 2008; Hsieh et al., 1991; Schwarz & Clore, 1983). Psychiatric symptoms such as behavioral bias, cognition decline, and other mental disorders have also been observed (Lercher et al., 1995; Rautio et al., 2018; Weuve et al., 2012). Investing is a mentally taxing activity and requires investors to make complicated decisions, so the negative effect of pollution on their mood and cognitive function can be significant (Huang et al., 2020) and may affect their investing performance and preferences.

Studies that have considered the physiological channel have focused on the effect of air pollution on investors' cortisol concentrations, which will increase their levels of risk aversion. Air pollution is known to increase cortisol concentrations in the body (Tomei et al., 2003), and

some studies have suggested that individuals with high cortisol concentrations will be risk-averse (Rosenblitt et al., 2001), which represents a cognitive bias. Air pollution can also inhibit the ability of red blood cells to transfer oxygen to organs, which can also lead to reduced concentration and cause confusion (Kampa & Castanas, 2008). Thus, the negative physiological effect of air pollution can lead to a similarly negative psychological effect, and some studies have therefore considered both effects.

### ***Investor Performance***

Most studies have suggested that air pollution has a negative effect on investor performance. That is, compared with investors not exposed to air pollution, investors exposed to air pollution will be more susceptible to the disposition effect, more likely to hold negative sentiments regarding the market, and more likely to misprice assets. However, whether individual investors are more prone to the negative effects of air pollution than institutional investors remains unclear.

#### ***Disposition Effect***

The disposition effect is the trading behavior of holding “losing stocks” and selling “winning stocks,” which is a commonly observed trading abnormality. Specifically, investors sell stocks that are likely to increase in price and retain those that are likely to decrease in price (Shefrin & Statman, 1985).

Air pollution was found to increase the disposition effect through mechanisms such as cognition impairment (Huang et al., 2020) or because investors aim to realize a gain from selling winning stock to offset their depressed moods, which have been caused by air pollution (Li et al., 2021). Huang et al. (2020) used account-level data from 87,054 households from 34 cities in China to examine the effect of air pollution on investor trading performance. The results of their fixed-effect panel regression indicated that air pollution made investors more susceptible to the disposition effect (Huang et al., 2020). Li et al. (2021) considered 773,198 account transactions from a private mutual fund and found that the proportion of disposition effect-related activities by investors was four times greater in areas of high air pollution than in areas of low air pollution. Li et al. (2021) used the Qin Lin Huai River as a boundary when measuring the spatial discontinuity of air pollution in China and used a difference-in-difference (DiD) model to confirm that air pollution negatively affects investors.

#### ***Negative Sentiments in the Financial Market***

Air pollution may lead to investors holding negative sentiments in terms of their expectations and perceptions of the financial market. Investors’ sentiments are closely related to market returns (Brown & Cliff, 2004; Lee et al., 1991; Wright & Bower, 1992), and early studies used the change in the market as a proxy to measure investors’ sentiment. This approach was later improved by directly measuring investor sentiment through comments on online forums.

Levy and Yagil (2011) proposed that air pollution leads investors to feel anxious and pessimistic about the market and used market data from the four main stock exchanges in the United States to measure investors’ sentiments. The results from their OLS model suggest that the air pollution in New York negatively affected the sentiments of investors on both the NYSE and the PHLX. These results supported their hypothesis that air pollution affects investors located in New York and consequently their trading on the PHLX (Levy & Yagil, 2011). Zhang et al. (2017) obtained similar results by examining the daily data of companies located in Beijing and air quality data to determine the effect of air pollution on the stock market. They hypothesized that air pollution could affect the stock market through the channel of investor mood. They

regressed 591,709 observations and found that air pollution worsens investor mood, and their resulting pessimistic sentiments about the market increase its volatility and decrease stock market yields (Zhang et al., 2017). The finds of the empirical study conducted by Wu et al. (2018b) are also consistent with the investor sentiment theory. They developed a regression discontinuity model using the data of heavily polluting Chinese listed enterprises from December 2014 to December 2016 and found that air pollution can induce pessimism in investors about the market, decreasing stock yields (Wu et al., 2018b).

The above studies have not directly measured investor sentiment, but An et al. (2018) built a generalized autoregressive conditional heteroskedasticity (1,1) model to investigate the effect of air pollution on investor sentiment and stock market yield. They examined investor comments from the Snowball website to measure sentiment and used weighted AQI as a proxy for air pollution. They indicated that a high air pollution level led to negative investor sentiment about the market, which ultimately decreased stock market yields and liquidity (An et al., 2018).

### *Mispricing*

Air pollution has also been associated with investors' mispricing of assets. Four main mechanisms have been identified that explain this effect.

First, air pollution can affect the mood of investors and lead them to misprice stocks. Ding et al. (2021) found that this effect can distort investors' perceptions of stock price value, particularly of companies located in the same province as the investors. They built an autoregression model using the data from 1,719 firms located in 221 cities in China and found that air pollution led investors to undervalue stocks, which ultimately decreased their companies' returns. Ding et al. (2021) argued that the undervaluation effect affects local companies more than non-local companies, following research that suggested investors tended to invest 8% more in local firms than the market prediction (Feng & Seasholes, 2004) and that Chinese investors invested more in stocks issued by firms from their province than in those issued by non-local firms (Huang et al., 2016).

However, Zhang et al. (2021) noted that investors' pricing of companies can be distorted as the severe air pollution in some cities can discourage company site visits, thus resulting in an insufficient analysis of the intrinsic value of the companies. Even if investors engage in on-site visits, their decisions may be unreliable due to air pollution, thus leading them to misprice these companies' stock prices. Zhang et al. (2021) used IPO data from the China stock market for 2013–2019 to build a multiple regression model, and the results indicated that the companies' IPO prices significantly decreased if the company was located in a severe air pollution area (Zhang et al., 2021).

Huang and Du (2022) suggested that air pollution can lead investors to produce biased projections and thus misvalue land. That is, investors may assume that air pollution will continue to be a problem, leading them to expect decreased profits from investing in the land market. This will decrease the demand for and the price of land (Huang & Du, 2022).

Huang and Du (2022) also applied the salience theory to explain how air pollution can affect investors' pricing in the land market. This theory holds that investors' decisions are more prone to the most unusual features (Bordalo et al., 2012). They conducted a lottery-based experiment and found that decision-makers pay more attention to lotteries with higher pay-offs than to those with lower pay-offs (Bordalo et al., 2012). In the land market context, investors may focus on air pollution and regard it as a significant risk that will inhibit land market development, and this may reduce their perception of the value of land in the polluted regions (Huang & Du, 2022).

### *Susceptibility*

Although most studies have not distinguished between individual and institutional investors, those that have compared investors' levels of susceptibility to the negative effects of air pollution have reported inconsistent results.

Jiang et al. (2021) argued that air pollution triggers investors to have pessimistic sentiments about the market and that individual investors are more prone to this effect than institutional investors. They noted that the limited experience of individual investors means that they are more susceptible to negative sentiment than institutional investors, and thus the former is more likely than the latter to rush to sell stocks in the market. They used data from the Shenzhen Exchange to construct a quantile regression and confirmed that investors' irrational selling, attributed to air pollution, had a statistically significant and negative effect on market returns (Jiang et al., 2021). Guo et al. (2021) analyzed individual transaction records of Chinese investors from the Snowball database and also found that air pollution had more of an effect on individual rather than institutional investors, in terms of inducing them to sell stocks (Guo et al., 2021).

Han et al. (2021) proposed that air pollution can influence the cognitive bias and emotions of individual investors more than those of institutional investors, as pessimism induced the former to undervalue stock prices. Their multiple regression model suggested that air pollution caused individual investors to submit lower bids than institutional investors on seasoned equity offerings (SEO) by firms and that air pollution had no significant effect on the bids received by firms if they only received them from institutional investors. This suggests that individual investors are more susceptible than institutional investors to the negative effects of air pollution (Han et al., 2021).

However, Wu et al. (2020) revealed that institutional investors were susceptible to the reverse effect of air pollution. They analyzed data from 3,028 open-ended funds and the behavior of 1,493 open-end fund managers in China and used a multiple regression model to establish that air pollution increased institutional investors' levels of risk aversion and ultimately affected their buying and selling decisions. That is, compared with institutional investors in the absence of air pollution, institutional investors in the presence of air pollution were more likely to sell risky assets such as stocks, resulting in a decline in market returns (Wu et al., 2020).

### *Investor Preferences*

Air pollution has also been found to affect investors' preferences for consumption-related financial instruments and portfolios. However, the findings on whether investors prefer green rather than polluting financial instruments when exposed to air pollution are inconsistent. Some studies have argued that evidence of air pollution increases investors' holdings of green stocks and bonds, while others have suggested that investors are indifferent about whether financial instruments are green or polluting.

#### *Preferences for Green Financial Instruments*

Studies that have examined whether air pollution encourages investors to apply more green financial instruments have reported inconsistent results.

Su et al. (2019) found that air pollution encouraged investors to hold more green stocks and fewer polluting stocks. In terms of air quality, high levels of air pollution decreased the stock returns of polluting industries such as coal, steel, and thermal power, but those of environmentally positive industries remained high regardless of the air quality. They suggested that this was due to air pollution affecting investors' moods and increasing their levels of risk aversion, thus

leading them to negatively evaluate the stocks of polluting industries and positively evaluate those of environment-protecting industries. Investors thus decreased their holdings of polluting stocks and increased their holdings of green stocks, which ultimately decreased the returns of the former and increased those of the latter (Su et al., 2019).

Gao et al. (2020) obtained similar results using aggregate trading data of A-share investors. They built an OLS regression model and used this data to study the relationship between air pollution and investors' preferences. They observed more buyer-initiated trading orders in responsible investment indexes when air pollution was high than it was low. This indicates that air pollution encouraged investors to hold green stocks (Gao et al., 2020). Jo et al. (2022) also found that air pollution increased the flow of green funds. They conducted a DiD test using the enactment of the Chinese Air Pollution Prevention and Control Law and a one-to-one matching sample for green funds and conventional funds. Their results imply that air pollution increased the investor demand for green funds (Jo et al., 2022).

However, some studies have suggested that investors were indifferent to whether financial instruments are green or polluting. Han et al. (2021) analyzed all Chinese uniform-price auction SEOs from 2013 to 2019 and developed a multiple regression model. They found that air pollution led investors to undervalue SEO prices. However, they found no significant differences in the adverse effects on polluting and non-polluting SEO prices, indicating that air pollution did not lead to any significant preference for polluting or non-polluting firms (Han et al., 2021). Liu et al. (2021a) analyzed investor attention and also found that investors were indifferent to whether stocks were from green or polluting companies. They used the Baidu index as a proxy to measure investors' attention towards green or polluting stocks and found that increased air pollution led to an increase in attention towards both types of stocks. Their mediating effect model used data from the China Center for Economic Research (CCER) database, and they found increased investor attention to be positively related to the stock price of a company, no matter whether it was green or polluting (Liu et al., 2021a).

#### *Preferences for Portfolios Related to Consumption*

Air pollution can also increase investors' preferences for portfolios related to consumption, and portfolio returns in various categories have been analyzed.

Muntifering (2021) used the fundamental capital asset pricing model and found that the AQI index in New York City has a strong positive relationship with portfolio returns for food products and wholesale. This might have been due to air pollution increasing psychological stress and motivating people to consume more, thus driving up the returns of these portfolios and making them more attractive to investors (Muntifering, 2021).

#### ***Investors' Willingness to Trade***

Research into whether air pollution affects investors' willingness to trade has obtained inconclusive results. In general, most studies have proposed that air pollution reduces investors' willingness to trade and that environmental awareness increases this negative effect. However, some studies have argued that air pollution stimulates investors to trade by enhancing their overconfidence.

#### *Willingness to Trade*

Most studies have found that air pollution discourages investors from trading, although there have been exceptions.

Li and Peng (2016) suggested that air pollution decreased investors' desire to trade. They conducted a causal step regression using the daily money inflow in the Shanghai Stock Exchange and found that air pollution led investors to make pessimistic predictions about the market, which ultimately decreased the demand for the stock.

Lepori (2016) also found a causal relationship between air pollution and investors' reluctance to trade, via a natural experiment in Italy. Based on a previous psychological study, he used the ambient air pollution level of the Milan Stock Exchange (MSE) as the proxy to measure the mood of investors. He hypothesized that air pollution negatively affected investors' moods and thus made them pessimistic about the market, ultimately leading them to buy fewer stocks. May 1994 was applied as the breakpoint, as the specific floor trading technology was retired after that date, such that investors did not need to present in the MSE to trade. The negative effect of air pollution on investors' willingness to trade was found to be significant before 1994 but statistically insignificant after 1994, as after 1994, investors could trade remotely, and thus from places with different levels of air pollution. Thus, a causal relationship was found between air pollution and investors' unwillingness to trade, as investors were only affected by the air pollution in the MSE if they were directly exposed to it (Lepori, 2016).

Wu et al. (2018a) also argued that air pollution inhibited the trading of investors. They designed a local bias test to assess this causal relationship, using data from listed firms on the Shanghai and Shenzhen Stock Exchanges. They found that air pollution depressed the moods of investors, which in turn induced them to trade less on high-pollution days than on low-pollution days. Their results suggested a causal relationship as the stock trading volume only significantly decreased for companies headquartered in highly polluted areas on days when the air quality suddenly deteriorated (Wu et al., 2018a).

Wu and Lu (2020) similarly found that investors had less desire to trade when air quality was bad than when it was good. They used the AQI weighted with the Baidu search volume to assess the moods of investors exposed to air pollution. They found that air pollution negatively affected investors' willingness to trade: investors became less interested in acquiring stock when the air quality worsened, and their trading volume decreased. They also found that individual investors were more prone to the negative effect of air pollution than institutional investors, for whom the effect was insignificant (Wu & Lu, 2020).

However, Huang et al. (2020) suggested that investors exhibited overconfidence on hazy days and thus engaged in excessive trading, which led to their poor trading performance on polluted days. They conducted fixed-effect panel regressions of 87,054 households from 34 cities in China and found that the likelihood of investors making a trade was relatively higher on polluted days than on non-polluted days (Huang et al., 2020).

### *Environmental Awareness*

Environmental awareness in our study context refers to the extent to which investors are aware of the detrimental effects of air pollution (He & Liu, 2018; Teng & He, 2020). A greater level of environmental awareness represents a better understanding of these effects. Environmental awareness has been found to positively moderate the relationship between air pollution and investors' willingness to trade.

He and Liu (2018) suggested that air pollution had an insignificant negative effect on the liquidity of the Chinese stock market by reducing investors' desire to trade in the long run and that their public environmental awareness (PEA) enhanced this effect. They used environmental events to signal the increase in the PEA of Chinese investors and found that the negative effect of air pollution became increasingly significant after these events (He & Liu, 2018). Teng and He

(2020) demonstrated similar results and found that investors' environmental awareness enhanced the negative effect of air pollution on their trading behavior. They use market price volatility, stock turnover rate, and stock illiquidity index on the Shanghai Stock Exchange to directly measure the trading behavior of Chinese investors. They used four significant events in China as a proxy for investors' increased environmental awareness, including the revised "Environmental Protection Law of China" published in 2015, and found that investors' environmental awareness enhanced the negative relationship between air pollution and their willingness to trade, which increased market illiquidity (Teng & He, 2020).

## Conclusion

In this chapter, we provide a comprehensive and retrospective review of the emerging topic of how air pollution affects investors' behavior. We summarize the essential information, including the data sources, variables, methods, and main results, presented in 25 studies. Most of these studies used the AQIs obtained from various government websites to measure air pollution and typically applied data from stock and fund markets as indirect measures of investors' behavior. Some studies used account-level data to identify the trading behavior of individual investors, which is a more direct approach than using market-level data.

Two potential mechanisms by which air pollution can affect investor behavior have been suggested. Most of the studies assessed the psychological effects and found that air pollution can affect investors' mental health and thus their behavior. Other studies focused on physiological effects and argued that air pollution affects investors' behavior by increasing their cortisol concentrations.

The 25 studies examined the effects of air pollution on three aspects: investors' performance, financial instrument preferences, and willingness to trade.

First, investors exposed to air pollution have been found to perform poorly, but whether this effect is greater for individual investors than institutional investors remains unclear. Investors have been found to become more susceptible to the disposition effect, lose confidence in the market, and misprice assets when air quality deteriorates. However, some studies found that individual investors are less professional and more prone to the negative effects of air pollution than institutional investors, while other studies argued that institutional investors also suffer from the negative effects of air pollution. That is, institutional investors may misprice stock IPOs, seasoned equity offers, and land when air pollution is severe.

Air pollution has also been found to increase investor preferences for portfolios related to consumption, but it remains unclear whether air pollution increases investor preferences for green financial instruments. Some studies suggested that air pollution induces investors to invest more in green funds and stocks, while others argued that air pollution focuses investors' attention on both green and polluting stocks, and found preferences for green financial instruments to be statistically insignificant.

Finally, research into whether air pollution affects investors' willingness to trade has produced inconclusive results. Some studies suggested that air pollution decreases investors' willingness to trade and that their level of environmental awareness exacerbated this effect. However, other studies determined that investors are overconfident on trading days when pollution levels are high and tend to engage in excessive trading despite insufficient information, leading to a poor trading performance on such days.

Our review also holds implications for broader green financial markets. First, our bibliographic analysis suggests that China is the most studied context of our topic. Research has brought a new perspective to China's green financial market that the natural environ-

ment can affect the green financial market through the channel of investors. Given the widely supported results that air pollution has negative effects on investor performance, it is worthwhile for China's policymakers to focus on environmental policies that aim at reducing air pollution to promote sustainable development of the green financial market. Second, studies have shown that air pollution may draw investors' attention to green financial instruments, which deserves further investigation. Extant research explains how air pollution affects investors' preferences for green financial instruments through the mechanisms of risk aversion, which implies that investors perceive green financial instruments as less risky than polluting alternatives in the condition of air pollution. It is suggested that air pollution helps promote green financial instruments to some extent. However, the financial instruments may be riskier than their polluting alternatives due to a limited standard for classifying and labeling relevant risks (Falcone & Sica, 2019). This misalignment of investors' perceived risk and actual risk of green financial instruments requires further attention. It implies that the green financial market should make efforts to improve the risk labeling scheme for green financial instruments to properly guide the investor. Finally, increasing investment in consumption-related portfolios in the condition of air pollution is also relevant for green financial markets. This behavior may increase carbon emissions, which is an important issue that green finance aims to address. The green financial market could focus more on integrating the green perspective with consumption to promote low-carbon consumption, which could alleviate the effects of air pollution.

Furthermore, although the effects of air pollution on investors' behavior have been examined, more extensive investigations could be conducted in future studies.

First, these effects could be assessed under different economic conditions. Although a consensus has been reached in these studies that air pollution is detrimental to investor performance, it may also have a positive effect under certain economic circumstances. For example, if the negative sentiments induced by air pollution coincide with a financial crisis, investors' performance may ultimately increase as they can limit their losses by selling before the market worsens. In addition, the reduction in investors' willingness to trade due to air pollution may also lead to a reduction in losses when exposed to unexpected financial shocks. Future research could therefore assess whether the effects of air pollution on investor performance depend on the state of the economic environment.

Second, the varying effects of air pollution on investors' preferences have not been fully explored. The disclosure of a firm's environmental, social, and governance (ESG) performance may moderate the relationship between air pollution and investor preferences for green financial instruments. Air pollution has been found to increase investors' preferences for green financial instruments, due to their negative sentiments regarding the instruments issued by polluting firms. Thus, if polluting firms comprehensively disclose their ESG activities, such as their promotion of innovative technologies that reduce air pollution, investors' views of these firms may become less negative, and thus their preferences for green financial instruments may decrease. However, if polluting firms have poor levels of ESG activity, investors' views of these firms may become more negative, and thus their preferences for green financial instruments may increase. The most likely of these potential outcomes could therefore be assessed in future studies.

There have also been few studies of investors' levels of environmental awareness. Few studies have focused on whether environmental awareness has a moderating effect on the relationship between air pollution and investors' preference for green financial instruments. In the presence of air pollution and compared with investors with a lower level of environmental awareness, those with a higher level of environmental awareness could be expected to invest more in green financial instruments. However, compared with investors with a lower level of environmental

awareness, those with a higher level of environmental awareness may also be more selective and likely to scrutinize the nature of such instruments, and thus the latter may ultimately be less interested than the former in the green financial instruments issued by the firms with poor performance in terms of air pollution. Variations in the moderating effect of investors' environmental awareness on the relationship between air pollution and investors' preferences for green financial instruments should therefore be examined in more detail.

Finally, further systematic comparisons of institutional and individual investors are needed to determine their respective susceptibilities to air pollution. The inconsistent results that have been found may be due to the contexts in which the studies have been performed. Most have concluded that compared with institutional investors, individual investors are more prone to the effects of air pollution and thus perform worse in the stock market. However, further tests of the effect of air pollution on the performance of these two types of investors in various asset categories and market conditions are required. Individual investors may be more resilient to the effects of air pollution than institutional investors in some categories or under specific market conditions. The mechanisms responsible for the differences between these two types of investors in terms of their susceptibility to air pollution remain unclear. Institutional investors may be more experienced than individual investors, thus more resilient to external distractions such as air pollution. Future research could investigate this possibility in more detail by assessing whether experienced individual investors are more resilient to air pollution than inexperienced ones.

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## Appendix

Table A1 Summary table of relevant studies

<i>Studies</i>	<i>Published in</i>	<i>Cited by</i>	<i>Year</i>	<i>Context</i>	<i>Dep variable</i>	<i>Dep variable source</i>	<i>AQI level</i>	<i>AQI frequency</i>	<i>AQI source</i>	<i>Main results</i>	<i>Psychological effect</i>	<i>Physiological effect</i>
Air pollution and stock returns in the US	Journal of Economic Psychology	83	2011	United States	daily data on stock returns	Yahoo Finance	stock exchange	daily	AirData web sites	negative sentiment towards market	No	
The stock market effect of air pollution: Evidence from China	Applied Economics	39	2016	China	demand for stocks (measured by rate of daily money inflow)	Wind Financial Terminal	16 big cities with daily a population of over 8 million		The Ministry of Environmental Protection of People's Republic of China (MEPC)	negative sentiment towards market	Yes	
Air pollution and stock returns: Evidence from a natural experiment	Journal of Empirical Finance	61	2016	Italy	daily return of Milan Stock Exchange index	World Federation of Exchanges and individual exchange websites	Milan	daily	three monitors in Milan Italian Environmental Protection Agency	reluctant to trade	Yes	No
The effects of haze pollution on stock performances:	Applied Economics	13	2017	China	stock returns and volatilities	Wind database	Beijing	hourly on trading days	website of US Department of State Air Quality Monitoring Program	website of US Department of State Air Quality Monitoring Program	Yes	Yes
Evidence from China	Pacific Basin Finance Journal	19	2018	China	daily stock returns, turnover, illiquidity, and volatility for each firm	Wind database and China Stock Market & Accounting Research (CSMAR) databases	city	daily	The MEPC	reluctant to trade	Yes	No
Study on the influence mechanism of air quality on stock market yield and volatility: Empirical test from China based on GARCH model	Finance Research Letters	13	2018	China	stock market yield; Snowball website comments	Wind database and Snowball website	national	daily	The MEPC	negative sentiment towards market	Yes	No

(Continued)

<i>Studies</i>	<i>Published in</i>	<i>Cited by</i>	<i>Year</i>	<i>Context</i>	<i>Dep variable</i>	<i>Dep variable source</i>	<i>AQI level</i>	<i>AQI frequency</i>	<i>AQI source</i>	<i>Main results</i>	<i>Psychological effect</i>	<i>Physiological effect</i>
The public environmental awareness and the air pollution effect in Chinese stock market	Journal of Cleaner Production	37	2018	China	Shenzhen Stock Exchange Index	Wind database	exchange center: daily	The MEPC Shanghai	The MEPC	reluctant to trade	Yes	No
Effect of air pollution on the stock yield of heavy pollution enterprises in China's key control cities	Journal of Cleaner Production	41	2018	China	stock yield	CSMAR database	key cities	maximum daily in December	The MEPC	negative sentiment on market	Yes	Yes
The asymmetric effect of air quality on cross-industries' stock returns: Evidence from China	Environmental Science and Pollution Research	3	2019	China	stock return in nine industries	Shanghai Exchange Index	exchange center: daily	The MEPC Shanghai	The MEPC	prefer green stocks	No	Yes
How does air pollution-induced fund-manager mood affect stock markets in China?	Journal of Behavioral and Experimental Finance	5	2020	China	stock price; stock liquidity	CSMAR database	city	daily	The MEPC	negative sentiment on market	Yes	No
Pollution and Performance: Do investors make worse trades on hazy days?	Management Science	25	2020	China	trading performance, A large brokerage firm trading behaviors (estimated by return and holding of attention-grabbing stocks)	A large brokerage firm in China	city	daily	The MEPC	disposition effect	Yes	No
Air pollution, individual investors, and stock pricing in China	International Review of Economics and Finance	11	2020	China	individual investor mood (measured by air quality weighted by Baidu search volume)	Wind database and Baidu Search Index	city	daily	website of the Chinese Air Quality Study Platform	negative sentiment on market	Yes	Yes

*Air Pollution and Investors' Behavior*

Responsible investment in the Chinese stock market	5	2020	China	holding preference	Shanghai Stock Exchange	national (measured by trading ratio times AQI of 31 provincial capitals)	daily	China National Environmental Monitoring Center (CNEMC)	preference for green stocks	Yes	No
Air quality levels, environmental awareness and investor trading behavior: Evidence from stock market in China	Journal of Cleaner Production	12	2020	China	variables directly measuring investor trading activities, including price volatility, stock turnover rate, stock illiquidity index, and rate of return	Wind database	city	The MEPC	reluctant to trade	Yes	No
How air quality affect health industry stock returns: New evidence from the Quantile-on-Quantile regression effect in China	Frontiers in Public Health	0	2021	China	stock return	Shanghai Stock Exchange	exchange center: daily Shanghai	The Ministry of Ecology and Environment of the People's Republic of China (MEEPRC)	preference for green stocks	Yes	No
Air pollution, behavioral bias, and the disposition effect in China	Journal of Financial Economics	15	2021	China	difference between the probability of selling winners and probability of selling losers	Center for Research in Security Prices (CRSP)	city	The MEPC	disposition effect	Yes	No
The relationship between air pollution, investor attention and stock prices: Evidence from new energy and polluting sectors	Energy Policy	4	2021	China	stock price	China Center for Economic Research (CCER) and Baidu Search Index	national (by summing the provincial AQIs weighted by the number of stock accounts)	The MEEPRC	no preference for green stocks	Yes	Yes
The effect of air quality and weather on the Chinese stock: Evidence from Shenzhen stock exchange	Sustainability (Switzerland)	2	2021	China	returns of the Shenzhen market	Infomax database	exchange center: daily Shenzhen	The MEPC	negative sentiment towards market	Yes	No

(Continued)

Studies	Published in	Cited by	Year	Context	Dep variable	Dep variable source	AQI level	AQI frequency	AQI source	Main results	Psychological effect	Physiological effect
Air pollution, investor sentiment and excessive returns	Journal of Asset Management	0	2021	United States	portfolio return	Dr French's personal website	exchange center: NYC	daily	Environmental Protection Agency	more consumptions	Yes	No
Air pollution, local bias, Finance Research Letters and stock returns	Finance Research Letters	7	2021	China	stock return	CSMAR database	city	daily	The MEPC	mispricing	Yes	Yes
Does air pollution affect seasoned equity offering pricing?	Journal of Financial Markets	1	2021	China	seasonal equity offers discounts	Oriental Fortune website, Wind database, and JuchaoInformation website	bidder's location	daily (hourly averaged)	all air quality monitoring stations in China	mispricing	Yes	No
Evidence from investor bids	Emerging Markets Review	4	2021	China	trading behaviors (measured by changes in investor portfolio)	Snowball website and China Stock Market and CSMAR database	city	daily	The MEPC	individual investors are more susceptible to air pollution	Yes	Yes
Does air pollution influence investor trading behavior?	Applied Economics	4	2021	China	market-adjusted IPO underpricing	CSMAR database	city	daily	city-level environmental protection bureaus	mispricing	Yes	No
Evidence from China	Air pollution and initial public offering underpricing	1	2021	China	land price premiums	Landchina website	city	daily	The MEPC	mispricing	Yes	Yes
Does air pollution affect Real Estate Economics	Investor cognition and land valuation?	1	2021	China	market	fund flow (calculated using a formula)	city	quarterly	the website of World Air Quality Index	preference for green funds	Yes	Yes
Evidence from the Chinese land market	Environmental preference, air pollution, and fund flows in China	0	2022	China	fund flow (calculated using a formula)	CSMAR database	city	quarterly	the website of World Air Quality Index	preference for green funds	Yes	Yes