The Smog That Hovers: Air Pollution and Asset Prices*

Lei Guo[a], Xing Han[b], Youwei Li[c]

[a] *Ghent University, Ghent 9000, Belgium*

[b] *University of Auckland Business School, Auckland 1010, New Zealand*

[c] *Hull University Business School, Cottingham Rd, Hull HU67RX, United Kingdom*

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Abstract

Air pollution affects mental well-being (mood) and amplifies behavioral biases. We test the adverse impact of air pollution on asset prices through the lens of dual-listed stocks. Using regression analysis and difference-in-differences tests, we document that a sharp increase of air pollution (in one location) leads to an immediate deterioration of the price parity of dual-listed shares, which is consistent with the air pollution-induced depressive symptoms. Moreover, increased institutional ownership attenuates the adverse impact of air pollution on asset prices, as institutions are less susceptible to air pollution-induced symptoms than individuals.

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* Corresponding author: Department of Accounting and Finance, University of Auckland Business School, 12 Grafton Road, Auckland 1010, New Zealand. E-mail: xing.han@auckland.ac.nz (X. Han).

E-mail addresses: lei.guo@ugent.be (G. Lei), xing.han@auckland.ac.nz (X. Han), and youwei.li@hull.ac.uk (Y. Li).

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1. Introduction

In the pursuit of rapid industrialization and modernization, environmental problems are becoming more pressing for the modern society. Climate change, resource depletion, water shortage, greenhouse gas emissions, and deforestation… These environmental issues are on the long list that have put severe constraints on the future growth of our world economy and the financial markets.

This paper aims to provide novel evidence on the broad impact of air pollution, a specific form of environmental issues, on the financial markets. Recent health science works document that air pollution negatively affects mental well-being, mood, and cognitive ability (see Block and Calderón-Garcidueñas, 2009; Chen et al., 2017; Fonken et al., 2011; Mohai et al., 2011; Weuve et al., 2012; Weir, 2012; among others). As is pointed out by Weir (2012), the yellow haze of smog hovering over the skyline is not just a stain on the view. It also leaves a mark on human's mind (i.e., depressive mental symptoms). Based on these psychological findings, we argue that air pollution has much broad implications in financial markets, as it temporarily "depresses" asset prices relative to its fundamental value due to investors' pessimistic feelings about the market developed by the sudden increased air pollution over time (i.e., air pollution-induced depressive symptoms).

However, it remains a challenging task to quantify the air pollution-induced price concession, as one needs to first identify the benchmark—the fundamental value. Dual-listed stocks—those that represent the same equity claims, but are traded in segmented markets by different investor clienteles— offer a *unique* design to circumvent this issue, as one could utilize the time variation of the relative price (dis-)parity between the dual-listed shares to quantify the air pollution-induced price concession.

To validate the above conjecture, we collect the market data of AH dual-listed stocks of Chinese companies. Those are firms headquartered in Chinese mainland cities with their stocks dual-listed in the onshore market (the domestic A-shares that are traded in Shanghai and Shenzhen stock exchanges) and in the offshore market (the foreign H-shares that are traded in the Hong Kong stock exchange). Due to a number of real-world frictions such as capital control, regulatory constraints, market segmentation, and the well-established empirical regularity of local bias (Ivković and Weisbenner, 2005;

Seasholes and Zhu, 2010), there exists a persistent clientele difference between the onshore A-share market and the offshore H-share market. That is, A-shares are overwhelmingly held by local investors, in particular local individual investors, while H-share are held mostly by foreign investors. We also collect the data of the air quality index (AQI) of all the Chinese mainland cities where the AH dual-listed companies are headquartered. As long as the air conditions in both markets (i.e., physical locations) do not move in tandem, severe air pollution in one location (assuming the Chinese mainland city where the company is headquartered) will lead the local investors to develop negative feelings and become overly pessimistic about the future prospects of the dual-listed company, which lowers the A-share stock price relative to its H-share stock price, manifested as a drop in the AH share premium.[1]

Empirically, we confirm a strong negative relation between air pollution and the AH share premium. In the regression analysis that controls for a number of well-known determinants of the AH share premium as well as the firm and time fixed effects, we find that increased air pollution (in the city where the company's headquarter is located) has a significant negative impact on the AH share premium, indicating a sizeable violation of the price parity of the dual-listed shares. This is consistent with our intuition that air pollution affects mental well-being (mood) and amplifies behavioral biases that leads to suboptimal market outcome—price concession (relative to its fundamental).

We also conjecture that institutional ownership could dampen the adverse impact of air pollution on asset prices, because institutions are less susceptible to air quality-induced depressive symptoms than individuals. The regression output confirms our intuition. We find that dual-listed stocks with high institutional ownership tend to have low AH share premium in the cross section. More importantly, increased institutional ownership attenuates the adverse impact of air pollution on asset prices, as the coefficient on the interaction term between instructional holding and air quality is highly positive and

[1] We are aware that there exists a persistent AH share premium—the price premium of A-share over its H-share counterpart. Existing literature suggests that the price disparity between onshore A-shares and offshore H-shares are partially explained by the factors related to the clientele difference and market segmentation, as well as the economic and regulatory differences between the onshore and offshore markets (see Chan et al., 2008; Chen et al., 2001; Chung et al., 2013; Ma, 1996; Wang and Jiang, 2004; among others). Therefore, in our empirical analysis in later sections, we explicitly control a wide range of firm-, market-, and macro-level variables, so that we could properly identify the *net* impact of air pollution on the AH share premium.

statistically significant. That is, conditional on the level of air pollution, an increase in institutional ownership partially mitigates the deterioration of price parity between the A- and H-share stocks.

To identify whether the negative relation between air quality and AH share premium implies a *causal* impact of air pollution on asset prices, we examine one plausible exogenous variation in air quality—a salient increase of air pollution in the mid of the week. To be specific, we first aggregate the AH share premiums to the city level, as there could be multiple AH dual-listed companies headquartered in the same city. Next, we adopt the difference-in-differences (DID) approach similar to Li et al. (2021). The spirit of our DID test works as follows: Suppose we test two different cities X (the treatment group) and Y (the control group), both of which have some AH dual-listed companies that are headquartered there. Both cities are exposed to good air quality early in the week (Monday through Tuesday). Furthermore, a sudden, salient increase in AQI (i.e., severe air pollution) occurs in city X during the middle of the week (i.e., Wednesday), and its AQI remains at a high pollution level for the rest of the week (Thursday through Friday). On the other hand, city Y does not experience such a salient change in air quality in mid of the week, and the AQI of city Y remains stable at the moderate level throughout the week. In this case, we can use the change in AH share premium of the corresponding AH dual-listed stocks in city X (relative to that of city Y) *before* and *after* a drastic increase of AQI in city X to identify the potential impact of air pollution. If air pollution has an adverse effect on asset prices, we would expect that the AH share premium of city X (the treatment group) should shrink dramatically more in the post-event period than that of city Y (the control group).

Using the above difference-in-differences framework, we confirm that the deterioration of air quality causes a large price concession, manifested by a drop in the AH share premium. The AH share premium of the treatment group is estimated to shrink by approximately 4% relative to that of the control group *after* the sharp increase of AQI for the cities of the treatment group. Moreover, the sharp contrast between the treatment group and the control group does not emerge in the placebo test, which relies on salient changes in other meteorological conditions (such as strong winds) that does not leads to increased air pollution. Therefore, the results of the placebo test reinforce the causal interpretation that increased air pollution leads to the large price concession relative to its fundamental.

Our paper contributes to the growing literature on air pollution, a specific form of environment issues, and its broad implications in the financial markets (see Ding et al., 2021; Li et al., 2021; Wu and Lu; 2020; among others). We show that increased air pollution imposes severe consequences on the market participants and the market as a whole. It leads to suboptimal market outcome—a price concession relative to the fundamental, manifested by a significant drop in the AH share premium. The paper also contributes new evidence to our understanding of the pricing puzzle of the dual-listed stocks (see Chan et al., 2008; Chen et al., 2001; Chung et al., 2013; Ma, 1996; Wang and Jiang, 2004; among others). In addition to the existing explanations on AH share premium that includes asymmetric information, differential risk preference, (il)liquidity, market segmentation, we show that air pollution, or more broadly the environmental issue, presents a new dimension that drives the magnitude of the AH share premium over time. Overall, these results highlight the broad implications of the environment in modern financial markets.

The rest of the paper is organized as follows. Section 2 develops the testable hypotheses. Section 3 describes the data and variables. Section 4 documents the key empirical evidence and checks the robustness of the findings. Section 5 concludes.

2. Hypothesis Development

Air pollution and the AH share premium. We hypothesize that *increased* air pollution depresses asset price relative to its fundamental value, because air pollution *adversely* affects investors' mood, mental well-being, and cognitive capacities (Block and Calderón-Garcidueñas, 2009; Chen et al., 2017; Fonken et al., 2011; Mohai et al., 2011; Weuve et al., 2012; Weir, 2012). The negative psychological influence and cognitive deterioration lead to suboptimal investment assessments and market outcomes.

We are aware that it remains a challenging task for the empirical researcher to validate the potential *irrational* price concession induced by air pollution, as one needs to first identify the benchmark—the fundamental value. Dual-listed stocks (i.e., A-shares and

H-shares) that represent the same equity claim but are traded in segmented markets by different investor clienteles, however, offer a *unique* design to circumvent this issue, as one could utilize the time variation of the relative price ratio (i.e., AH share premium) on the same underly stock to quantify the air pollution-induced price concession.

As long as the air conditions in both markets (i.e., physical locations) do not move in tandem (or are perfectly correlated), severe air pollution in one location (assuming the Chinese mainland city where the company is headquartered) will lead the local investors, in particular the individual investors, to develop negative feelings and become overly pessimistic about the future prospects of the dual-listed company, which lowers the A-share stock price relative to its H-share stock price traded in the other location (i.e., in Hong Kong). Therefore, our main testable hypothesis can be formulated as follows:

Hypothesis 1 (H1): *Everything else equal, increased air pollution at the city where the firm is headquartered induces heightened negative feelings by the local investors about the future prospects of the company, leading to a depressed A-share stock price manifested by a shrinkage in the AH share premium.*

That is, we expect a negative relation between the local air pollution at the Chinese mainland city where the company is headquartered and the AH share premium. Of course, our hypothesis builds on the theory and evidence of the local bias (also called home bias) that investors tend to overweight the domestic stocks (as opposed to foreign stocks) in their portfolio (Ivković and Weisbenner, 2005; Seasholes and Zhu, 2010). The strong home bias also applies to the Chinese A-share market (Huang et al., 2016). Moreover, a number of real-world frictions such as capital control and regulation-induced market segmentation further strengthen our empirical design of focusing on the A-share and H-share dual-listed stocks, because the respective investor clienteles are located in different physical locations.

The attenuation by institutional holding. We also hypothesize that institutional holding can mitigate the adverse impact of air pollution on asset price. Compared to individual investors, institutional investors have more economic resources and greater analytical skills, and are less subject to behaviour biases. In principle, they are more sophisticated, have sufficient expertise to more precisely assess the fundamental value of the underlying stocks. As a result, they should exhibit more rationality, and are subject to air pollution-induced symptoms to a *lesser* degree (i.e., limited behavioural bias). Previous studies find consistent evidence that companies with higher institutional holding tend to have less mispricing risk, because institutional investors act more rationally (Baik et al., 2010; Boehmer and Kelley, 2009). In comparison, individuals tend to trade stocks based more on intuition, mood, and market sentiment. Therefore, our second testable hypothesis is formulated as follows:

Hypothesis 2 (H2)*: Everything else equal, high institutional holding can attenuate the adverse impact of air pollution on asset price.*

3. Data and Variable Constructions

3.1. Data and data sources

Our stock data of AH dual-listed companies, which includes the market data, financial data, and institutional holding data, are all retrieved from WIND Financial Terminal. Initially, we retrieve a total of 137 AH dual-listed companies that headquartered in 37 Chinese mainland cities over the sample period. We require an AH dual-listed firm to have its headquarter registered in mainland China (rather than Hong Kong or other overseas locations) to be included in our sample. One company is excluded due to missing firm-specific data, and another company (i.e., Lufeng Lithium Co., Inc from Jiangxi province) is excluded due to insufficient air quality data of the city where the company is headquartered. This leads to a final sample of 135 AH dual-listed companies located across 36 Chinese mainland cities (As shown in Panel A of **Table 1**).

[Insert **Table 1** about here]

We collect the daily data of the A-share and H-share stock prices. Note the domestic A-shares are denominated in Chinese yuan (CNY), while the foreign H-shares are denominated in Hong Kong dollars (HKD). Daily official exchange rates between HKD and CNY are also retrieved. We also collect a number of firm-level variables (such as market capitalization, number of shares outstanding, daily share trading volume) that are well-known in determining the AH share premium in the cross section.

Daily information on air condition (such as air quality and pollutant concentrations) is compiled from multiple sources. In particular, the air quality of a particular city, measured by the air quality index (AQI), is retrieved from WIND Financial Terminal as well as the Chinese Air Quality Study Platform (www.aqistudy.cn). Our final sample is the combined dataset of stock data matched with air quality data, which spans the sample period from December 2013 to July 2021 (i.e., 106 months in total).

3.2. Variable constructions

AH premium. Following the convention, the AH premium (denoted as $Premium$) is defined as the ratio of A-share stock price relative to its H-share stock price converted into one common currency (see Chung et al., 2013; among others). It measures the relative price parity between the A-share stock and its H-share counterpart:

$$Premium_{i,t} = \frac{P_{i,t}^{A}}{P_{i,t}^{H} \times S_t}, \tag{3.1}$$

where $P_{i,t}^{A}$ is the A-share price of company i on day t (measured in Chinese yuan), and $P_{i,t}^{H}$ the H-share price of the same company on day t (measured in Hong Kong dollar), and S_t is the prevailing spot exchange rate on the same day that converts the Hong Kong dollar into Chinese yuan. Based on the above definition, a value above (below) 1 indicates that the A-share is trading at a premium (discount) over its H-share (see Chan et al., 2008; Chen et al., 2001; Chung et al., 2013; Ma, 1996; Wang and Jiang, 2004; among others).

Air quality index (AQI). Our main measure of air pollution is the daily Air Quality Index (AQI) for each city, which synchronizes various contents of air pollution, including carbon monoxide (CO), ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2), and various concentrations of fine particulate matter (PM). In particular, the particulate matter less than 2.5 micrometers in diameters (PM2.5) has drawn substantial public and media attention in recent years, as it poses severe health risks to human beings. The AQI data are originally compiled by the Ministry of Environmental Protection of China (MEPC). Since 2013, MEPC has set up environmental monitoring points in more than 350 Chinese mainland cities to monitor the local air quality.

The AQI ranges from 0 to 500 in China. According to the Environmental Air Quality Index Technical Regulations (HJ633-2012) issued by the Science Standards Division of the Ministry of Ecological Environment of China, the air quality levels are divided into six categories, excellent (AQI from 0 to 50), good (AQI from 51 to 100), mild pollution (AQI from 101 to 150), moderate pollution (AQI from 151 to 200), heavy pollution (AQI from 201 to 300), and severe pollution (AQI from 301 to 500). Generally, a higher level of AQI indicates a higher level of local air pollutants and a poor air quality. It is generally agreed that AQI values above 100 indicate unhealthy air conditions (See Li et al., 2021). Since the value of AQI spans a wide range (from 0 to 500), we follow the convention in the literature to use the logarithm of AQI in our empirical analysis in later sections (see Ding et al., 2021; Li et al., 2021; Wu and Lu; 2020; among others).

Institutional holding. We retrieve the institutional holding—the proportion of equity ownership by institutions (expressed in percentage points), which are updated on a quarterly basis. We match the (lagged) institutional holding data with the daily AQI and AH share premium data for empirical analysis in later sections.

We also construct a number of other firm-, market-, and macro-level variables (such as market capitalization and earnings-to-price ratios) for our empirical analysis in later sections, as existing literature suggests that the (persistent) AH share premium are related to a number of factors related to the clientele difference and market segmentation, as well as the economic and regulatory differences between the onshore and offshore markets (see Chan et al., 2008; Chen et al., 2001; Chung et al., 2013; Ma, 1996; Wang and Jiang, 2004; among others).

3.3. Summary statistics

Table 2 presents the descriptive statistics for the key variables of our dataset. Over the full sample period from December 2013 to July 2021, the average value of the AH share premium is 1.68, indicating that on average the onshore A-share stocks are traded at a premium of 68% over the offshore H-share stocks. The sample standard deviation amounts to 55%, indicating that the large heterogeneity in AH share premium exists in the cross section (i.e., across the AH dual-listed stocks). The magnitude of the AH share premium is comparable to, albeit smaller than, that reported in prior works which covers earlier period in history (see Chung et al., 2013; for example). In fact, a long-term trend of declining AH share premium is expected, as markets become integrated over time.

Next, we examine the statistics for institutional holdings. The mean (median) value of institutional shareholding hovers around 63% (66%), with a sample standard deviation amounts to 23.54%. Among all AH dual-listed companies, the firm with the smallest (largest) institutional ownership has an institutional holding of approximately 52% (98%). In fact, the large cross-sectional differences of institutional ownerships across the dual-listed firms offers an ideal setting for us to evaluate the potential mitigation effect of institutional holding on the adverse impact of air pollution on asset prices.

Finally, we focus on the sample observations of air quality. For consistency purpose, we report the statistics for the logarithm of AQI, which is used in the panel regression in later sections. The sample mean and standard deviation are 4.22 and 3.69 respectively.[2] Note that an AQI value above 100 (equivalent to a log value of 4.60) is generally considered as unhealthy air condition. Our sample statistics is fairly similar to that reported in Li et al. (2021), who also note that the standard deviation of AQI in China hovers about 44 (equivalent to a log value of approximately 3.78).

[Insert **Table 2** about here]

4. Empirical Results

4.1. Multivariate analysis

In this section, we conduct a multivariate analysis to verify the relation between air quality and stock price with the following model specification:

$$\begin{aligned} Premium_{i,t} = \alpha + \beta \log(AQI)_{c,t} + \gamma Institutions_{i,t} + \\ \mu \log(AQI)_{c,t} \times Institutions_{i,t} + \theta Z_{i,t} + \varepsilon_{i,t}, \end{aligned} \qquad [4.1]$$

where $Premium_{i,t}$ is the AH share premium for the dual-listed stock i on day t, $\log(AQI)_{c,t}$ is the log of the daily value of the air quality index for city c (the corresponding city where the company i is headquartered) on day t, $Institutions_{i,t}$ is

[2] The sample average and standard deviation for the original AQI data are 78 and 41, respectively.

the institutional holding (measured in percentages), $Z_{i,t}$ is a vector stacking the control variables, and $\varepsilon_{i,t}$ is the residual term in the panel regression. The list of control variables encompasses both the firm characteristics (including market capitalization, earning-to-price ratio, and liquidity), and city-level characteristics such as the GDP and total population of the city. We also include local weather conditions (such as city-level temperature, pressure, wind speed, hours of sunlight), seasonality (i.e., day-of-the-week effect and seasonal affective disorder effect), autocorrelation of the AH share premium (i.e., the lagged term), and firm fixed and time fixed effects. The coefficient, β, on the log of AQI measures the contemporaneous relation between air quality and the AH share premium (i.e., the relative asset price), while the coefficient, μ, on the interaction term measures the mitigation effect of institutional holding on air pollution.

Table 3 reports the output of the panel regression on the impact of air quality on AH share premium. Model specification 1 (column 1) does not include the interaction term between air quality and institutional holding, while model specification 2 (column 2) does. As predicted, air quality in the city where the company is headquartered in mainland China (i.e., increase in AQI value) is negatively related to AH share premium. In both cases, the slope coefficient on AQI is highly negative, and is statistically significant. Moreover, the impact of air pollution is also economically significant, as a one-standard-deviation increase of the log AQI value would leads to a large price concession, manifested as a drop in the AH share premium by two to twelve percent (depending on the model specification). These results are consistent with **H1** that increased air pollution is linked with a depressed A-share stock price relative to H-share stock price, as it induces negative feelings by the local investors about the future prospects of the company.

Another salient feature in the table is that high institutional ownership is linked with low AH share premium in the cross section. This is expected, as institutional investors are more capable to properly assess the value of the dual-listed stocks and are subject to constraints than individuals, which reduces the price premium of A-shares over H-shares. More crucially, consistent with our conjecture that institutions are less susceptible to air pollution-induced symptoms, we find confirming evidence that increased institutional ownership attenuates the adverse impact of air pollution on asset prices. The slope coefficient on the interaction term between air quality and institutional holding has the predicted sign and is statistically significant at the 1% level, which confirms **H2**.

Overall, our baseline analysis indicates that air pollution negatively affects the AH share premium (i.e., a price concession relative to the fundamental), and this negative impact is partially mitigated by (increased) institutional ownership.

[Insert **Table 3** about here]

4.2. Difference-in-Differences analysis

In this section, we further explore whether the negative relation between AQI and AH share premium implies a *causal* impact of air pollution on the asset prices. Our identification test is based on exogenous variation in AQI—a salient increase of AQI that is more than two standard deviations in magnitude. These drastic deteriorations in air quality (i.e., a sudden, sharp increase of AQI) are exogenous to the financial market, which provides researchers a natural experiment (i.e., a difference-in-differences setting) to identify the causal influence of air quality on asset prices.

To be specific, our difference-in-differences (DID) test is performed at the city level. We aggregate the AH share premiums to the city level, as there could be multiple AH dual-listed companies headquartered in the same city. After that, we identify the treatment group by focusing on all cities (where AH dual-listed firms are headquartered) that experienced (1) moderate air pollution in the early of the week (i.e., AQI below 100 on Monday and Tuesday before the treatment event, and the AQI difference between the two days is less than one standard deviation (i.e., 40)) and (2) the treatment event when salient changes in meteorological conditions occurs on Wednesday. This causes the AQI to increase sharply by two standard deviations or more (i.e., an increase of 80 or more in AQI values) on Wednesday, and its AQI continues at a high level for the rest of this week (i.e., the daily AQI values on Thursday and Friday are both above 100 and the AQI difference between the two days is smaller than 40). The reason for choosing two standard deviations increase in AQI value as the threshold is because the magnitude of 80 increase or more in AQI will undoubtedly change the air quality from good to unhealthy in the local city, and is more likely to bring pessimistic feelings and mood (i.e., air pollution-induced depressive symptoms) than a moderate change in air quality.

Next, we identify the control group. For each city in the treatment group, the valid control group includes cities that (1) have a similar AQI level (to the treatment group) at the start of the week (the cities in the control group should have an AQI value below 100 on Monday through Tuesday, and the AQI difference between the two days is smaller than 40), and (2) do not experience a large increase of AQI at the mid of the week (Wednesday). In other words, we focus on the cities with AQI value below 100 and the absolute change of AQI less than 40 over the entire week (i.e., the five weekdays). Following Li et al., (2021), we perform a one-to-one matching by choosing the one from all the eligible cities that has the closest pretreatment AQI conditions within the same week as the control sample of the treatment city. Thus, the potential impact of air pollution on AH share premium can be tested directly in the following difference-in-differences model with time- and city-fixed effects:

$$Premium_{i,t} = \alpha + \beta Post_{c,t} + \gamma Treat_{c,t} \times Post_{c,t} + \theta Z_{i,t} + \varepsilon_{i,t}, \qquad [4.2]$$

where $Treat_{c,t}$ is the indicator which equals to one if the city *c* on date *t* is in the treatment group, and $Post_{c,t}$ is the dummy variable that takes the value of one if city *c* on date *t* is in the post event period, and zero otherwise. $Z_{i,t}$ is vector of control variables that contains all city-level characteristics, including the number of local listed firms, local government income, local city population, and local city GDP. The coefficient of interest is γ on the interaction term, which captures the difference of AH share premium induced by a significant AQI increase in the treatment group relative to the control group. We suppress the term $Treat_{c,t}$ in the model specification, because it is captured by the city-fixed effect.

[Insert **Table 4** about here]

The results of DID test are shown in **Table 4. Panel A** of the table presents the level of AQI and AH share premium before and after the event for the treatment and control groups. Initially, both groups have a good air quality with an AQI close to 60 at the start of the week (Monday through Tuesday). For the treatment group, the post-event AQI increases to around 165, representing a sharp increase of air pollution by the magnitude that is more than two standard deviations. In comparison, the post-event

AQI of the control group is nearly unchanged, as it remains at the level of around 60. The AH share premium of the treatment group is initially higher than that of the control group with a difference of 14% *before* the event. It then shrinks to 10% *after* the sharp increase of AQI in the treatment group. That is, the difference-in-differences amounts to 4% in the AH share premium in the univariate analysis.

Panel B of the table first tabulates the main results of the multivariate analysis of the DID test after controlling for the city-level characteristics and fixed effects (see column 1). As expected, the coefficient on the interaction term, $Treat_{c,t} \times Post_{c,t}$, is negative and sizeable, which amounts to –0.0425 and is statistically significant (*t*-statistics of –1.7712). This suggests that air pollution induced pessimism causes a (temporary) price concession of the A-share relative to its H-share counterpart. Given that our treatment event is designed as a sudden two-standard-deviation increase in AQI, it implies that a one-standard-deviation increase of AQI leads to a sizeable drop of 2.12% in the AH share premium. Meanwhile, the coefficient for $Post_{c,t}$ is insignificant, indicating that the influence of air pollution stems mainly from the treatment effect.

Previous studies have shown that sudden deterioration in air quality (the formation and dissipation of air pollution) is often associated with other drastic changes in meteorological conditions in general and wind conditions in particular (Seaman, 2000; Li et al., 2021). For example, strong wind may blow the contaminants on the ground into the air, bring air pollutants (i.e., sand storms) from surrounding regions to the local areas, and cause the accumulation of air pollutants in the local city. Therefore, to ensure that the drop in AH share premium is indeed caused by air pollution, rather than a general phenomenon (or a spurious relation) that is linked with sudden shifts in other weather conditions such as strong winds, we also perform a placebo test in **Panel B** (see column 2). The placebo test is designed as follows. We focus on all cities that have good air quality at the beginning of the week (AQI < 100), and the AQI remain stable for the rest of this week (AQI < 100 and the AQI difference between consecutive weekdays is less than 40). Next, the treatment group is defined as the cities that experiences strong wind in the middle of the week (Wednesday) with local wind speed exceeds 3 meters per second, but does not experience the deterioration of air quality over the week. In comparison, the control group does not experience strong wind in the mid of the week. Again, we perform a one-to-one matching by choosing the one from all the eligible cities that has the closest pretreatment AQI conditions within the same week as the control sample of the treatment city. As expected, the coefficient on the interaction term, $Treat_{c,t} \times Post_{c,t}$, in the placebo test is indistinguishable from zero, indicating that strong wind, by itself, does not influence the AH share premium. This reinforces the validity of our baseline DID test, as it shows that the AH share premium will not vary dramatically if there happens a sudden shift of meteorological conditions (in the form of a strong wind) but without any significant increase in air pollution. Overall, the results in **Table 4** facilitates a causal interpretation of the adverse impact of AQI on the asset price (i.e., AH share premium).

4.3. Robustness test

In this section, we shed more light on the causal effect of air quality on asset price by performing two additional DID tests to validate the robustness of our key findings. We replicate the DID exercises similar to the baseline test in **Section 4.2**, but with alternative thresholds for the sudden AQI increase to define the treatment group. To be specific, we set the thresholds of an AQI increase to 70 or 60 in the mid of the week, rather than 80 (i.e., two standard deviations of AQI values), while keep all other requirements unchanged. This helps us to examine whether our key findings are sensitive to the AQI threshold used.

Table 5 presents the estimation output. Again, our interest is the coefficient on the interaction term, $Treat_{c,t} \times Post_{c,t}$, which captures the (incremental) drop in AH share premium induced by the sudden jump in AQI (i.e., drastic air pollution). For the case of a threshold of 70 in AQI jump (column 1), the coefficient amounts to –0.044, which is both sizeable and statistically significant at the 5% level. Similarly, for the case of a threshold of 60 in AQI jump (column 2), the coefficient on the interaction term amounts to –0.029, which remains sizeable but is not significant. Comparing both cases, it seems that as we lower the bar—the threshold value decreases from 70 to 60—the impact of AQI on AH share premium also drops. This is reasonable, because our identification test requires a salient, drastic change in air quality that induces a sudden contrast in psychological feelings (mood) which would transmit into large price concession. Therefore, lower threshold values indicate smaller changes in air pollution, which is less likely to cause large mood swings and price movements. Therefore, we expect that the causal impact of AQI on AH share premium is more pronounced with larger AQI jump (which is indeed the case in **Table 5**).

Overall, when interpreting the evidence collectively from **Tables 4** and **5**, we find strong support for a causal interpretation that inferior air quality (i.e., increased air pollution) intensifies pessimistic feelings by the investors which generates a negative impact on asset price, manifested by an immediate drop in the AH share premium.

[Insert **Table 5** about here]

5. Conclusion

This paper contributes to our evolving understanding of the interrelation between air quality and the financial markets. We provide novel evidence on the adverse impact of air pollution, a specific form of environment issue, on asset prices through the lens of dual-listed stocks—onshore A-shares and offshore H-shares that represent the same equity claim but are traded in segmented markets by different investor clienteles in different locations.

Utilizing the time variation of the relative price parity (i.e., AH share premium) on the same underlying stock, we document that a sharp increase of air pollution (in one location) leads to an immediate drop of the AH share premium of the dual-listed stocks, which supports the recent health science findings that air pollution adversely affects mental well-being (mood) and amplifies behavioral biases that could lead to suboptimal investment outcomes (i.e., the air pollution-induced depressive symptoms). Moreover, we document that increased institutional ownership attenuates the adverse impact of air pollution on asset prices in the cross section, as institutions are less susceptible to air pollution-induced symptoms.

We also examine one plausible exogenous variation in air quality—a salient increase of air pollution in the mid of the week—to identify the causal impact of air pollution on asset prices. Using the difference-in-differences framework, we confirm that the deterioration of air quality causes a large price concession, manifested by a drop in the AH share premium. These results have broad implications regarding the role of the environment in modern financial markets. It suggests that increased air pollution imposes adverse consequences to the market participants with a significant price concession (a suboptimal market outcome).

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Table 1: Sample selection and industrial composition of the dual-listed companies

The table lists the sample selection and filtering of the AH dual-listed companies in Panel A, and the industrial composition of the AH dual-listed companies in Panel B.

Panel A: Composition of the Sample Stocks

AH Dual-listed Companies	
AH Dual-Listed Companies (2013 – 2020)	137
Missing Firm-Specific Data (1 Company)	1
Missing City-level Air Quality Index (1 Company)	1
Total Number of Valid AH dual-listed Companies	**135**

Panel B: Industry Composition

Industries	
Capital Goods	21
Transportation	15
Food & Tobacco	3
Materials	13
Energy	9
Property	4
Pharmaceuticals	12
Media	1
Business Service	2
Utilities	7
Consumer Durables	3
Semiconductors	2
Retail	1
Insurance	5
Diversified finance	13
Automotive Parts	5
Bank	15
Technical hardware	4
Total Number of Valid AH dual-listed Companies	**135**

Table 2: Summary statistics

This table provides the summary statistics for the key variables, including the log of AQI (Log(AQI)), the AH share premium (Premium), and the institutional holding measured in percent (Institutions). Min, Pct(25), Median, Pct(75), Mean, and STD denote the minimum, the lower quartile, the median, the upper quartile, the maximum, the mean, and standard deviation of the variable.

Variables	Min	Pct(25)	Median	Pct(75)	Max	Mean	STD
Log(AQI)	2.40	3.89	4.21	4.55	6.22	4.23	3.69
Premium	0.84	1.24	1.57	2.00	3.20	1.68	0.55
Institutions	1.38	52.19	66.07	78.79	97.59	62.88	23.54

Table 3: Multivariate analysis

The table reports the baseline relationship between AQI and the AH share premium in the multivariate regression: $Premium_{i,t} = \alpha + \beta \log(AQI)_{c,t} + \gamma Institutions + \mu \log(AQI)_{c,t} \times Institutions + \theta Z_{i,t} + \varepsilon_{i,t}$. The dependent variable is the AH share premium. The key variables of interests are the log of AQI (Log (AQI)), the institutional holding scaled by 100 (Institutions), and the interaction between Log (AQI) and Institutions. $Z_{i,t}$ is a vector of the control variables that includes firm-level and regional-level characteristics, seasonality, and other weather conditions (unreported for brevity purpose). Firm- and year-fixed effects are also included. Robust t-statistics are reported in parenthesis, which are based on clustered standard errors. The sample period is from December 2013 to July 2021. *, **, *** *denote the significance levels at the 10%, 5%, and 1% levels, respectively.*

	(1)	**(2)**
Log(AQI)	–0.0062***	–0.0344***
	(–2.6406)	(–5.5005)
Institutions	–0.0012***	–0.0031***
	(–12.6757)	(–7.9114)
Log(AQI) × Institutions		0.0004***
		(4.8574)
Controls	Yes	Yes
Firm Fixed Effect	Yes	Yes
Year Fixed Effect	Yes	Yes
Observations	78,120	78,120
R^2	0.7871	0.7875

Table 4: Difference-in-Differences test

Panel A presents the AQI and AH share premium for the treatment group and control group before and after the treatment event, respectively. Treatment group is defined as the cities that have good AQI at the beginning of the week (Monday through Tuesday), but experiences a sharp increase of more than 80 (i.e., more than two standard deviation) in AQI on Wednesday. Panel B tabulates the main output of the difference-in-differences (DID) test:

$$Premium_{i,t} = \alpha + \beta Post_{c,t} + \gamma Treat_{c,t} \times Post_{c,t} + \theta Z_{i,t} + \varepsilon_{i,t}.$$

The dependent variable is the AH share premium. $Treat_{c,t}$ is the indicator which equals to one if the city *c* on date *t* is in the treatment group, and $Post_{c,t}$ is the dummy variable that takes the value of one if city *c* on date *t* is in the post event period, and zero otherwise. $Z_{i,t}$ is a vector of the control variables that includes regional-level characteristics (unreported for brevity purpose). City- and year-fixed effects are also included. Robust t-statistics are reported in parenthesis, which are based on clustered standard errors. The sample period is from December 2013 to July 2021. *, **, *** *denote the significance levels at the 10%, 5%, and 1% levels, respectively*.

Panel A: Univariate analysis

Univariate Analysis				
AQI		Before Event	After Event	After – Before
	Treat	61.80	165	103.20***
	Control	58.90	60.40	1.50
	Treat – Control	2.90	104.60***	101.70***
AH Share Premium		Before Event	After Event	After – Before
	Treat	1.67	1.63	–0.04*
	Control	1.53	1.53	0.00
	Treat – Control	0.14*	0.10*	–0.04*

Panel B: DID test using large AQI increase as the treatment group

	Dependent Variable: AH share premium	
	Sharp increase in air pollution	Placebo test
	(1)	**(2)**
Treat × Post	–0.0425*	–0.0015
	(–1.7712)	(–0.8949)
Post	0.0153	0.0069
	(1.0341)	(0.8264)
Controls	Yes	Yes
City fixed effect	Yes	Yes
Year fixed effect	Yes	Yes
Observation	330	2080

Table 5. Robustness test on the impact of AQI

The table tabulates the main output of the difference-in-differences (DID) test with the following model specification:

$$Premium_{i,t} = \alpha + \beta Post_{c,t} + \gamma Treat_{c,t} \times Post_{c,t} + \theta Z_{i,t} + \varepsilon_{i,t}.$$

The dependent variable is the AH share premium. $Treat_{c,t}$ is the indicator which equals to one if the city *c* on date *t* is in the treatment group. The treatment group is defined as the cities that have good AQI at the beginning of the week (Monday through Tuesday), but experiences a sharp increase of more than 70 (column 1) or 60 (column 2) in AQI on Wednesday. $Post_{c,t}$ is the dummy variable that takes the value of one if city c on date t is in the post event period, and zero otherwise. $Z_{i,t}$ is a vector of the control variables that includes regional-level characteristics (unreported for brevity purpose). City- and year-fixed effects are also included. Robust t-statistics are reported in parenthesis, which are based on clustered standard errors. The sample period is from December 2013 to July 2021. *, **, *** *denote the significance levels at the 10%, 5%, and 1% levels, respectively.*

	Dependent Variable: AH share premium	
	Threshold = 70	Threshold = 60
	(1)	**(2)**
Treat × Post	–0.0436**	–0.0288
	(–1.9954)	(–1.5063)
Post	0.0208	0.0131
	(1.4173)	(1.0463)
Controls	Yes	Yes
City fixed effect	Yes	Yes
Year fixed effect	Yes	Yes
Observation	540	780