The effect of air pollution on stock returns: evidence from Thailand and Indonesia

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ผลกระทบจากมลพิษทางอากาศต่อผลตอบแทนจากหุ้นสามัญ: หลักฐานจากประเทศไทยและอินโดนีเซีย

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The objective of this paper is to investigate the impact of air pollution on stock returns in Thailand and Indonesia from January 1, 2016, to June 30, 2021. Further effects of air pollution on stock returns during the seasonal pollution period, full moon period, new moon period, and high pollution period are also studied.

The result shows that a lagged day of air pollution proxy significantly reduces stock returns in Thailand. The significant negative effect of air pollution on stock returns is similar to that after controlling for the January effect. This is consistent with the finding of Li and Peng (2016). In addition, the negative effects of the lag air pollution agent on stock

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1. Introduction

Air pollution has become a major issue on a worldwide scale. According to the report[1] published in 2016 by World Health Organization (WHO), PM2.5 can endanger human health as the most important component of air pollutants, however, 92 percent of the population of the globe lives in places where PM2.5 exceeds the standard. This report also says that air pollution kills about 6.5 million people in 2012, with most of these deaths occurring in the Southeast Asia and Western Pacific regions.

Furthermore, people find that the harm of air pollution is not only limited to the physical aspects. A large number of scholars have begun to research the psychological impact of air pollution. Zeidner and Shechter (1988) find that air pollution can cause anger and anxiety. Rotko et al. (2002) discover that the pollution of air has been linked with increased annoyance.

Previous studies also find that investors' trading behavior can be affected by mood. Investors invest in a way that is consistent with their mood and they often make more optimal decisions when in positive sentiment and more pessimistic decisions when in a negative mood (Lucey and Dowling, 2005), and they are more tend to risk-averse by bad mood (Harding and He, 2016).

In addition, several papers investigate the effect of the environment on the stock market. They find local cloud cover ratio (Saunders, 1993), the speed of wind (Keef and Roush, 2002), and temperatures and moisture capacity (Yoon and Kang, 2009) can affect the stock returns.

Some scholars have also found a strong link between lunar phases and returns on

[1] The website address of the report published in 2016 by WHO is https://www.who.int/news/item/27-09-2016-who-releases-country-estimates-on-air-pollution-exposure-and-health-impact .

equity. Dichev and Janes (2003) investigate lunar cycle effects in stock returns in the U.S. stock market and other 24 countries around the world and find that the stock returns during the new moon period are about twice as those during the full moon period. They think people are more optimistic during a new moon than during a full moon. Yuan et al. (2006) study the link between lunar phases and the stock returns based on the psychological theory that people are more depressed during the periods of the full moon and find that the returns are shallower during the period of a full moon compared with those during the period of a new moon. Keef and Khaled (2011) use 62 international stock indexes to study the link between the lunar phases and the daily stock returns and find that returns during the new moon period are higher. Does air quality, as one of the environmental variables, also affect the stock market?

According to the implication of air pollution on investors' mood and the impact of investors' mood on trading behavior, scholars investigate the air pollution impact on stock markets. Levy and Yagil (2011) find a significant negative effect on stock market return related to air pollution by using AQI data from Kings County and Philadelphia. And they also find this negative correlation exists in six locations, including New York, Sydney, and so on (Levy and Yagil, 2013). Lepori (2016) studies in the Milan province with pollutants such as PM_{10}, NO_x, and SO_2 and also finds a negative effect. Demir and Ersan (2016) find air pollution's implication is negative on stock returns in the three cities where most investors live in Turkey. Li and Peng (2016) further have discovered that in the same period, the negative link exists in 16 cities in China. Försti (2017) uses data of PM10 to find a negative effect in Finland and no significant effect in Hong Kong. Zhang et al. (2017) find the negative impact is achieved through investor sentiment in Beijing. However, He and Liu (2018) find a different conclusion that the air pollution implication on stock returns is not obvious by using Shanghai city as the sample. Kiihamäki et al. (2021) further expand the geographic location of the study to include 47 cities around the world (including

Singapore, Jakarta, and Ho Chi Minh City) and find although the effect is different in some cities, the summary effect is that the increase of PM 2.5 leads to the decrease of stock returns.

Although the popular conclusion is that the air pollution implication on stock returns is negative, some studies have reached different conclusions due to the different sample selections. More empirical tests are still needed in this research area. Additionally, the previous research areas are mostly concentrated in the US, Europe, and China. However, the study on the rapidly developing Southeast Asia region is limited. For the area of Southeast Asia, only Singapore, Jakarta, and Ho Chi Minh City are studied before by Kiihamäki et al. (2021) and they find a negative effect of PM2.5 on stock return in these three cities.

In addition, previous literature finds lunar phase affects investors' moods and the stock returns are shallow during the periods of the full moon compared with those during the periods of the new moon (Yuan et al., 2006). To the best of my knowledge, the joint effect between the pollution of air and lunar phases on stock returns has not been investigated before. This study will also examine this joint effect in Thailand and Indonesia stock markets.

Moreover, previous literature has studied the difference in the effect of air pollution levels on stock returns usually by dividing air pollution levels into "heavy pollution" and "good" groups (Levy and Yagil, 2011; Försti, 2017). According to Mary and Olivier (2020) and Muhayatun et al. (2020), the average level of air pollution in Thailand and Indonesia is highest during the dry season. Considering the seasonal characteristics of air pollution in both countries, I study the extent to which air pollution affects stock returns not only during periods of high air pollution but also during periods of seasonal pollution.

The reasons why I study Thailand and Indonesia are as follows. First, according to World Bank, Thailand and Indonesia have the second-largest and third-largest stock market capitalization in ASEAN in 2019 respectively. Studying these two countries is representative since they are an important part of the stock market in Southeast Asia. Second, according to the 2020 average PM2.5 ranking from IQAir, Indonesia ranked 9th with PM2.5 at 40.7$\mu g/m^3$ and Thailand ranked 34th with PM2.5 at 21.4$\mu g/m^3$. However, the WHO guidelines have an average limit of 10$\mu g/m^3$ for PM2.5 per year. Obviously, the situation of air pollution is serious in these two countries. Third, IQAir reported in 2020 that although Indonesia and Thailand still suffer from bad air quality, the number of air-quality monitoring stations is growing rapidly in recent years and public air quality awareness is on the rise.

1.1 Objective of the research

This paper has four objectives. First, I examine the air pollution implication on the stock market in Thailand and Indonesia to enrich the geographical area of the study. Second, I study this impact during seasonal air pollution periods and other periods to give a reference for investors' investment strategies in different pollution periods and further enrich the research from the time aspect of air pollution degree. Third, I test the joint effect of air pollution and lunar phases to further enrich the study on the combined effects of air pollution and other non-economic variables on the stock market. Fourth, I study this impact during high pollution periods and other periods to enrich the impact of air pollution degree on stock returns.

1.2 Research questions

Accordingly, I propose four research questions.

I. Is there a correlation between air pollution and stock returns in Thailand and Indonesia respectively?

II. Is there a significant effect on stock returns during the seasonal air pollution period?

I do this research because of the seasonal nature of air pollution in Thailand and Indonesia. The average level of air pollution in both countries is highest during the dry season (Mary and Olivier, 2020; Muhayatun et al., 2020).

III. What is the difference in the effect of air pollution between full moon periods and other lunar phase periods and between new moon periods and other lunar phase periods?

The reason why I do this research is that the lunar phase affects investors' moods. During full moon periods, investors tend to be more depressed (Yuan et al., 2006). And during new moon periods, investors tend to be more optimistic (Dichev and Janes, 2003). Since air pollution also causes a bad mood (Rotko et al., 2002), I can test the joint effect of air pollution and lunar phases on stock returns.

IV. Is there a significant effect on stock returns during the high pollution period?

According to the standard of the US Federal Environmental Protection Agency (EPA), the classification criteria for the Air Quality Index (AQI) is that the values of the index from 0 to 100 are classified as "Good", while the values of the index bigger than 100 are classified as "Unhealthy". So I take the value of 100 as the boundary, and those higher than 100 are considered as the high pollution group.

1.3 Hypothesis of the research

The hypothesis for the results of these four research questions above are as follows:
H1: Air pollution is negatively associated with stock returns in the Thai stock market or the Indonesian stock market.
Since air pollution can harm mood (Rotko et al., 2002). A bad mood can make investors more risk-averse (Harding and He, 2016). From previous studies I mentioned, a popular and widespread result is that the effect of air pollution on stock returns is a significant negative.

H_2: The impact of air pollution on stock returns is significantly negative during the seasonal air pollution period.
The reason I expect to find this result is that air pollution is associated with increased bad mood (Rotko et al., 2002). Accordingly, I suppose the negative effect of air pollution would be significant during the seasonal air pollution season.

H_3: The negative effect of air pollution on stock returns is stronger during the full moon periods, or the negative effect of air pollution on stock returns is weaker during the new moon periods.
I expect to find this because the full moon harms individual sentiments, which in turn affects investing practices and causes the dropping of stock returns (Yuan et al., 2006). Based on this, I assume that the negative implication of air pollution on stock returns would be greater during periods of the full moon. And according to Dichev and Janes (2003), people are more optimistic during a new moon than during a full moon. Based on this, I assume that the negative implication of air pollution on stock returns would be weaker during a new moon period.

H_4: The impact of air pollution on stock returns is significantly negative during the high pollution period.

The reason I expect to find this result is the same as hypothesis2. Air pollution is associated with increased bad mood. Accordingly, I suppose the negative effect of air pollution would be more significant during high pollution days.

1.4 Contributions

There are two main contributions to this paper. First, it extends upon past research by enriching the research area in the countries of Southeast Asia and studying the implication of air pollution degree in seasonal air pollution season and high pollution days. Second, it is the first paper to test the joint effect of air pollution and the lunar phase on stock returns.

2. Literature Review

2.1 The implication of air pollution on mood

Zeidner and Shechter (1988) find that air pollution causes anger and anxiety by studying the emotional reaction of air pollution in approximately 900 homes in Northern Israel. Rotko et al. (2002) find that population-level annoyance is correlated with average exposure levels of pollutants through a study of subjects in Athens, Basel, Milan, Oxford, Prague, and Helsinki.

2.2 The effect of mood on investors' trading behavior

Lucey and Dowling (2005) find that investors invest in a way that is consistent with their mood and errors can be resulted if investors allow irrelevant emotional states to influence their judgment by analyzing studies on the effect of investor sentiment on stock pricing. Harding and He (2016) find that risk aversion among male investors will be increased by bad mood and this negative effect is on the whole stock market, not on any particular company.

2.3 The correlation between environment and stock market

Saunders (1993) discovers that local cloud cover has a negative link with stock returns by studying New York Stock Exchange-listed stock. Keef and Roush (2002) study the relationship between eight weather variables, such as cloud cover, temperature and wind speed, and the New Zealand stock market. And they find that wind speed has a significant impact on daily stock returns. Yoon and Kang (2009) find that stock returns are also affected by temperatures and humidity by studying the relationship between the Korean stock market and weather.

2.4 The relationship between lunar phases and stock returns

Dichev and Janes (2003) study the lunar cycle effects in stock returns in the U.S. stock market and 24 other countries around the world based on the theory that human abnormal behaviors would reach their peak during the full moon, and behavioral deviations would affect investors' decisions and thus affect stock prices and returns. And they find that stock returns are about twice as high during new moons as they are during full moons and that people are more optimistic during new moons than they are during full moons.

Yuan et al. (2006) study the relationship between the moon phases and stock returns in 48 countries around the world, based on the biological and psychological evidence that lunar phases affect human behavior and emotions and that people are more pessimistic during a full moon. And they find that the stock returns are lower during the period of full moons compared with that during the period of new moons and this effect is independent of calendar-related anomalies such as the Monday effect and the January effect.

Keef and Khaled (2011) study the relationship between the lunar phases and the daily stock returns by using 62 international stock indexes. They construct a control day and find that stock returns increase during the new moon period compared to the control day, but do not find that stock returns during the full moon period differ from the control day. So they argue that the relationship between the lunar phases and stock returns is an enhanced new moon effect rather than a negative full moon effect.

2.5 The relationship between air pollution and stock returns

Levy and Yagil（2011） find that a significant negative effect on stock market returns related to air pollution, which will be weaker as the distance of the stock exchange from the polluted area increases, by using AQI data from Kings County in New York, and Philadelphia. In addition, they find that the negative effect of local air pollution on traders also affects their trading on the stock exchange located in another geographical location. On this basis, Levy and Yagil (2013) expand the research areas to New York, Philadelphia, Toronto, Amsterdam, Sydney, and Hong Kong and also find a negative correlation.

Lepori (2016) studies the effect of air pollution on three stock indexes in the Milan province in Italy with the data of pollutants such as PM, NOx, and SO2 which is collected from the background monitoring station near the stock exchange from January 2, 1989, to May 19, 2006, and finds a negative relationship between air pollution and market returns by using a binary logit model and controlling the effect of temperature, rain, SAD, lunar cycle.

Demir and Ersan (2016) find lag of air pollution is negatively associated with stock returns in the three cities where most investors live, while the relationship is not significant in other cities, by using air pollution as a proxy for sentiment to test its effect on Turkish stock returns.

Li and Peng (2016) control the effects of humidity, wind speed, season, and calendar anomalies and find that the negative relationship between air pollution and stock returns in 16 cities in China exists in the same period, while for periods with a two-day lag, they are positively related.

Försti (2017) concludes that there is a negative relationship between unhealthy air quality and next-day stock returns and this relationship is particularly pronounced in the oil and gas industry, by using data of PM10 in Finland and controlling calendar effect. However, they also find this effect is not significant in Hong Kong.

Zhang et al. (2017) find the negative impact of PM2.5 on stock returns is achieved through investor sentiment, through studying Beijing listed companies in China from 2010 to 2014. They also find PM2.5 has a significant positive impact on stock volatility and this effect is weakened gradually over time.

He and Liu (2018) find a different conclusion from previous studies by studying the city named Shanghai in China, that is the link between air pollution and stock returns is not significant, by controlling the effects of temperature, seasonal affective disorder (SAD), humidity, cloud, the speed of the wind, rain and calendar anomalies. They also test four events about public environmental awareness and find after four events, the implication of air pollution on the stock market tends to shift significantly negatively.

Wu et al. (2020) use the air quality index in 33 Chinese cities to construct an individual investor sentiment index to further study the impact of bad sentiment caused by air pollution on the stock market and find that pessimistic sentiment negatively affects stock returns by influencing the behavior of individual investors.

Kiihamäki et al. (2021) further expand the geographic location of the study to include 47 cities around the world (including Singapore, Jakarta, and Ho Chi Minh City) and find that although the effect is different in some cities, the summary effect is that the increase of PM 2.5 leads to the decrease of stock returns by controlling the effects of precipitation, wind speed, sea level pressure, visibility, SAD, temperature, dew point and calendar anomalies.

3. Research Data and Methodology

3.1 Sample and Data

First, I explore how air pollution affects stock returns by employing daily stock index returns of the Stock Exchange index of Thailand (SET) and Jakarta Stock Exchange Composite Index (JCI) from January 1, 2016, to June 30, 2021. All of these data can be collected from Bloomberg Database.

Second, the pollutant I focused on is $PM_{2.5}$. The reasons are as follows. First, $PM_{2.5}$ has a significant impact on health. According to the WHO, major air pollutants include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide. Among these, particulate matter (PM) is a common proxy for air pollution because it has the broadest impact. Compared with PM_{10}, $PM_{2.5}$ is more harmful to health. Second, $PM_{2.5}$ data in the study area are more comprehensive. I choose the daily $PM_{2.5}$ from January 1, 2016, to June 30, 2021. The data source of the daily $PM_{2.5}$ is from the Pollution Control Department in Thailand, Meteorological, Climatological, and Geophysical Agency (BMKG) in Indonesia, and the website of The World Air

Quality Project[2]. I collect data by hand-collected and the data is given by 24-hour average to represent the air pollution index for one day. All the values provided by the website are converted from ug/m^3 to the AQI levels using EPA standards. The classification criteria for AQI is that the values of the index between 0 to 100 are classified as "Good" or "Moderate", while the values of the index bigger than 100 are classified as "Unhealthy".

Third, the data of weather conditions which include daily humidity, daily wind speed, and lunar phases can be collected from the website of the Weather Underground Corporation (WUC)[3] and the website of Cycletourist[4] by hand-collected.

Fourth, the data of population can be collected from the website of World Population Review[5] and the website of CEIC[6].

3.2 Methodology

3.2.1 Stock market returns

First, I define the index returns as:

$$RET_{i,t} = (\ln(P_{i,t}) - \ln(P_{i,t-1})) * 100 \quad (1)$$

where $RET_{i,t}$ is the daily index return of i at day t. And $P_{i,t}$ is the daily total return index of SET and JCI respectively, and $P_{i,t-1}$ is the term at day t-1. I use the total return index since it contains the dividend. Same method is used by Kiihamäki et al. (2021).

[2] The website address of The World Air Quality Project is https://aqicn.org .

[3] The website address of the Weather Underground Corporation is https://www.wunderground.com .

[4] The website address of Cycletourist is https://cycletourist.com/moon/ .

[5] The website address of World Population Review is https://worldpopulationreview.com .

[6] The website address of CEIC is https://www.ceicdata.com/en .

3.2.2 Pollution Index measurement

I refer to the method used by Li and Peng (2016) to represent the majority of investors' locations in a country by using population to select major cities. Because the stock markets in Thailand and Indonesia are both order-driven, in which investors trade through their brokers, stock prices are influenced by investors from all over the country (Li and Peng, 2016). It is not reasonable to choose only the city which is close to the stock exchange. Based on the population data that can be collected, I take the top 10 cities in each country by population.

Next, I collect the daily average $PM_{2.5}$ value for each selected city. Based on the top 10 cities in terms of population size in 2016 and the availability of data, our final choices are Bangkok, Nakhon Ratchasima, Ubon Ratchathani, Khon Kaen, Chiang Mai and Chonburi in Thailand, and Jakarta, Palembang in Indonesia. Then, I construct the national pollution index PM2.5 that represents daily air quality across the country. First, I calculate the weight of city c in year y by using:

$$\alpha_{c,y} = \frac{Population_{c,y}}{\sum_{c=1}^{c=n} Population_{c,y}} \quad (2)$$

where $\alpha_{c,y}$ is the weight of city c in year y and $Population_{c,y}$ is the population of city c at the end of year y.

Second, I calculate the national air pollution weighted index PM2.5 according to the weight of each city:

$$PM2.5_{m,t} = \sum_{c=1}^{c=n} (\alpha_{c,y} * PM2.5_{c,t}) \quad (3)$$

where $PM2.5_{m,t}$ is the national air pollution index in country m at day t and $PM2.5_{c,t}$ is the daily average PM2.5 of city c at day t.

A total of 9,175 PM2.5 data are collected from six cities in Thailand's top 10 cities by population. For the top 10 cities in Indonesia by population, only 2,243 PM2.5 data from two cities can be collected. The calculation of the daily national PM2.5 is specified in the following way. In Thailand, the proportion of the population of the six selected cities to the total population of the six cities is first calculated. Then, the proportion of the population of each city is multiplied by the air quality index of each city on that day. Finally, the population-weighted PM2.5 for each city is summed up to obtain the daily national PM2.5. For Indonesia, the same method is used, except that the population share is calculated by dividing the population of each of the two cities by the sum of the populations of the two cities.

And a total of 1,338 RET data were collected in Thailand and 1,331 RET data in Indonesia, from January 1, 2016 to June 30, 2021. The total number of the wind speed data collected is 7,895 in Thailand and 2,182 in Indonesia, and the number of humidity data which can be collected is 12,045 from Thailand and 2,182 from Indonesia. The daily national wind speed and humidity are calculated using the same method used to calculate the daily national PM2.5.

After matching daily stock returns, national PM2.5 and weather data, a total of 1,081 PM2.5 observations from Thailand and 1,260 PM2.5 observations from Indonesia can be obtained. Table 1 provides descriptive statistics of the variables.

Table 1: Summary statistics of variables

This table contains the summary statistics of variables of the full period from January 1, 2016 to June 30, 2021 and sub-periods which include dry season and non-dry season. It is separated into 6 panels. Panel A and panel D show the summary descriptive statistics of variables during the full period in Thailand and Indonesia respectively. And panel B and panel E perform the summary statistics of variables during the dry period in Thailand and Indonesia respectively while panel C and panel F show the summary descriptive statistics of variables during the non-dry period respectively.

Variables	Obs.	Mean	Median	Std. Dev.	Min	Max
Panel A: Thailand of the full period						
PM2.5	1,081	87.0253	80.7361	32.0895	25	222.2215
RET (%)	1,081	0.0717	0.0601	0.9516	-11.3837	7.6562
HUM (%)	1,081	71.4504	71.5711	8.1943	48.7892	93.1433
WIND (mph)	1,081	5.3326	5.3002	1.3816	1.1000	10.2688
Panel B: Thailand during the dry period						
PM2.5	265	104.2470	102.2591	24.6112	25	162.9411
RET (%)	265	0.1372	0.0730	0.8218	-2.8342	4.2154
HUM (%)	265	67.8046	67.0846	6.9608	49.7589	92.0241
WIND (mph)	265	4.9437	4.8251	1.5302	1.1000	10.2668
Panel C: Thailand during the non-dry period						
PM2.5	816	81.4325	70.8521	32.2584	26	222.2215
RET (%)	816	0.0504	0.0575	0.9896	-11.3837	7.6562
HUM (%)	816	72.7161	73.3814	8.2151	48.7892	93.1433
WIND (mph)	816	5.4588	5.4368	1.3061	1.1000	9.5500

Table 1: Summary statistics of variables (cont.)

Variables	Obs.	Mean	Median	Std. Dev.	Min	Max
Panel D: Indonesia of the full period						
PM2.5	1,260	97.5777	100.3333	29.4442	19	179
RET (%)	1,260	0.0151	0.0634	1.0535	-6.8051	9.7042
HUM (%)	1,260	77.1531	76.6973	4.8689	65.3467	91.4173
WIND (mph)	1,260	3.4177	3.3000	1.4763	0	16.9000
Panel E: Indonesia during the dry period						
PM2.5	633	110.2785	113	24.2654	24	179
RET (%)	633	0.0258	0.0729	0.9850	-5.1385	3.9940
HUM (%)	633	75.6182	75.7400	3.6298	66.5240	82.8920
WIND (mph)	633	3.1134	3	1.2184	0	13.6000
Panel F: Indonesia during the non-dry period						
PM2.5	627	84.7553	82	28.6597	19	165
RET (%)	627	0.0044	0.0588	1.1192	-6.8051	9.7042
HUM (%)	627	77.9681	78.5280	5.2473	65.3467	91.4173
WIND (mph)	627	3.7249	3.5000	1.6421	0	16.9000

As can be seen from Table 1, the average air pollution levels are higher during the dry season in both countries compared to the full period. In contrast, the average air pollution levels during the non-dry season are lower than those during the full period.

This indicates that the air pollution levels are indeed higher in the dry season period we have chosen.

In terms of the stock returns and humidity, in Thailand and Indonesia, although both the maximum and minimum values are in the non-dry season period, the mean values are higher in the dry season period, while the mean wind speed is lower in the dry season period compared to the full period and non-dry period. An interesting phenomenon is that in both countries, the average air pollution is worse in the seasonal pollution period, but the average stock return is higher in this period than in the others.

Figure 1: Trend of national daily PM2.5

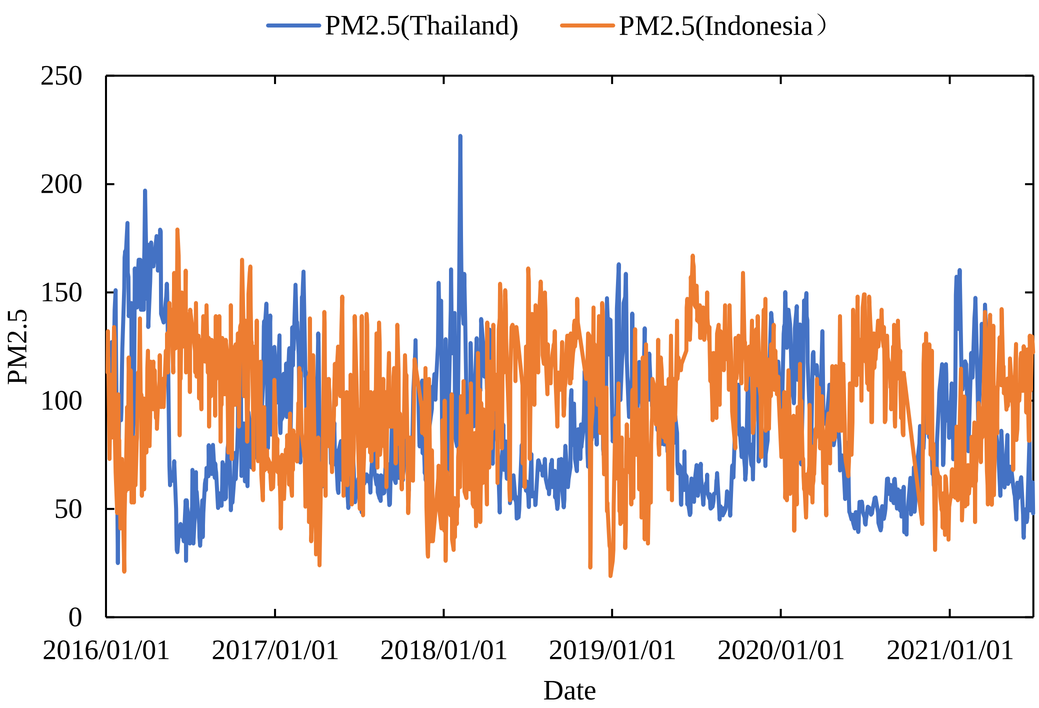


Figure 2: Trend of daily stock returns

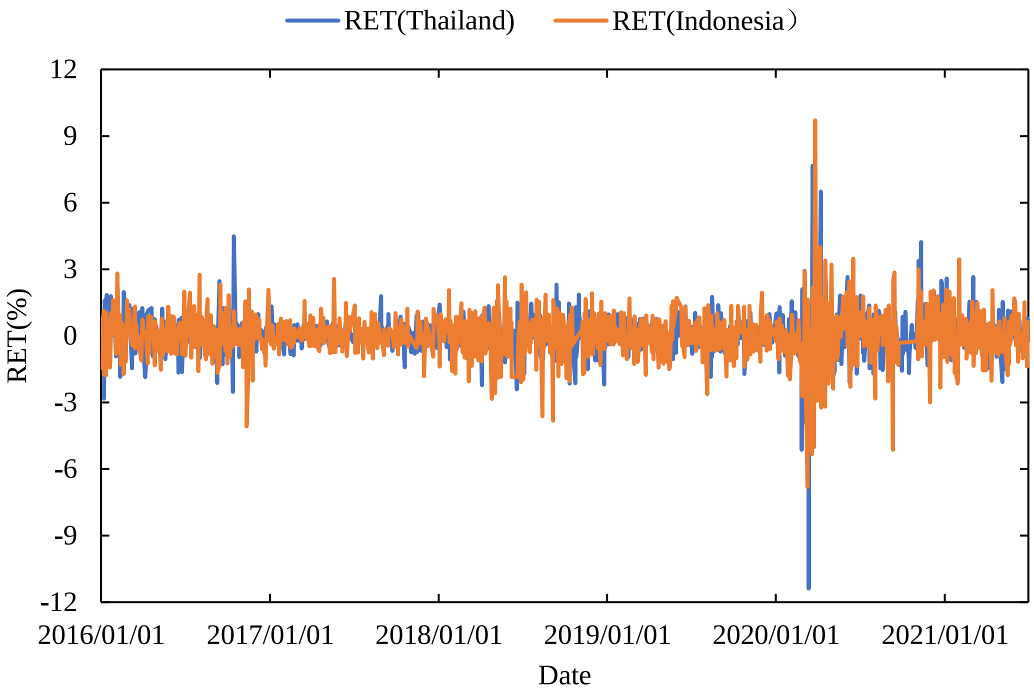


Figure 3: Trend of national daily humidity

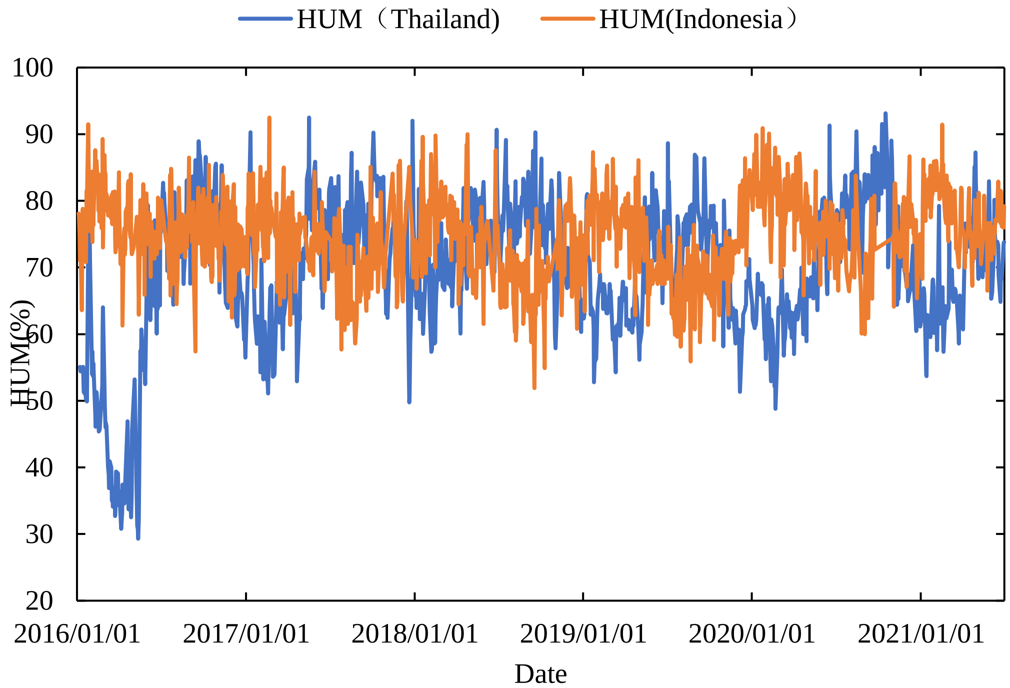
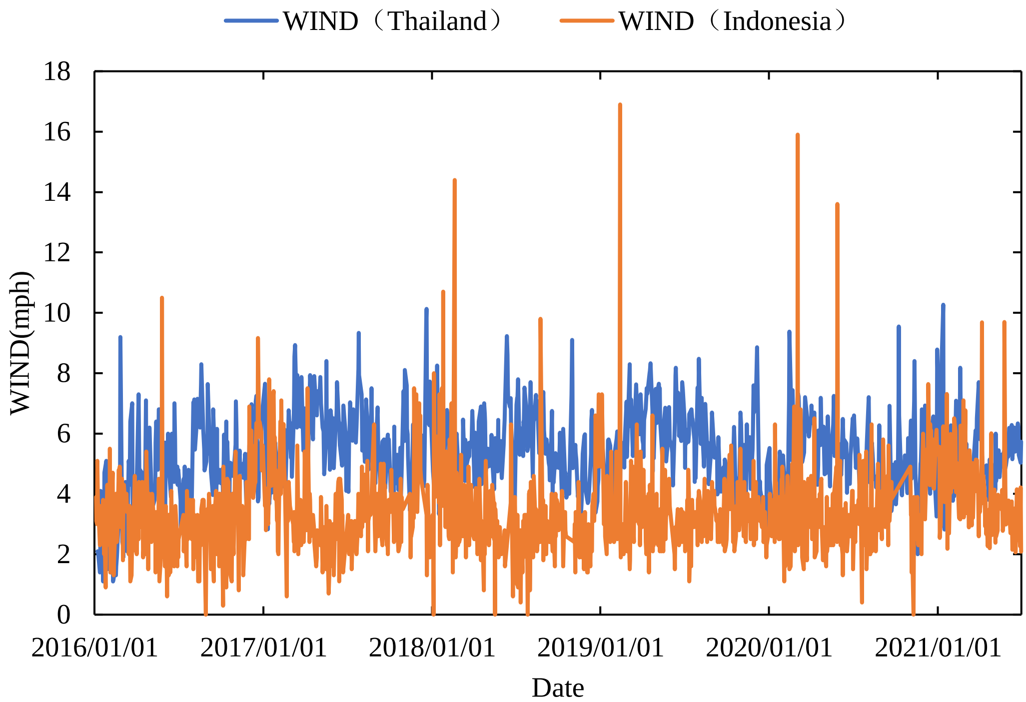


Figure 4: Trend of national daily wind speed



As seen in figure 1, the national daily PM2.5 has been fluctuating between January 1, 2016 to June 30, 2021 and the magnitude of the fluctuations is stable and does not show an upward or downward trend. Figure 2 shows the daily stock returns fluctuating more around January 2020 in both countries, and it is important to note that this period is also the period of Covid-19 outbreak. Figure 3 represents that the national daily humidity also fluctuates at a stable level, with higher volatility in Thailand during 2016. Figure 4 demonstrates that the national daily wind speed also maintains fluctuations at a stable level and does not show a trend in one direction in both countries.

3.2.3 Examining the implication of air pollution on stock returns

First, I build a basic regression model to test the effect of the national $PM_{2.5}$ index on the stock index return. Considering the effect of the weather conditions on stock returns mentioned in previous literature, I add continuous variables HUM and WIND to control for the weather effects. And a lagged period of the dependent variable is added to increase the explanation of the model because stock returns are susceptible to the effects of the previous period. Considering the lagged effect of air pollution on mood (Bullinger, 1989), I also added a lagged core explanatory variable, namely PM2.5t-1. I construct the model as:

$$RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \varepsilon_t \quad (4)$$

$$RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 PM2.5_{m,t-1} + \beta_3 HUM_{m,t} + \beta_4 WIND_{m,t} + \beta_5 RET_{i,t-1} + \varepsilon_t \quad (5)$$

where $RET_{i,t}$ is the daily stock return of stock index i at day t. $RET_{i,t-1}$ is the daily stock return of stock index i at one order lagged day.

$PM2.5_{m,t}$ is the national air pollution index of country m at day t. $PM2.5_{m,t-1}$ is the national air pollution index of country m at one lag day. They are continuous variables.

HUM is a continuous variable for daily average humidity. The website of WUC provides daily 24-hour mean humidity data. First, I collect the daily average humidity in the six selected cities of Thailand and the two selected cities of Indonesia. Then the national average daily temperature is calculated by the population weight of each city:

$$HUM_{m,t} = \sum_{c=1}^{c=n} (\alpha_{c,y} * HUM_{c,t}) \quad (6)$$

$HUM_{m,t}$ is the national humidity index in country m at day t and $HUM_{c,t}$ is the daily 24-hour mean humidity data of city c at day t.

WIND is a continuous variable for the daily wind speed. The website of WUC provides daily 24-hour mean wind speed in each city. For a country, I use the same method as HUM to calculate the national wind speed index:

$$\mathrm{WIND}_{m,t} = \sum_{c=1}^{c=n}(\alpha_{c,y} * \mathrm{WIND}_{c,t}) \quad (7)$$

$\mathrm{WIND}_{c,t}$ is the daily 24-hour mean wind speed data of city c at day t. $\mathrm{WIND}_{m,t}$ is the national wind speed index in country m at day t.

ε_t is the error term. The model and the control variables above are widely used in previous studies (Levy and Yagil, 2011; Li and Peng, 2016; He and Liu, 2018; Wu et al., 2020; Kiihamäki et al., 2021).

Second, I add control variables to control for the calendar effects. Such model is used in past relative researches (Levy and Yagil, 2011; Försti, 2017; Kiihamäki et al., 2021):

$$\mathrm{RET}_{i,t} = \beta_0 + \beta_1 \mathrm{PM2.5}_{m,t} + \beta_2 \mathrm{HUM}_{m,t} + \beta_3 \mathrm{WIND}_{m,t} + \beta_4 \mathrm{RET}_{i,t-1} + \beta_5 \mathrm{JAN}_t + \varepsilon_t \quad (8)$$

$$\mathrm{RET}_{i,t} = \beta_0 + \beta_1 \mathrm{PM2.5}_{m,t} + \beta_2 \mathrm{PM2.5}_{m,t-1} + \beta_3 \mathrm{HUM}_{m,t} + \beta_4 \mathrm{WIND}_{m,t} + \beta_5 \mathrm{RET}_{i,t-1} + \beta_6 \mathrm{JAN}_t + \varepsilon_t \quad (9)$$

where JAN is dummy variable to control January effect (Rozeff and Kinney, 1976). If it is January, JAN equals 1 and 0 otherwise. Other variables are the same as the meaning in the model (4) and model (5).

3.2.4 Examining the implication of air pollution on stock returns during seasonal air pollution periods

First, I choose the dry season as the observation period, which is from November to next January in Thailand and from April to September in Indonesia (Mary and Olivier, 2020; Muhayatun et al., 2020).

Then, referring to the method of He and Liu (2018), I regress by adding the air pollution seasonal control variable (DRY) into the basic model to test the changing extents of the air pollution effect. DRY is a dummy variable which is one if the date during the dry period and zero otherwise. The new model is:

$$RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \beta_5 (PM2.5_{m,t} * DRY_{m,t}) + \beta_6 DRY_{m,t} + \varepsilon_t \quad (10)$$

$$RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 PM2.5_{m,t-1} + \beta_3 HUM_{m,t} + \beta_4 WIND_{m,t} + \beta_5 RET_{i,t-1} + \beta_6 (PM2.5_{m,t-1} * DRY_{m,t}) + \beta_7 DRY_{m,t} + \varepsilon_t \quad (11)$$

where $DRY_{m,t}$ is a dummy variable for seasonal air pollution of country m at day t. The other variables are the same as the model (4) and model (5).

3.2.5 Examining the difference of the effect of air pollution between full moon periods and other lunar phase periods and between new moon periods and other lunar phase periods

Based on the model (4) and model (5), I test the joint effect by using the model:

$$RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \beta_5 FULLM_{m,t} + \beta_6 (PM2.5_{m,t} * FULLM_{m,t}) + \varepsilon_t \quad (12)$$

$$RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \beta_5 NEWM_{m,t} + \beta_6 (PM2.5_{m,t} * NEWM_{m,t}) + \varepsilon_t \quad (13)$$

$$RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 PM2.5_{m,t-1} + \beta_3 HUM_{m,t} + \beta_4 WIND_{m,t}$$
$$+ \beta_5 RET_{i,t-1} + \beta_6 FULLM_{m,t} + \beta_7 (PM2.5_{m,t-1} * FULLM_{m,t})$$
$$+ \beta_8 NEWM_{m,t} + \beta_9 (PM2.5_{m,t-1} * NEWM_{m,t})$$
$$+ \varepsilon_t \qquad (14)$$

where FULLM is a dummy variable for the effect of lunar phases which is one when the three days before and after each full moon and zero otherwise. And NEWM is a dummy variable for the new moon which is one when the three days before and after each new moon and zero otherwise.

3.2.6 Examining the implication of air pollution on stock returns during the high air pollution periods

First, all the trading days are divided into two groups, namely, Unhealthy days and Good days. According to the standard of EPA, the classification criteria for AQI is that the values of the index from 0 to 100 are classified as "Good", while the values of the index bigger than 100 are classified as "Unhealthy". So I take the value of 100 as the boundary, and those higher than 100 are considered as the Unhealthy group. The Unhealthy group represents high air pollution periods and the Good group represents periods of good air quality.

Next, I regress by adding the Unhealthy group control variable (Unhealthy) into the model (4) and model (5) to test the changing extents of the air pollution effect. And since the Unhealthy group is determined by the value of the air pollution on that day, for the lag air pollution proxy, I use the lag unhealthy dummy variable to represent the joint effect of the air pollution during the high pollution period. The new model is:

$$RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1}$$
$$+ \beta_5 (PM2.5_{m,t} * Unhealthy_{m,t}) + \beta_6 Unhealthy_{m,t} + \varepsilon_t \qquad (15)$$

$$RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 PM2.5_{m,t-1} + \beta_3 HUM_{m,t} + \beta_4 WIND_{m,t} + \beta_5 RET_{i,t-1} + \beta_6 (PM2.5_{m,t-1} * Unhealthy_{m,t-1}) + \beta_7 Unhealthy_{m,t-1} + \varepsilon_t \quad (16)$$

where Unhealthy is a dummy variable which is one if the trading day is in the Unhealthy group and zero otherwise. Since the Unhealthy group is determined by the PM2.5 index of the day, for the $PM2.5_{t-1}$, I use the $Unhealthy_{t-1}$ to estimate the effect of $PM2.5_{t-1}$ during high pollution days. The other variables are the same as the model (4) and model (5).

4. Results

4.1 The effects of air pollution on stock returns

I perform the OLS regression of model (4) and model (5) in these two countries. Next, a control variable named JAN is added to control for the January effect by using model (8) and model (9). Table 2 shows us the results in Thailand and Indonesia.

As can be seen from the results of the basic model (4) and model (5), most of the variables are insignificant based on the p-values. Only the model with the lag term named $PM2.5_{t-1}$ for Thailand is significant at the 10% level (p-value = 0.0859). Nevertheless, we can simply analyze the impact of these factors on stock returns based on the coefficients. For Thailand, the coefficients of $PM2.5_t$ in model (4) is a very small positive number while it is also insignificant. However, after adding a lag PM2.5 in this model, that is model (5). It is found that the coefficients on $PM2.5_{t-1}$, HUM as well as RET_{t-1} are negative, while the other variables are positive. In a sense, an increase in $PM2.5_{t-1}$ and hum can reduce stock market returns in Thailand, while an increase in other factors may increase stock return yields. For Indonesia, on the other hand, only the RET_{t-1} is significant at the 10% level with the p-value being 0.0554 for model (4) and 0.0550 for model (5) respectively, which means the lagged stock returns have a positive effect on today's stock returns of JCI. The coefficients on $PM2.5_t$ and $PM2.5_{t-1}$ are both a very small positive number, but none of them is significant.

The significance of variables after adding JAN in model (8) and model (9) is similar to the basic models. In Thailand, $PM2.5_{t-1}$ is still significant at the 10% level (p-value = 0.0859), of which the coefficient is similar to that of model (5). However, after adding the January dummy variable, the coefficient of $PM2.5_t$ in model (8) is slightly changed to a negative number compared to model (4), but this coefficient is still not significant. In Indonesia, the coefficients almost keep the same compared to the basic models. The coefficients of $PM2.5_t$ and $PM2.5_{t-1}$ are still positive, but it should be noted that this is still not statistically significant. RET_{t-1} is still significant at 10% level with the p-value being 0.0555 in model (8) and 0.0552 in model (9).

In Thailand, air pollution reduces stock returns. Specifically, we find that the one-stage lag of air pollution agents hurts stock returns and this impact is significant, which supports part of our hypothesis 1 for the Thai stock market, that is, air pollution is negatively correlated with the stock returns of the Thai stock market. However, the air pollution level on the current day does not have a significant impact on stock returns, which may be caused by the lagged effect of air pollution on mood (Bullinger, 1989). This is consistent with the finding of Li and Peng (2016) that a negative correlation between the one-day lag air pollution proxies and stock returns in China.

While this impact of air pollution is not significant in Indonesia, the possible reason is that since our sample only collects air indices from two cities to represent the national air pollution levels in Indonesia, this may face the risk of providing an inaccurate proxy for the actual pollution levels.

Table 2: The effects of air pollution on stock returns

This table represents the results of the regression that test the effects of air pollution on stock returns. It contains two panels. Panel A and panel B show the results of Thailand and Indonesia respectively. Model (4) is the basic model with only the current air pollution proxy while model (5) is added the lag air pollution proxy. Model (8) and model (9) are added the January dummy variable based on model (4) and model (5).

Model (4): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \varepsilon_t$

Model (5): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 PM2.5_{m,t-1} + \beta_3 HUM_{m,t} + \beta_4 WIND_{m,t} + \beta_5 RET_{i,t-1} + \varepsilon_t$

Model (8): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \beta_5 JAN_t + \varepsilon_t$

Model (9): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 PM2.5_{m,t-1} + \beta_3 HUM_{m,t} + \beta_4 WIND_{m,t} + \beta_5 RET_{i,t-1} + \beta_6 JAN_t + \varepsilon_t$

Variables	Dependent Variable (RET_t)			
	Model (4)	Model (5)	Model (8)	Model (9)
Panel A: Thailand (SET)				
$PM2.5_t$	0.0001 (0.0272)	0.0036 (1.4358)	-0.0002 (-0.1574)	0.0034 (1.3552)
$PM2.5_{t-1}$	-	-0.0038* (-1.6871)	-	-0.0038* (-1.7192)
HUM_t	-0.0018 (-0.4554)	-0.0018 (-0.4584)	-0.0019 (-0.4778)	-0.0019 (-0.4819)
$WIND_t$	0.0254 (1.1314)	0.0300 (1.3264)	0.0293 (1.2876)	0.0341 (1.4902)
RET_{t-1}	-0.0365 (-1.3293)	-0.0358 (-1.3056)	-0.0376 (-1.3675)	-0.0369 (-1.3451)
JAN_t	-	-	0.1164 (1.1018)	0.1215 (1.1510)
Constant	0.0606 (0.1428)	0.0542 (0.1278)	0.0578 (0.1361)	0.0511 (0.1205)
Obs.	1,081	1,081	1,081	1,081
Adjusted R-Square	0.0033	0.0059	0.0044	0.0072

Table 2: The effects of air pollution on stock returns (cont.)

Variables	Dependent Variable (RET_t)			
	Model (4)	Model (5)	Model (8)	Model (9)
Panel B: Indonesia (JCI)				
$PM2.5_t$	0.0005	0.0001	0.0005	0.0001
	(0.4084)	(0.0166)	(0.3996)	(0.0212)
$PM2.5_{t-1}$	-	0.0006	-	0.0006
		(0.4164)		(0.4178)
HUM_t	-0.0034	-0.0031	-0.0034	-0.0031
	(-0.6597)	(-0.6029)	(-0.6545)	(-0.6025)
$WIND_t$	0.0358	0.0366	0.0358	0.0365
	(1.6156)	(1.6426)	(1.6102)	(1.6359)
RET_{t-1}	0.0540*	0.0542*	0.0540*	0.0541*
	(1.9173)	(1.9209)	(1.9163)	(1.9195)
JAN_t	-	-	0.0010	0.0039
			(0.0092)	(0.0374)
Constant	0.0980	0.0590	0.0982	0.0595
	(0.2107)	(0.1243)	(0.2108)	(0.1254)
Obs.	1,260	1,260	1,260	1,260
Adjusted R-Square	0.0057	0.0058	0.0057	0.0058

t-statistics are stated in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.2 The impact of air pollution on stock returns during seasonal air pollution period

Having examined the existence of the January effect in the stock markets of these two countries, we also want to examine the extent of variation in the air pollution effect by including a seasonal control variable for air pollution (DRY) in the model. Then I perform the OLS regression of model (10) and model (11). In these models, not only is DRY_t added as a dummy variable with an intercept term, but the impact of DRY_t on returns is also fully accounted for by multiplying $PM2.5_{t-1}$, which is lagged by one order, with this dummy variable as a slope term in the regression model. And table 3 shows the results in the two countries.

After adjusting for seasonal pollution controls in Thailand, $PM2.5_{t-1}$ is still significant at 10% level (p-value = 0.0792) with a negative coefficient. For model (10), the coefficient of $PM2.5_t$ is negative and of the interaction term of $PM2.5_t$ and DRY is positive. And in model (11), the lagged pollution proxy coefficient remains negative. And this negative coefficient of $PM2.5_{t-1}$ is slightly weakened during the seasonal pollution period, from -0.0037 to -0.0007. In Indonesia, RET_{t-1} is still significant at 10% level with p-value is 0.0551 for model (10) and 0.0550 for model (11), and WIND is significant at 10% level (p-value = 0.0973) in model (10) with a positive coefficient. However, other variables are not significant. In terms of the dummy variable itself, DRY_t is positive in model (10) but negative in model (11). The coefficient of $PM2.5_{t-1}$ is negative, indicating that air pollution with a lag period causes the decline of stock returns during the seasonal pollution period, however, there is not enough statistical evidence to conclude.

For hypothesis 2, the joint effect is tested by the term $PM2.5_{m,t-1}$ + $PM2.5_{m,t-1}$ * $DRY_{m,t.}$ And the results show that the joint effect of air pollution and dry season on stock returns is negative at 10% significant level (p-value = 0.0886) in Thailand, which indicate there is statistical evidence to conclude that this negative impact of air pollution on stock returns is stronger during the seasonal air pollution period.

Table 3: Air pollution effect on stock returns during seasonal pollution period

This table represents the results of the regression that test the effects of air pollution on stock returns during the seasonal pollution period. It contains two panels. Panel A and panel B show the results of Thailand and Indonesia respectively. Model (10) is the model with only the current PM2.5 while model (11) is added the lag PM2.5. The one-side test is used for $PM2.5_{t-1}$ in model (11) of Thailand.

Model (10): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \beta_5 (PM2.5_{m,t} * DRY_{m,t}) + \beta_6 DRY_{m,t} + \varepsilon_t$

Model (11): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 PM2.5_{m,t-1} + \beta_3 HUM_{m,t} + \beta_4 WIND_{m,t} + \beta_5 RET_{i,t-1} + \beta_6 (PM2.5_{m,t-1} * DRY_{m,t}) + \beta_7 DRY_{m,t} + \varepsilon_t$

Variables	Dependent Variable (RET_t)			
	Panel A: Thailand (SET)		Panel B: Indonesia (JCI)	
	Model (10)	Model (11)	Model (10)	Model (11)
$PM2.5_t$	-0.0007	0.0031	0.0006	-0.0001
	(-0.4710)	(1.2100)	(0.3909)	(-0.0113)
$PM2.5_{t-1}$	-	-0.0037*	-	-0.0002
		(-1.5788)		(-0.1063)
HUM_t	-0.0027	-0.0024	-0.0029	-0.0029
	(-0.6563)	(-0.5795)	(-0.5476)	(-0.5467)
$WIND_t$	0.0278	0.0317	0.0373*	0.0353
	(1.2342)	(1.3962)	(1.6593)	(1.5629)
DRY_t	0.0251	0.1845	0.0814	-0.1528
	(0.0920)	(0.6742)	(0.3426)	(-0.6557)
$PM2.5_t DRY_t$	0.0008	-	-0.0006	-
	(0.3173)		(-0.2620)	
$PM2.5_{t-1} DRY_t$	-	-0.0007	-	0.0017
		(-0.2690)		(0.7658)
RET_{t-1}	-0.0388	-0.0379	0.0541*	0.0542*
	(-1.4125)	(-1.3805)	(1.9195)	(1.9210)
Constant	0.1447	0.0956	0.0360	0.1132
	(0.3337)	(0.2213)	(0.0736)	(0.2286)
Obs.	1,081	1,081	1,260	1,260
Adjusted R-Square	0.0055	0.0083	0.0058	0.0063

t-statistics are stated in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

4.3 The effects of air pollution on stock returns during the full moon and new moon periods

To further test the impact of air pollution on stock returns during the full moon and new moon periods, I perform the OLS regression of model (12), model (13), and model (14). Table 4 summarizes the results.

As panel A shows, in Thailand, $PM2.5_t$ is still insignificant with a positive coefficient in model (12) and the positive coefficient of air pollution at the day decreases to a negative number in terms of the interaction term of $PM2.5_t$ and $FULLM_t$. During the new moon period, the result is similar to that during the full moon period. For model (14), $PM2.5_{t-1}$ is still negative after the addition of the full moon and new moon dummy variables, but it is not significant now compared to the basic model. The negative coefficient of $FULLM_tPM2.5_{t-1}$ means that the negative effect of the full moon on $PM2.5_{t-1}$ is enhanced to some extent, from -0.0024 to -0.0039. Specifically, the existence of full moon strengthens the effect of lagged pollution proxy on the degree of negative return. And this interaction term is significant at 10% level (p-value = 0.0704). The coefficient of $NEWM_tPM2.5_{t-1}$ compared with that of $PM2.5_{t-1}$ decreases from -0.0024 to -0.0032. $NEWM_t$ has a positive coefficient, however, this is insignificant.

Panel B represents the regression results in Indonesia. All the variables are insignificant except for RET_{t-1} and $NEWM_t$. RET_{t-1} is significant at the 10% level with p-value is 0.0766 in model (12), 0.0741 in model (13) and 0.0745 in model (14) and has a positive effect on stock returns. The influence of the new moon on stock return is positive and significant at 5% level with p-value is 0.0399 in model (13). The coefficients of $PM2.5_t$ are negative in model (12) and model (14), while it is positive for model (13). It can be noted that in model (14), the single $PM2.5_{t-1}$ has a positive coefficient, while $PM2.5_t$ has a negative coefficient. And this of the interaction term of the new moon and the lag PM2.5 turns to be negative, but is still positive for the interaction term of the full moon and the lag PM2.5.

For the regression analysis during the full moon, the coefficient of the interaction term between the lag air pollution proxy and the full moon is significantly negative in Thailand, which means that the existence of the full moon strengthens the effect of lagged pollution proxy on the degree of negative return. In addition, the new moon variable has a positive effect on stock returns in both countries, and this finding is statistically significant in the Indonesian sample, which is consistent with the finding of Dichev and Janes (2003), that stock returns are higher during the new moon periods.

For the joint effect, the results represent that the joint effect of air pollution and the full moon is significant negative at 5% level (p-value = 0.0234), and this negative effect is stronger during the full moon period, which indicates that the negative effect of air pollution on stock returns is stronger during the full moon periods. But this effect is not significant during the new moon period.

Table 4: Air pollution effect on stock returns during the full moon and new moon

This table represents the results of the regression that test the effects of air pollution on stock returns during the full moon and new moon. It contains two panels. Panel A and panel B show the results in Thailand and Indonesia respectively. Model (12) and model (13) are the models with only the current PM2.5 while model (14) is added the lag PM2.5.

Model (12): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \beta_5 FULLM_{m,t} + \beta_6 (PM2.5_{m,t} * FULLM_{m,t}) + \varepsilon_t$

Model (13): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \beta_5 NEWM_{m,t} + \beta_6 (PM2.5_{m,t} * NEWM_{m,t}) + \varepsilon_t$

Model (14): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 PM2.5_{m,t-1} + \beta_3 HUM_{m,t} + \beta_4 WIND_{m,t} + \beta_5 RET_{i,t-1} + \beta_6 FULLM_{m,t} + \beta_7 (PM2.5_{m,t-1} * FULLM_{m,t}) + \beta_8 NEWM_{m,t} + \beta_9 (PM2.5_{m,t-1} * NEWM_{m,t}) + \varepsilon_t$

Variables	Dependent Variable (RET_t)		
	Model (12)	Model (13)	Model (14)
Panel A: Thailand (SET)			
$PM2.5_t$	0.0007	0.0003	0.0038
	(0.5003)	(0.2120)	(1.5185)
$PM2.5_{t-1}$	-	-	-0.0024
			(-1.0459)
HUM_t	-0.0017	-0.0024	-0.0023
	(-0.4226)	(-0.5921)	(-0.5789)
$WIND_t$	0.0264	0.0238	0.0297
	(1.1750)	(1.0594)	(1.3143)
$FULLM_t$	0.2266	-	0.2957
	(1.1636)		(1.4578)
$PM2.5_t FULLM_t$	-0.0027	-	-
	(-1.2944)		
$PM2.5_{t-1} FULLM_t$	-	-	-0.0039*
			(-1.8111)
$NEWM_t$	-	0.0360	0.1470
		(0.1837)	(0.7131)
$PM2.5_t NEWM_t$	-	-0.0017	-
		(-0.8114)	
$PM2.5_{t-1} NEWM_t$	-	-	-0.0032
			(-1.4264)
RET_{t-1}	-0.0371	-0.0371	-0.0374
	(-1.3499)	(-1.3539)	(-1.3635)
Constant	-0.0124	0.1120	-0.0035
	(-0.0290)	(0.2626)	(-0.0080)
Obs.	1,081	1,081	1,081
Adjusted R-Square	0.0049	0.0065	0.0128

Table 4: Air pollution effect on stock returns during the full moon and new moon (cont.)

Variables	Dependent Variable (RET_t)		
	Model (12)	Model (13)	Model (14)
Panel B: Indonesia (JCI)			
$PM2.5_t$	-0.0004 (-0.2990)	0.0014 (1.1438)	-0.0001 (-0.0244)
$PM2.5_{t-1}$	-	-	0.0010 (0.5662)
HUM_t	-0.0034 (-0.6651)	-0.0038 (-0.7500)	-0.0035 (-0.6688)
$WIND_t$	0.0357 (1.6084)	0.0346 (1.5624)	0.0359 (1.6128)
$FULLM_t$	-0.3524 (-1.5094)	-	-0.1574 (-0.6494)
$PM2.5_t$ $FULLM_t$	0.0032 (1.3969)	-	-
$PM2.5_{t-1}FULLM_t$	-	-	0.0013 (0.5406)
$NEWM_t$	-	0.5297** (2.0571)	0.3381 (1.3137)
$PM2.5_tNEWM_t$	-	-0.0050 (-1.137)	-
$PM2.5_{t-1}NEWM_t$	-	-	-0.0032 (-1.2618)
RET_{t-1}	0.0501* (1.7722)	0.0505* (1.7876)	0.0506* (1.7852)
Constant	0.1942 (0.4139)	0.0357 (0.0767)	0.0601 (0.1245)
Obs.	1,260	1,260	1,260
Adjusted R-Square	0.0075	0.0090	0.0082

t-statistics are stated in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.4 Air pollution effect on stock returns during the high pollution period

To test the joint effect of air pollution on stock returns during the high pollution days, I regress the model (15) and model (16). And table 5 performs the results. It is easy to see that all the variables in this equation are insignificant except for RET_{t-1} of Indonesia, which are significant at 10% level with p-value is 0.0741 for model (15) and 0.0593 for model (16), and $PM2.5_{t-1}Unhealthy_{t-1}$ of Thailand, which is significant at 10% level with p-value is 0.0936 for model (16). In model (15), the positive coefficient of $PM2.5_t$ changes to a negative number in the term of $PM2.5_tUnhealthy_t$ in Thailand while this variable has a positive coefficient in Indonesia.

And for model (16), in Thailand, the coefficient on $PM2.5_{t-1}$ is negative and $PM2.5_t$ is positive, while they are both negative in Indonesia. For the term of $Unhealthy_{t-1}$, it is positive for Thailand and negative for Indonesia. About the coefficients of the interaction term of $PM2.5_{t-1}Unhealthy_{t-1}$ is significantly negative with the coefficient of -0.0049, while it is positive in Indonesia and insignificant.

For the result of the joint effect of air pollution and unhealthy group, it shows that this joint effect is significantly negative at 5% level (p-value = 0.0385), which means that this negative effect of one-day lag air pollution proxy on stock returns is stronger during the high pollution days.

Table 5: Air pollution effect on stock returns during high pollution period

This table represents the results of the regression that test the effects of air pollution on stock returns during high pollution period. It contains two panels. Panel A and panel B show the results of Thailand and Indonesia respectively. Model (15) is the model with only the current PM2.5 while model (16) is added the lag PM2.5. $PM2.5_{t-1}Unhealthy_{t-1}$ is testes by one-side test for model (16) in Thailand.

Model (15): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 HUM_{m,t} + \beta_3 WIND_{m,t} + \beta_4 RET_{i,t-1} + \beta_5 (PM2.5_{m,t} * Unhealthy_{m,t}) + \beta_6 Unhealthy_{m,t} + \varepsilon_t$

Model (16): $RET_{i,t} = \beta_0 + \beta_1 PM2.5_{m,t} + \beta_2 PM2.5_{m,t-1} + \beta_3 HUM_{m,t} + \beta_4 WIND_{m,t} + \beta_5 RET_{i,t-1} + \beta_6 (PM2.5_{m,t-1} * Unhealthy_{m,t-1}) + \beta_7 Unhealthy_{m,t-1} + \varepsilon_t$

Variables	Dependent Variable (RET_t)			
	Panel A: Thailand (SET)		Panel B: Indonesia (JCI)	
	Model (15)	Model (16)	Model (15)	Model (16)
$PM2.5_t$	0.0021	0.0029	0.0003	-0.0001
	(0.9363)	(1.1157)	(0.1302)	(-0.0016)
$PM2.5_{t-1}$	-	-0.0015	-	-0.0012
		(-0.4691)		(-0.4730)
HUM_t	-0.0032	-0.0031	-0.0034	-0.0029
	(-0.7891)	(-0.7581)	(-0.6668)	(-0.5557)
$WIND_t$	0.0158	0.0219	0.0349	0.0348
	(0.6793)	(0.9373)	(1.5654)	(1.5604)
$Unhealthy_t$	0.5580	-	-0.2029	-
	(1.5218)		(-0.5037)	
$PM2.5_tUnhealthy_t$	-0.0056	-	0.0016	-
	(-1.6360)		(0.4299)	
$Unhealthy_{t-1}$	-	0.5062	-	-0.3763
		(1.4391)		(-0.9693)
$PM2.5_{t-1}Unhealthy_{t-1}$	-	-0.0049*	-	0.0039
		(-1.4617)		(1.0737)
RET_{t-1}	-0.0364	-0.0360	0.0542*	0.0533*
	(-1.3273)	(-1.3128)	(1.9176)	(1.8873)
Constant	0.0759	0.0856	0.1213	0.1430
	(0.1740)	(0.1974)	(0.2509)	(0.2870)
Obs.	1,081	1,081	1,260	1,260
Adjusted R-Square	0.0058	0.0079	0.0059	0.0068

t-statistics are stated in parentheses *** p<0.01, ** p<0.05, * p<0.1

5. Conclusion

This study focuses on the effect of air pollution on stock returns for the sample of Thailand and Indonesia. Our empirical findings find a significant negative effect of air pollution on stock returns in Thailand, that is when air pollution increases, stock returns decline. This negative effect is only reflected in the one-day lagged air pollution proxy due to the lagged effect of air pollution on sentiment. In contrast, we do not find a significant relationship between air pollution proxies and stock returns for the current period. The significant negative effect of air pollution on stock returns is similar to that after controlling for the January effect. This is consistent with the finding of Li and Peng (2016).

This paper further tests this effect during seasonal pollution periods, full moon periods, new moon periods, and periods of high air pollution. The results of Thailand show that the negative impact of air pollution on stock returns is stronger during the seasonal air pollution period, the full moon periods and the high pollution days. It is important to notice that all these findings depend on the one-day lagged air pollution proxy. However, the effect of air pollution on stock returns is not significant in any of the periods above in Indonesia. Only the positive effect of the new moon on the return of Indonesian stock market is proved, which is consistent with the finding of Dichev and Janes (2003).

This paper does not do the test for serial correlation, which means that there may be correlation between the error term and its observations, leading to the inaccurate outcomes of the standard error of the estimators and impacting on inference. Moreover, our sample only collects air indices from two cities to represent the national air pollution levels in Indonesia, this may face the risk of providing an inaccurate proxy for the actual pollution levels.

Suggestions for further research are as follows. First, only the air pollution index represented by $PM_{2.5}$ is studied in this paper, and we can go for better air pollution proxy indices in the future, such as a comprehensive index that includes PM_{10}. Second, the calculation method of the national air quality index and the control variables of the model can still be improved in this paper. Third, the study can also be extended in the future to study the effects of air pollution on volatility and stock trading volume.

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