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Is there relationship between air quality and China's stock market? Evidence from industrial heterogeneity

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ABSTRACT

This study investigates the unsymmetrical effect from air quality (AQ) to stock return (SR) in China's different industries. Depending on quantile-on-quantile (QQ) test, it draws the important results in following aspects. For tourism, iron and steel, and automobile industries, their coefficient values between AQ and SR turn into negative from positive with deteriorating AQ. Conversely, the coefficients in the wind power, hydro power, thermal power, environmental protection, and medical equipment industries turn positive from negative. Some contributions are thus drawn when compared to existing literatures. Government industrial policy is regarded as an important supplement in explaining mechanism from AQ to SR, except investor sentiment. Industrial heterogeneity is seriously treated in this paper due to different industries have different responses to AQ. Besides, the QQ test is able to capture nexus between AQ and SR in specific quantiles through embedding non-parametric estimation into conventional quantile approach. Therefore, investors should avoid biased trading decisions under different air qualities. Meanwhile, government intervention is paid special attention when appearing serious air pollution.

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1. Introduction

Air quality (AQ) is an urgent issue confronted by undeveloped countries due to their industrialisation and urbanisation process, and increasing fossil fuels consumption in the past decades (Su, Pang, et al., 2022; Teng & He, 2020; Wang, Zhao, et al., 2022). The bad AQ would increase mortality and morbidity (Yazdi & Khanalizadeh, 2017), reduce agricultural production (Guan et al., 2016), and damage ecological environment (Bhat et al., 2022; Liu, 2021). In 2015, air pollution leads to over 9 million people death, and the number is higher than wars and other violence (Landrigan et al., 2019). Apart from health problems, it also produces adverse impacts on economic

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operation and activities (Chang et al., 2016; Li et al., 2022). For example, in 2060, the amount of healthcare expenditure related to air pollution would achieve 176 billion U.S. dollars, and the number of working days lost also reaches 3.7 billion in the same year. Apart from human health issues and economic performance, financial market, especially the stock market, has obtained increasing attention in the world. Air pollution commonly affects investors' sentiment, and trading behaviours, which ultimately reflects on stock returns (SR) (Levy & Yagil, 2011; Nguyen & Pham, 2021; Wu et al., 2020; Zhang et al., 2017). It is noticed that investors are not just influenced by polluted air, healthy air also produced significant impacts on them. Hirshleifer and Shumway (2003) indicate sunshine is obviously related to stock returns in 26 countries such as Milan and Brussels. Levy and Galili (2008) also offer clear evidence that SR is significantly higher on sunny days in the U.S. stock market. The link has been widely discussed in developed countries and regions, but few concerns about China. Thus, this paper aims to investigate unsymmetrical effect from AQ to SR, and provide important reference for participants in China's stock market.

China undergoes fast development in recent decades, and has been the second-biggest economic power globally. The high economic growth inevitably brings serious air pollution, which threats its sustainable development (Nie et al., 2020). Even though China has taken many pollution control measures and policies, it is still the major emitter in CO_2, SO_2 and NOx, which reaches 9.89 billion tons, 3.7 million tons and 11.57 million tons, respectively. Meanwhile, China's average $PM_{2.5}$ concentration is 39.1 $\mu g/m^3$ in 2019, which is nearly four times higher than the WHO air quality standard (10 $\mu g/m^3$), and exceeds U.S. (9.01 $\mu g/m^3$), the U.K. (16.6 $\mu g/m^3$), Brazil (15.77 $\mu g/m^3$), and Malaysia (19.36 $\mu g/m^3$). Less than 1% of China's cities achieve good air quality standards, and occupies 7 of the top 10 worst air pollution cities globally. Some cities of China, such as the Beijing-Tianjin-Hebei (BTH) area, suffer extreme pollution episodes from 2012 to 2013, which causes public health issues and trigger social tensions (Wang et al., 2021). Besides, air pollution's influence rapidly expands to economic and financial fields. For example, the economic losses triggered by air pollution accounts for 1.2% of China's GDP (Liu, Dong, et al., 2021). Some studies, such as Lepori (2016), Wu et al. (2020), and Nguyen and Pham (2021), provide evidence that polluted air would affect people's sentiment, causing them make biased trading decisions in stock market. This phenomenon may be more remarkable due to individual investors are major participants in China's stock market. These investors are easily influenced by weather and other external shocks, which leads to behavioural bias in the decision making process (Chang et al., 2008; Li et al., 2020; Saunders, 1993). Besides, the existing literatures, such as Levy and Yagil (2011) and Levy and Yagil (2013), commonly discuss the nexus between AQ and SR in developed nations and areas. China's stock market is the second largest in the world with more than 8.7 trillion U.S. dollars market capitalisation in 2019, which attracts domestic and foreign, institutional and individuals investors (Zhao et al., 2020). Therefore, given serious air pollution problems often occur in China, and significant character in its stock market, we are trying to probe the impact of air quality on SR.

This study examines the relationship between AQ and different industries' SR in China's stock market, and the results are shown as follows. For tourism, iron and steel, and automobile industries, their coefficient values between AQ and SR turn into negative from positive with deteriorating AQ. Conversely, the coefficients in the wind power, hydro power, thermal power, environmental protection, and medical equipment industries turn positive from negative. Thus, we provide some contributions based on empirical findings. First, government industrial policy is found to be an important supplement in interpreting the asymmetric influence from AQ to SR. Previous studies such as He and Liu (2018) and Liu, Tian, et al. (2021) usually select physiology and psychology as explaining aspects. However, it does not consider China's realities, and thus cannot completely explain the mentioned relationship. With the purpose to solve air pollution, it publishes a lot of environmental regulations and laws, and makes new and sustainable industrial plans. China's stock market is proved to be sensitive to these external events and strategies (Chen et al., 2020; Wang et al., 2021). Therefore, government intervention should be taken into consideration, and has power in explaining the influence from AQ to SR. Second, as shown by Ciner (2019), different industries have different reactions to the same shocks, thus industrial heterogeneity against air quality is fully taken into account in our study. However, previous studies commonly utilise the whole stock market as a sample to discuss its link with polluted air (An et al., 2018; Guo et al., 2022; Kirk-Reeve et al., 2021; Lepori, 2016; Levy & Yagil, 2011). Thus, with the purpose to get detailed results, we choose eight subdivide industrial indexes such as thermal power and iron and steel as the sample, which can provide heterogeneous analysis. Last, the quantile-on-quantile (QQ) test embeds non-parametric estimation into conventional quantile approach, thus it can capture relations among variables in specific quantiles. Many methods, such as the linear panel regression model (He & Liu, 2018; Liu, Kang, et al., 2021; Wang, Liu, et al., 2022; Wu et al., 2020), have been employed to investigate the nexus between AQ and SR. However, these methods rely on linear relationship assumption, which is inconsistent with realities, and their results are not enough convincing. Therefore, we pay attention to the asymmetric character between these two variables through the QQ test, which can provide more detailed and valuable conclusions.

The remaining of this study is organised as follows. Section 2 reviews and sort out the literatures. Section 3 describes the transmission mechanism. Section 4 exhibits the QQ regression test. The major empirical results and policy implications are shown in Sections 5 and 6, respectively.

2. Literature review

2.1. Weather and stock returns

The weather first attracts scholars' attention and is introduced to investigate its influence on the stock market. Saunders (1993) indicates that New York's weather is obviously related to stock index returns. Cao and Wei (2005) discover an obvious and negative link between temperature and stock return. Levy and Galili (2008) show that cloud coverage produces differential influences on individuals' decisions to purchase and sell stocks. Chang et al. (2008) reveal that stock returns are found to be lower on cloudier days. Apergis and Gupta (2017) demonstrate that unusual deviations of weather in New York produce significant obvious influence on the stock returns in South Africa. Venturini (2022) find that weather risks are more likely to affect the cross-section of stock returns, both within and across sectors. However, Shahzad (2019) holds the opposite opinion that the weather variables such as humidity have an insignificant influence on the returns in Shanghai and Hong Kong stock markets.

2.2. Air pollution and stock returns

Companying with the increasing serious air pollution, and awake of environmental protection awareness, some studies start to focus on the relation from air pollution to stock market. Levy and Yagil (2011) indicate that polluted air affects stock return negatively, but its nexus becomes weaker with increasing distance from the polluted area. Levy and Yagil (2013) further demonstrate that polluted air produces more significant and negative influence on high pollution enterprises' stock return. Lepori (2016) points out that air pollution make people feel bad, and leads risk aversion behaviours, which decreases stock trade and its returns. Heyes et al. (2016) demonstrate that the return of S&P 500 is lowered when Manhattan-based traders suffers serious air pollution. Forsti (2017) shows that Helsinki's air pollution would negatively affect the following day's stock returns, especially for energy industries. Nguyen and Pham (2021) points out air pollution intensifies individual behavioural biases, which is more easily lead to abnormal fluctuations in the stock market.

Given serious air pollution and rapid development financial market, some studies start to discuss the link from AQ to SR in China's stock market. Li and Peng (2016) put forward that air pollution is a behavioural factor with connections to stock return. Zhang et al. (2017) show that polluted air has obvious and negative impacts on stock return, but significant positive effects are discovered for stock volatilities. An et al. (2018) indicate that investor's sentiment is influenced by air quality significantly, which further affects stock market volatility. Wu, Chen, et al. (2018) demonstrate polluted air is of time effect, and has negative influence on the stock yield. Wu, Hao, et al. (2018) present that the sensitivity of stock returns to air pollution is more significant for high growth, distressed, and high volatile stocks. Wu et al. (2020) find that depressed investors' sentiment, induced by local air pollution, obviously reduces the contemporaneous stock returns and liquidity. Teng and He (2020) points that physiological effects induced by high polluted air has strong influence on investors' trading behaviours, which reflects on fluctuations in stock price. Liu, Dong, et al. (2021) find that polluted air is negatively related to polluting enterprises' stock price, but positively related with new energy enterprises' stock price. Xu et al. (2021) reveal that the joint effect of the current day's and consecutive days' air condition would affect stock returns through environmental awareness. Ding et al. (2021) discover that enterprises located in regions that suffer higher levels of air pollution have lower stock returns. Guo et al. (2022) discover that polluted air negatively affects investors' desire to buy, and positively influences investors' decision to sell. Even though many studies prove that there exists a nexus between AQ and SR, but some scholars offer different opinions. Guo et al. (2016) put forward that local polluted air condition does not affect stock returns through physiological change. He and Liu (2018) reveal that there is no significant effect of air pollution on China's stock market during a long-term period. Giudici et al. (2019) argue that polluted has obvious and mixed effects on stock returns in China during the period from 2003 to 2015.

3. Transmission mechanism

Air pollution has been considered an essential factor in affecting stock market, and the influencing channels are shown as follows. The first channel is government intervention. With the purpose to combat air pollution, government usually publishes environmental protection laws, make industrial strategic planning, levy environmental tax, and subsidy green innovation (Chen et al., 2020; Hu et al., 2022; Liu, Wang et al., 2021; Su, Li, et al., 2022). Thus, government intervention would influence enterprise's daily operation, and change investors' expectation, which finally reflect on stock returns. The second channel is investors' physiology and psychology. For physiological aspect, air pollution increases cortisol level in human body, which reduces risk-taking behaviours (Liu, Dong, et al., 2021). From a psychological aspect, air pollution brings bad sentiment, and damage cognitive function (Levy & Galili, 2008; Li & Peng, 2016). In other words, air pollution can affect investors' trading behaviours in stock market through changing their physiology and psychology (An et al., 2018; Tomei et al., 2003).

Meanwhile, good air quality also produces influence on stock market, which is discussed in previous literatures. People usually become excitement, happiness, and relaxation in environment with good air quality, which produces positive expectations for enterprise's performance (Li & Peng, 2016; Zhang et al., 2017). Meanwhile, investors probably attribute their good sentiment to prosperous economy mistakenly, rather than good air quality (He & Liu, 2018). Besides, being contacted to good air may bring spirit concentration, more sleep, and clear logic, and well cognitive functioning (Dong et al., 2021). Therefore, the good air would bring positive impacts on investors, which finally reflects on stock returns.

Industry heterogeneity is fully considered, because different industries would produce different responses to air quality, especially air pollution (Hao et al., 2021; Li & Li, 2019; Lin et al., 2021; Wang, Su, et al., 2022). Besides, the heterogeneity also affects the direction and degree of impact from air quality to stock return. Liu, Kang, et al. (2021) indicate that air pollution would make new energy enterprises obtain more social attention, which increases investor's trading desire and leads to higher stock price. Kirk-Reeve et al. (2021) prove that stocks with the character of high-sensitive to air pollution, usually have lower risk-adjusted returns. Meanwhile, the incentive and coercive government policies may bring operating pressure for high-polluted enterprises, and offer opportunities for environmental-friendly enterprises (Li et al., 2018; Su, Yuan, et al., 2022; Wang et al., 2020; Wu, Chen, et al., 2018).

Given the separate influence from bad and good air quality, and industrial heterogeneity, we provide the following hypothesis: Air quality produces a nonlinear and heterogeneous influence on stock returns in different industries.

4. Quantile-on-quantile regression

Depending on works of Sim and Zhou (2015), this study shows QQ method as follows:

$$SR_t = \beta^{\theta}(AQ_t) + \mu_t{}^{\theta} \tag{1}$$

where AQ_t and SR_t indicate air quality and stock return in time t. β, θ and μ_t express parameter, θ_{th} quantile and error term, separately. This paper takes a first-order Taylor expansion for AQ^{τ} to linearise $\beta^{\theta}(\cdot)$. The equation is obtained as follows:

$$\beta^{\theta}(AQ_t) \approx \beta^{\theta}(AQ^{\tau}) + \beta^{\theta'}(AQ^{\tau})(AQ_t - AQ^{\tau}) \tag{2}$$

where AQ^{τ} is the τ_{th} quantile of AQ, $\beta^{\theta'}$ denotes the partial derivative of $\beta^{\theta}(AQ_t)$ respective to AQ. According to Equation (2), $\beta^{\theta}(AQ^{\tau})$ and $\beta^{\theta'}(AQ^{\tau})$ are clearly functions of θ, and AQ^{τ} is a function of τ, thus both parameters are twice indexed in θ and τ. This paper also utilises $\beta_0(\theta,\tau)$ and $\beta_1(\theta,\tau)$ to replace $\beta^{\theta}(AQ^{\tau})$ and $\beta^{\theta'}(AQ^{\tau})$, and new equation is shown as follows:

$$\beta^{\theta}(AQ_t) \approx \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(AQ_t - AQ^{\tau}) \tag{3}$$

Through combining Equations (3) and (1), we draw a new equation:

$$SR_t = \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(AQ_t - AQ^{\tau}) + \mu_t{}^{\theta} \tag{4}$$

Due to β_0 and β_1 are functions of θ and τ, the relationship between AQ and SR can be captured in each quantiles. With the purpose to estimate Equation (4), we utilise $\widehat{AQ}_t$ and $\widehat{AQ}^{\tau}$ to replace AQ_t and AQ^{τ}. The local linear regression measures of the parameters b_0 and b_1 are the estimates of β_0 and β_1 through which the following equation is found:

$$\min_{b_0, b_1} \sum_{i=1}^{N} \rho\theta\left[SR_t - b_0 - b_1\left(\widehat{AQ}_t - \widehat{AQ}^{\tau}\right)\right] \times K\left(\frac{F_n\left(\widehat{AQ}_t\right) - \tau}{h}\right) \tag{5}$$

In Equation (5), $\rho\theta(\mu)$ shows the quantile loss function. $K(\cdot)$ is kernel function, which is simple and efficient in calculation. h indicates the kernel bandwidth parameter and is set to 0.05. The kernel function is employed to weight the observations in the neighbourhood of AQ_t. The function is symmetric around zero and assigns low weights to far observations. These weights are inversely related to the distance between the empirical distribution function of $\widehat{AQ}_t$, expressed as $F_n\left(\widehat{AQ}_t\right) = \frac{1}{n}\sum_{k=1}^{n} I\left(\widehat{AQ}_k < \widehat{AQ}_t\right)$.

Table 1. The AQ index classification levels.

Air quality index (values)	Levels of health	Health concern
0 – 50	Good	Air is not polluted
51 – 100	Moderate	Air quality is acceptable for most people
101 – 150	Unhealthy for sensitive groups	Air quality brings risks for people with disease
151 – 200	Unhealthy	Air quality threats physical health
201 – 300	Very unhealthy	Air quality seriously affect people's health
301 – 500	Hazardous	Air quality is intolerant for people

Source: Author's calculation.

5. Data and empirical analysis

5.1. Data select and description

Daily trading data that ranges from January 1, 2014, to June 30, 2021 is adopted in this study. The variable of AQ is represented by Shanghai's air quality index, which comes from China's Ministry of Ecology and Environment. It publishes the data in January 2014, which is consistent with the starting point of the sample. The AQ index has been extensively adopted in environmental and financial fields (He & Liu, 2018; Teng & He, 2020; Wu, Chen, et al., 2018). According to the values, it can be divided into many levels, and the detailed description is written in Table 1. The other variable is stock return (SR). We choose eight different industrial indexes include environmental protection (EP), hydropower (HP), iron and steel (IS), wind power (WP), thermal power (TP), tourism (TI), medical care (ME) and automobile (AT). These industries are closely related to AQ, and their corresponding indexes come from Shanghai Stock Exchange Market. Many large and influential enterprises are listed in this stock market, which is commonly regarded to be tightly with China's economy (Jiang, 2019). These daily indexes are drawn from Wind database. According to Wang and Li (2020), the SR is obtained by taking logarithmic difference for stock index, and is written as $SR_t = LnP_t - LnP_{t-1}$. In the formula, P_t and P_{t-1} express the stock index at time t and t-1.

Figure 1 shows that the AQ fluctuates greatly, but the fluctuation range is narrowing. In December 2015, Beijing first issues a red warning of heavy air pollution, and this bad weather leads to the highest point of AQ index. The Law of Air Pollution Prevention and Control is implemented in 2016, which stabilises the AQ index in the whole year of 2006. The 19th National Congress of the Communist Party of China is held in October 2017, which creates 'Political Blue Sky' and lows AQ index. Since 2018, the peak concentration, pollution intensity, duration and influence range of heavy pollution weather process decrease significantly. However, AQ index would sharp rebound when suffering extreme events such as smog and haze weather. It is also noticed that the high values of AQ are more likely to occur in spring and winter, which can be explained in following aspects. For one thing, the North China is in heating period, and major fuel is coal that produce large number of pollutants. For the other thing, government commonly relax environmental supervision in order to achieve the predetermined economic growth target.

Figure 2 indicates the trends of all eight indexes. Generally, we find that there is a significant turning point in 2015, which is attributed into stock market crashes. In detailed, the Shanghai Stock Exchange Composite Index reaches peak point of 5353

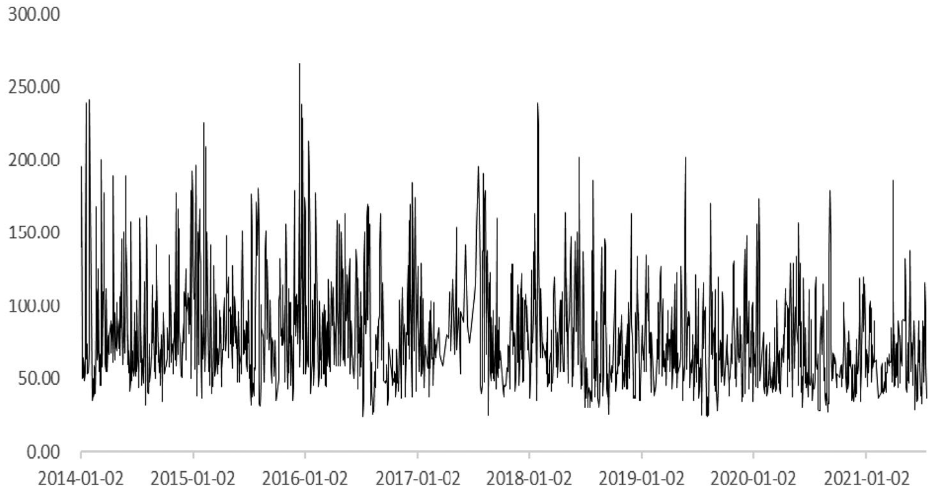


Figure 1. The trends of AQI.
Source: Author's calculation.

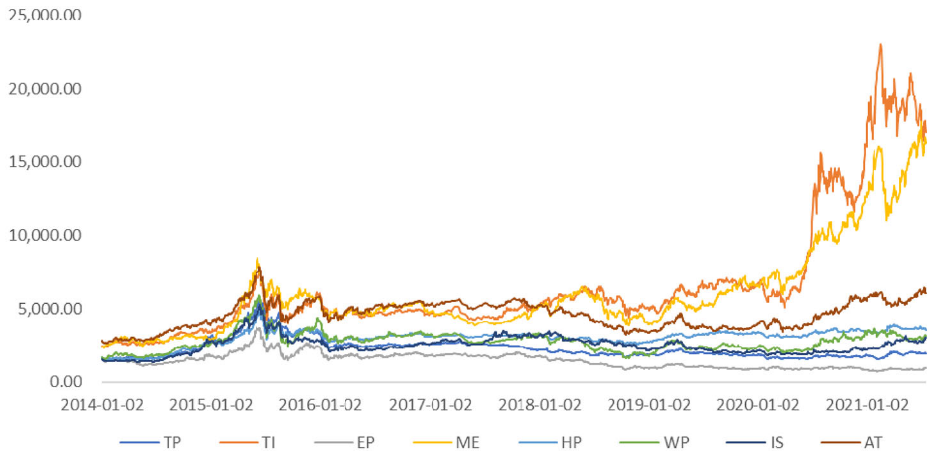


Figure 2. The trends of eight industrial indexes.
Source: Author's calculation.

on June 12, 2015, and rapidly collapses to 3342 on August 29, 2015, plunging 2000 points and losing more than 18 trillion Yuan in share value. After this stock crisis, the indexes of TP, EP, HP, WP and IS present stable fluctuating trend. However, the indexes of TI, ME and AT fluctuate more violently. The TI is tightly with air quality, as pointed by Hao et al. (2021), air quality plays an important role in tourist's decision. In 2020, the average percent of good air days in 337 China's cities is 87%, which increases 5% when comparing to 2019. The increasing level of air quality leads to the development of tourism industry. Similarly, medical equipment industry also presents upward trend, which is attributed into the increasing awareness of public health for air pollution, which raise the demand for medical service. For the AT, its development is mainly from new energy vehicles, especially electric vehicle. In 2018, China allows to set up foreign sole proprietorship enterprise for the first time, which attracting Tesla, the world's most famous electric vehicle manufacturer, to establish its first

Table 2. Descriptive statistics of the variables.

	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
AQ	266	24	35.032	1.393	5.506	1019.027***
TP	0.084	−0.152	0.017	−0.965	12.111	6292.543***
TI	0.109	−0.189	0.024	−0.421	7.809	1728.827***
EP	0.095	−0.193	0.023	−0.638	9.033	2758.587***
ME	0.077	−0.127	0.021	−0.423	5.131	381.311***
HP	0.063	−0.109	0.014	−0.894	9.473	3271.604***
WP	0.096	−0.209	0.024	−0.849	9.391	3172.037***
IS	0.073	−0.156	0.019	−0.772	7.923	1931.161***
AT	0.072	−0.179	0.018	−1.289	11.509	5734.636***

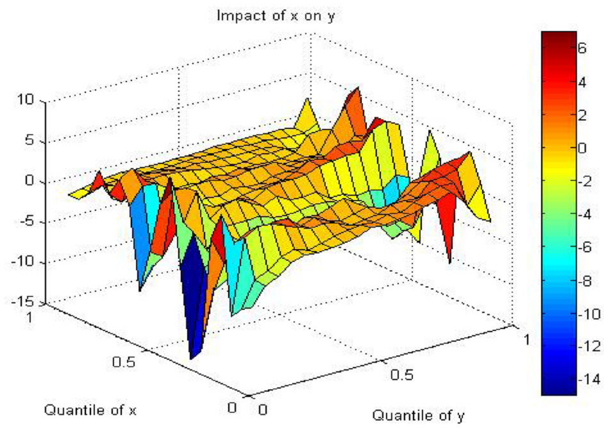
Note:
***denotes significance at 1% level.
Source: Author's calculation.

overseas factory in Shanghai. China's government attempt brings prosperity for domestic automobile market, especially for BYD and other new energy vehicle enterprises. Table 2 shows descriptive analysis for AQ and different industries' SR. The skewness values for EP, HP, IS, WP, TP, TI, ME and AT are negative, indicating their tail of the left side of the distribution is fatter. Meanwhile, Kurtosis values for all variables are bigger than 3, demonstrating that they follow a leptokurtic distribution. In addition, the statistics of Jarque-Bera test are significant at 1% level, showing the variables obey a non-normal distribution.

5.2. Empirical analysis

Figure 3 points out the influences from AQ to TP, using quantile-on-quantile regression method. In the figure, dark red and dark blue demonstrates the highest and lowest values of coefficients, respectively. We calculate and discover that mean coefficient value is −0.639 for [0, 0.5] quantiles of AQ and SR, and turn into 0.502 for [0.5, 1] quantiles of AQ and SR. That demonstrates as air quality decreases (as it changes from 0 towards 1) its relation with SR changes towards positive. In China, TP meets over 70% of electric demand and consumes 50% of coal production, which is the single biggest contributor to air pollution. When air quality becomes unhealthy, government would make and implement strict pollution control laws and regulations (Liu, Tian, et al., 2021). Investors naturally predict that thermal power plants suffer great pressure, thus they would change desires for purchasing and selling stock, which produce a negative influence on SR. However, the continuous deterioration of air quality leads to higher public health risks and huge economic loss. Therefore, government would commit to environmental management with capital and technologies input into thermal power plants, which transmits a positive signal for investors and brings raising stock return. For example, in 2011, the government publishes a document of 'Emission Standard of Air Pollutants for Thermal Power Plants', to increase the requirement for controlling air pollution. In 2016, National Development and Reform Commission (NDRC) also announces to require local government to reduce the construction of TP plants.

Besides, there is also insignificant relationship and appears when AQ ranges in the quantile of [0.3, 0.4], which can be explained from following aspects. Air quality is not good enough to produce positive influence on investors' psychological and physical condition, which does not lead to trading behaviour bias and further influence

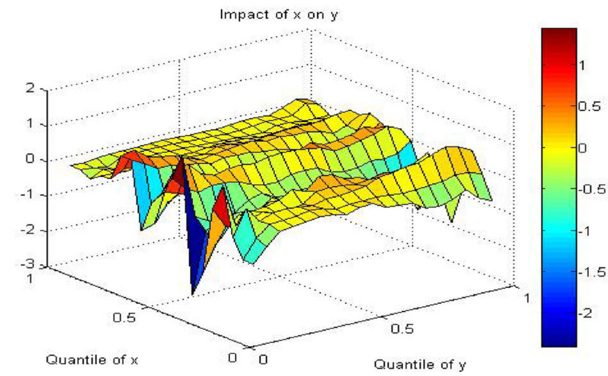


Quantile for AQ / Quantile for SR	(0, 0.5)	(0.5, 1)
(0, 0.5)	-0.639	-0.159
(0.5, 1)	-0.118	0.502

Figure 3. The coefficients between AQ and TP, and the mean values of coefficients in each quadrant are located at the base of figure.
Source: Author's calculation.

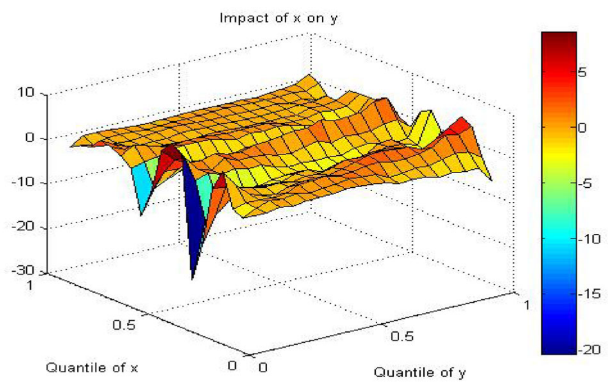
stock returns. Next, being consistent with Liu and Kong (2021), this level of air quality is not bad enough to trigger social attention and influence government official promotion, politicians have little incentives for environmental protection and would not launch corresponding laws and policies. Therefore, the traditional transmission mechanism of physiology, psychology, and government intervention lose power, and the relationship between AQ and SR become insignificant.

Figures 4 and 5 show the coefficients between AQ and WP, and between AQ and HP, respectively. These figures indicate that the mean coefficient values are negative for [0, 0.5] quantiles of AQ and SR, and turn into positive for [0.5, 1] quantiles of AQ and SR. Renewable electric generation accounts for a small proportion, such as 16.2% of hydropower and 2.9% of wind power. With the increasing environmental problem of CO_2 emissions, renewable electric generation starts to receive attention. China commits to decreasing carbon intensity by about 60% in 2030 when compared with the 2005 level, and reach carbon neutralisation before 2060. Therefore, the government publishes a series of targets and supporting measures based on the guideline of 'common but differentiated responsibilities' to achieve environment-friendly economic development. For example, the National Energy Administration launches 'Opinions on Encouraging Social Capital to Invest in Hydro Stations' in 2015, making sure that investors who observe laws own equal rights to participate in hydro development plans. In addition, some specific files, such as 'Notice on the evening wind power tariff policy' and 'Completion inspection and acceptance of safety facilities in wind farm project', are published to speed up the process of wind power generation



Quantile for AQ / Quantile for SR	(0, 0.5)	(0.5, 1)
(0, 0.5)	-0.678	0.061
(0.5, 1)	0.123	0.077

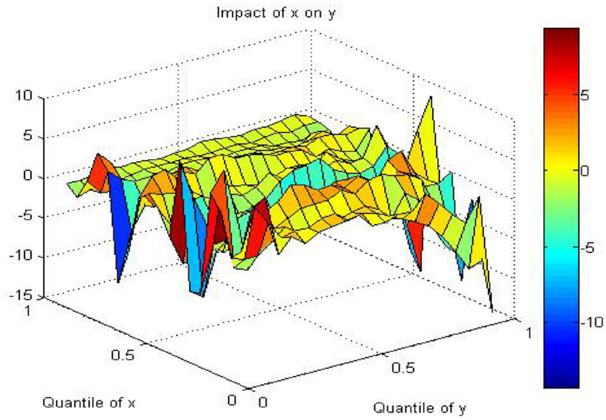
Figure 4. The coefficients between AQ and WP, and the mean values of coefficients in each quadrant are located at the base of figure.
Source: Author's calculation.



Quantile for AQ / Quantile for SR	(0, 0.5)	(0.5, 1)
(0, 0.5)	-11.781	0.331
(0.5, 1)	0.682	0.229

Figure 5. The coefficients between AQ and HP, and the mean values of coefficients in each quadrant are located at the base of figure.
Source: Author's calculation.

(Wang et al., 2020). Therefore, the serious air pollution would accelerate the process of renewable energy power generation, which brings good development opportunities for related enterprises, and finally strengthen investors' confidence.

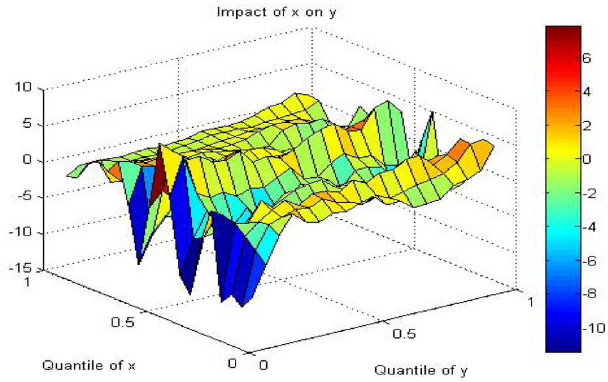


Quantile for SR \ Quantile for AQ	(0, 0.5)	(0.5, 1)
(0, 0.5)	0.086	-0.164
(0.5, 1)	1.194	-0.069

Figure 6. The coefficients between AQ and TI, and the mean values of coefficients in each quadrant are located at the base of figure.
Source: Author's calculation.

In addition to positive relationship, there is also insignificant relationship when AQ ranges in the quantile of [0.7, 1], and is able to be interpreted from following perspectives. The AQ's fluctuation is of temporal and geographical features, i.e., serious air pollution generally appears in winter of the North China (Xu et al., 2019). China has a typical monsoon climate that is cold and short of water in winter, which leads to low work efficiency for wind and hydro turbines. Therefore, HP and WP are not enough to make up for the gap after the withdrawal of thermal power, especially in northern China. Therefore, at this time, corporate performance would not change greatly in HP's and WP's enterprises. Besides, when facing high AQ index, investors have recognised that government would adopt measures to control pollution, and thus, the effect of political policies is discounted. Therefore, the stable enterprise performance and predictable government policies cannot transmit the influence from AQ to SR.

Figure 6 points out the mean coefficient value between AQ and TI turns into negative when AQ ranges in quantile of [0.5, 1]. Tourism can provide a lot of employment and without huge capital input, and has little influence on the environment (Hao et al., 2021). Thus, it is regarded as one of the emerging pillar industries and plays an important role in achieving sustainable development. However, it is noticed that the tourism industry has a high requirement for the ecological environment and climatic conditions (Zhang et al., 2015). For instance, haze pollution is once serious in Beijing-Tianjin-Hebei damages the image of the region in tourists, which changes their travel decisions and even let them give up travel plans. As estimated by Zhang et al. (2015), being influenced by haze pollution, only 4.501 million inbound tourists travel to Beijing in 2013, and the corresponding tourism income is



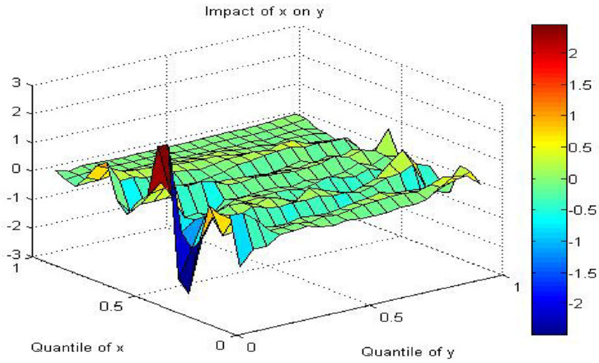
Quantile for AQ / Quantile for SR	(0, 0.5)	(0.5, 1)
(0, 0.5)	-0.739	0.231
(0.5, 1)	0.463	0.095

Figure 7. The coefficients between AQ and EP, and the mean values of coefficients in each quadrant are located at the base of figure.
Source: Author's calculation.

4.795 billion U.S. dollars, which declined by 6.9% when compared to the 2012 level. In other words, polluted air produces a negative influence on tourism in the aspects of supply and demand, which reduces economic benefits of tourism enterprises and hinder long-term development.

Figure 7 demonstrates the mean coefficient value between AQ and EP is negative when AQ and SR runs in quantile of [0, 0.5], and becomes positive in [0.5, 1] quantile of AQ. This phenomenon can be explained by environmental protection policies (Liu, Wang, et al., 2021). In 2013, the government publishes 'Guidelines for accelerating the development of energy-saving and environmental protection industries', which encourages investment in environment-friendly industries. In 2014, the authority proposes to set up an operation mechanism for protecting the ecological environmental investment, and actively introduces private capital. In 2015, China launches a new version of environmental protection law, particularly concerns air pollution issue. In 2016, the NDRC publishes 'Guidelines on cultivating the market role in governing environment and protecting ecology', which clearly shows that the output of EP would achieve about 2 trillion RMB, and creates a lot of environmental enterprises. In 2018, the National People's Congress publishes a new version of the 'Air pollution prevention and control law', which aims to improve air quality and promotes the sustainable development of the economy and society. These laws and regulations put forward to control serious air pollution, which increases investors' good expectation for the environmental protection industry and produces a positive influence on stock returns.

Figure 8 indicates the mean coefficient value between AQ and ME is negative in [0, 0.5] quantiles of AQ and SR, but coefficient become positive in [0.5, 1] and [0, 0.5] quantiles of AQ and SR. Some human organs directly contact with polluted air

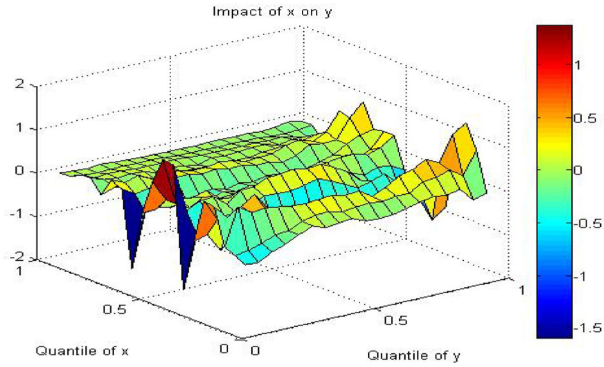


Quantile for SR \ Quantile for AQ	(0, 0.5)	(0.5, 1)
(0, 0.5)	-0.031	0.042
(0.5, 1)	-0.087	-0.013

Figure 8. The coefficients between AQ and ME, and the mean values of coefficients in each quadrant are located at the base of figure.
Source: Author's calculation.

that brings respiratory system injury, emotional upset, and other diseases (Liao et al., 2021). Thus, the negative relationship link can be explained from physiology and psychology. The polluted air would produce stressful stimuli, which brings people's emotional, mental, and physical changes. Investors may feel pessimistic and anxious with increasing air pollution, and erroneously attribute their bad sentiment to depressed macro-economic performance rather than polluted air (Li & Peng, 2016). That may result in biased decisions and reduces desire of trading stock, and finally affect stock returns. However, due to air pollution brings serious health risks for the public, government launches the 'Healthy China' strategy to cultivate medical equipment industry for reducing these risks. For example, 'The 14th Five-Year Plan for Universal Medical security (2021)', 'Guidance on expanding investment in strategic medical equipment industry (2020)', 'Regulations on production management of medical equipment (2020)' and other polices are successively issued, which brings prosperous and developing industrial prospects, boost investors' confidence, and finally increase stock return.

Figure 9 points out the mean coefficient values between AQ and IS are positive when AQ in quantile of [0, 0.5], and turn into negative in [0.5, 1] quantile of AQ. Under good air quality, cortisol levels would decrease in the human body, which strengthens the desire for risk-taking behaviours (Lepori, 2016; Levy & Galili, 2008). In addition, the cortisol level influences cognition and further increases investors' risk preference (Dong et al., 2021). In general, good air quality brings good sentiment and physical state, which enables investors to tend to trade and increases stock return. However, when facing air pollution, the coefficients become negative, which can be explained by government industrial policies and national environmental protection laws. China is the biggest steel producer, and CO_2 emissions from this industry

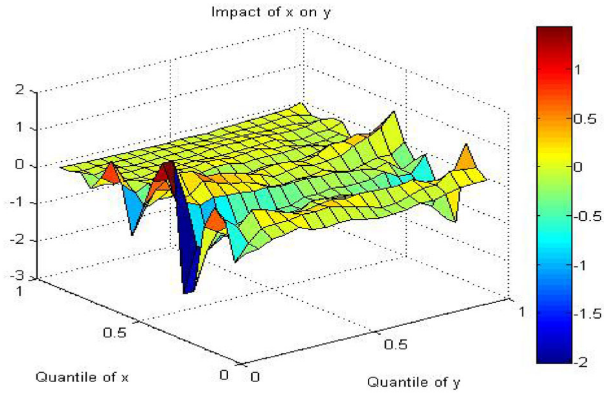


Quantile for SR \ Quantile for AQ	(0, 0.5)	(0.5, 1)
(0, 0.5)	0.043	-0.033
(0.5, 1)	0.015	-0.038

Figure 9. The coefficients between AQ and IS, and the mean values of coefficients in each quadrant are located at the base of figure.
Source: Author's calculation.

occupy 14% of the national total in 2019. Thus, control air pollution of iron and steel industry is the key part in achieving national environmental improvement (Liu & Kong, 2021; Zhu et al., 2021). Government thus publishes stricter emission standards since 2012, and launches 'Opinions on promoting the implementation of ultra-low emission in iron and steel industry (2020)', 'Guideline on control the total and intensity of energy consumption in iron and steel industry (2019)', and other policies. These measures demonstrate that iron and steel enterprises would face the pressure of long-term emission reduction, investors thus hold less optimistic expectations for enterprises' performance, and results in low stock return.

Figure 10 presents the mean coefficient values between AQ and AT are positive when AQ in quantile of [0, 0.5], and turn into negative when AQ runs in [0.5, 1] and SR runs in [0, 0.5]. People feel good in good air quality, thus they are easy to make investment decisions with risk preference, and maintain optimistic for the automobile industry, which leads to increasing SR. However, China is the global biggest automobile consumer and producer. Due to automobiles are beneficial for fast economic development, they are often chosen as people's preferred travelling mode; thus, China's automobile ownership is increasing rapidly (Chen et al., 2020). In 2020, its automobile production is 25.33 million vehicles, occupying 27.6% of global total production. Because of the fast development in the automobile market, the problem of fuel over-consumption and gases over-emission has become prominent. Thus, China provides some policies to solve mentioned problems such as strengthening the legal system, providing stimulus taxation policies, and improving environmental markets. In addition, China launces a series of programs, such as 'Ten Cities, Thousand Vehicles Demonstration, as a component of the Government Eleventh Five-Year Plan



Quantile for AQ / Quantile for SR	(0, 0.5)	(0.5, 1)
(0, 0.5)	0.011	-0.019
(0.5, 1)	0.084	0.017

Figure 10. The coefficients between AQ and AT, and the mean values of coefficients in each quadrant are located at the base of figure.
Source: Author's calculation.

(2006–2010)' to guide the development of the automobile market. After a series of government policy intervention, China's automobile enterprises confront pressure from energy saving, reducing emission and increasing competition, which influences investors' judgement, trading behaviours and finally reduces stock return.

To sum up, this paper discovers common and heterogeneous responses from SR to AQ across different industries. For tourism, iron and steel, and automobile industries, their mean coefficient values between AQ and SR turn into negative from positive with deteriorating AQ. Conversely, the mean coefficients in the wind power, hydro power, thermal power, environmental protection, and medical equipment industries turn positive from negative. Besides, different potential reasons can be employed to explain industrial heterogeneity. For example, TI is sensitive to air quality, and tourists would choose destination with good environment, and avoid polluted areas, thus, the deteriorating air quality would undoubtedly hit tourism and related enterprises. For HP and WP, they are important substitute for thermal power, and can obtain government continuous policy support, which stimulates investors to generate good expectations.

6. Conclusions and policy implications

This study deeply examines the impacts from air quality to stock return in China's stock market. The key empirical conclusions indicate that stock return has heterogeneous responses to air quality in different industries. In detail, the coefficient values between AQ and SR turn into negative from positive with deteriorating AQ in tourism, iron and steel, and automobile industries. Conversely, the coefficients in the wind power, hydro power, thermal power, environmental protection, and medical equipment industries turn positive from negative. To sum up, the asymmetric and heterogeneous relations between air quality and stock return are captured in our paper. Consequently, our study provides valuable contributions for the scientific knowledge. First, government intervention, especially its industrial policy, is regarded as an important supplement in interpreting responses from SR to AQ. China's authority is an important strategic planner, and owns strong power in economic activities, thus its role should be fully considered in influencing mechanism. Second, industrial heterogeneity is fully taken into account in our paper. Different industries own their special characters, which may lead to heterogeneous responses to air quality. Thus, eight different industries such as tourism and thermal power are selected, which provides individual and comparative empirical results. Last, the quantile-on-quantile test embeds non-parametric estimation into traditional quantile regression, and thus has ability to investigate influence in specific quantiles between variables. To sum up, the asymmetric and heterogeneous relations between air quality and stock return, and the role of government intervention are captured in our paper.

Based on the conclusions, this study consequently offers some policy implications. For individual investors, their biased decisions may mistakenly due to air pollution, rather than bad macro-economic performance. Thus, air quality can be used as a reference for investors in avoiding making biased trading behaviours in stock market. Next, polluted air not only affect people's cortisol level and other physiological activities, but also brings anxiety, upset, and other psychological states. Therefore, government ought to take drastic measures such as environmental protection law system to reduce pollutants emission. As supporting tool, the strict disclosure mechanism for environmental information is also needed for the public. Finally, China should develop alternative and renewable energy sources, and optimise its energy structure. Central and local governments need to support the development of new energy enterprises through financial subsidies, tax deduction, talent cultivation and other measures.

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