



# Modeling Stock Yield Reaction to Environmental Changes: Does Geopolitical Risk Matter? A VECM Framework in China

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## ABSTRACT

This paper examines the impact of air pollution on stock market performance, emphasizing geopolitical risk as a mediator. It explores how air pollution's health effects disrupt investor behavior and financial market dynamics, with geopolitical risk bridging the relationship between air quality, emissions policies, and stock performance, thus highlighting the interplay between environmental and financial systems. This study employs the Vector Error Correction Model (VECM) to analyze both short-term and long-term dynamics among the regressors. Using updated data from A-share listed firms on the Shanghai Composite Index, covering the period 2012–2021, the analysis is supported by rigorous stationarity and cointegration tests to ensure the robustness and reliability of the findings. The long-term results indicate that air pollution and geopolitical risk significantly influence stock yield volatility, with deviations from equilibrium gradually corrected over time. In the short term, there is a significant Granger causality between stock yield and both air pollution and geopolitical risk, highlighting their combined impact on stock market performance. The study shows that air quality index negatively affects stock yield by depressing investor sentiment and driving irrational behaviors, emphasizing its role as both a social challenge and a key driver of financial market stability and economic development.

**Keywords:** Air Pollution, Geopolitical Risk, Stock Yield, Vector Error Correction Model, China

**JEL Classifications:** G11, G15, Q53, F51, C32

## 1. INTRODUCTION

Air quality remains a significant global environmental challenge, with more than 99% of the global population exposed to unsafe air, leading to over six million premature deaths annually (World Health Organization, 2022; Health Effects Institute, 2020). The economic burden of air pollution is similarly profound, costing an estimated USD 8.1 trillion each year, equivalent to 6.1% of

global GDP (Lee et al., 2022).<sup>1</sup> According to the Environmental Performance Index (EPI) report (2022), countries with low EPI scores, such as China, rank poorly on-air quality, and despite

<sup>1</sup> The world has not gained much progress to mitigate noxious pollutants such as ozone exposure, households' solid fuels consumptions, sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NOX), carbon monoxide (CO), volatile organic compounds, and Fine Particulate Matter (PM<sub>2.5</sub>) exposure (Environmental Performance Index (EPI) report, 2022).

substantial progress in trade, China continues to grapple with severe air pollution challenges. This is largely due to rising industrial waste and carbon emissions, which hinder its efforts toward sustainable development (He et al., 2023; Nie et al., 2020; Zhao et al., 2017). China's economic growth, heavily reliant on fossil fuels, has contributed to severe environmental degradation, while its publicly listed companies have become significant contributors to air pollution, posing risks to public health and creating investment uncertainties (Zhou et al., 2021). China is also responsible for 30% of the world's total annual carbon emissions, further underscoring its role in global environmental challenges (Xie et al., 2023).

In response to these environmental concerns, China has committed to significant carbon reduction targets, including reducing carbon intensity by 40–45% by 2020, established during the Copenhagen Climate Conference in 2009. The country has also introduced the Carbon Emissions Trading System (CETS) in 2013 and set more ambitious goals to peak carbon emissions by 2030 and achieve carbon neutrality by 2060 (Xie et al., 2023; Fan et al., 2022; Liu et al., 2022; Yu et al., 2021). Further, China has reinforced its environmental governance by implementing action plans addressing air, water, and soil pollution, aimed at enhancing pollution control and strengthening air pollution supervision (Li et al., 2022; Li et al., 2020). Since 2014, continuous monitoring of air pollutants has been mandated, and real-time pollution data is disclosed online, promoting transparency in environmental management (Zhou et al., 2021).

Despite these efforts, air quality remains a critical issue for China. He et al. (2023) reported that 121 of China's 339 cities failed to meet national air quality standards, and the 2022 EPI ranked China 160<sup>th</sup> out of 180 countries, reflecting a decline from its previous ranking in 2020. This deterioration underscores the gap in pollution control efforts and highlights China's ongoing struggle with severe air pollution, which continues to hinder sustainable development. The economic losses from air pollution in China are estimated to be around 1.2% of the country's GDP (Liu et al., 2021). Furthermore, China remains one of the world's largest emitters of pollutants, with emissions of 9.89 billion tons of CO<sub>2</sub>, 3.7 million tons of SO<sub>2</sub>, and 11.57 million tons of NO<sub>x</sub> annually, illustrating the scale of its environmental challenges.

To this end, while the direct effects of air pollution on human health are well-documented, its potential influence on financial markets and stock performance has not been fully explored in academic literature. This paper suggests that the health impacts of air pollution extend to investor behavior, causing psychological deviations and pessimism, such as depression, which disrupts investment decision-making (He et al., 2023; Su et al., 2022; Zhang et al., 2022; Fan et al., 2020). These emotional disruptions can lead to investor uncertainty, with pessimistic sentiments leading to a higher tendency to sell stocks (Alsabah et al., 2025). Additionally, the economic burden imposed by air pollution, such as increased medical expenses, reduces individual savings and affects investment strategies.

This paper argues that non-financial factors, like air pollution, have a significant adverse impact on financial markets and stock

performance, by diminishing investors' ability to make informed decisions within digital financial systems (Al-Okaily et al., 2025). Furthermore, in digital environments, investor engagement and decision quality are sensitive to perceived risk and psychological stress, which influence platform usage and behavioral responses (AlGhannam et al., 2026). He et al. (2023) stresses the importance of understanding how air pollution impacts stock market performance for two key reasons: it diverts investors' attention from thorough stock analysis and increases medical expenditures, thus limiting investors' capital for market engagement.

Notably, this paper introduces a novel perspective by identifying geopolitical risk (GPR) as a critical mediating factor that links air quality, emissions policies, and stock market performance, providing a comprehensive framework integrating environmental and financial dynamics.<sup>2</sup> Existing literature identifies GPR as an exogenous factor influencing business cycles and financial markets, with financial institutions, media, and investors recognizing it as a key determinant in investment decisions. Several studies confirm that GPR is a major driver of changes in economic fundamentals and stock market dynamics (He, 2023; Caldara and Iacoviello, 2022; Balcilar et al., 2018), although the impact of GPR on stock market performance remains nuanced. Some research suggests GPR negatively impacts stock prices, leading to crashes, while others argue that it increases market volatility (Fiorillo et al., 2023; Saadaoui et al., 2023; Agoraki et al., 2022). The interaction between GPR and air pollution presents a unique channel through which geopolitical uncertainty influences stock market outcomes. Firms exhibit varying levels of exposure to geopolitical risk, and the way stock prices respond to GPR is shaped not only by geopolitical threats but also by the actions taken in response. Understanding these dynamics is crucial to assessing GPR's impact on financial markets and corporate resilience.

Against this backdrop, the current paper examines the influence of both air pollution and geopolitical risk on stock market performance, particularly stock yields, extending previous research by exploring GPR's potential mediating effect. The analysis incorporates GDP per capita as a control variable to account for income effects and firms' return on assets (ROA) as a proxy for performance. This comprehensive approach aims to provide insights into how external and internal factors shape stock yields over time. The paper employs the Vector Error Correction Model (VECM) framework to examine both short-term and long-term dynamics using updated data from A-share listed firms on the Shanghai Composite Index from 2019 to 2023, with rigorous stationarity and cointegration tests ensuring the robustness of the results.

The findings reveal a significant influence of air pollution and geopolitical risk on stock yield volatility. In the short term, the results confirm Granger causality between stock yield and both air pollution and geopolitical risk, emphasizing the combined impact of environmental and political factors on stock market performance. The results show that air pollution adversely affects stock yield, primarily by reducing investor sentiment and inducing

<sup>2</sup> Geopolitical risks can be in the form of wars, armed conflicts, political tensions across countries or regions, militarization, terrorist attacks, and a like.

irrational investment behavior. The economic control variables also demonstrate that air pollution is a critical driver of financial responses in capital markets, underlining its broader implications for market stability and national economic development.

This paper contributes to the literature in several ways: First, by examining air pollution as a non-financial factor influencing stock market performance, offering new insights through behavioral finance; second, by highlighting the role of geopolitical risk in shaping financial cycles and market dynamics; and third, by including heterogeneity across firms, enabling a more nuanced understanding of how these factors affect stock yields. This approach provides valuable insights for investors and policymakers alike, helping them make more informed decisions. The paper concludes by offering policy recommendations and suggesting directions for future research, emphasizing the need for more strategic environmental policies and investment decisions to mitigate the financial impacts of air pollution.

The structure of this paper is as follows: Section 2 offers a comprehensive review of the relevant literature. Section 3 outlines the data sources and proxies of variables, while Section 4 presents the research model. Section 5 presents the empirical analysis and the key findings. Finally, Section 6 concludes the paper by summarizing the results, outlining policy implications, addressing study limitations, and suggesting directions for future research.

## 2. LITERATURE REVIEW

Air pollution demonstrates a significant association with firms' stock prices, encouraging investors to prioritize long-term returns in exchange markets while heightening public awareness of the influence of environmental quality on portfolio investment decisions. The detrimental effects of air pollution on both individuals and businesses are well-documented, encompassing adverse psychological and physiological impacts on human health. However, the extent to which air pollution shapes individuals' behavior and equity investment decisions, and the subsequent reactions of the stock market, remains insufficiently explored in the literature. Furthermore, periods of elevated geopolitical risk are frequently accompanied by heightened uncertainty and volatility in financial markets, underscoring the need for comprehensive analysis. The following sections review the relevant literature, focusing on the impact of air pollution and geopolitical risk on stock market performance through the lens of behavioral finance.

### 2.1. Stock Market Performance and Air Pollution

Extensive research has established the detrimental impact of air pollution on stock market performance, highlighting its negative influence on returns and trading behavior. Studies by Xu (2022) and Guo et al., (2022) demonstrate that air pollution reduces stock returns, discourages stock purchases, and promotes risk-averse behavior. Liu et al., (2022) and Xu et al., (2021) emphasize the immediate adverse effects of poor air quality on investor emotions and health, with pollution in larger regions showing a significant negative impact on stock returns. Ding et al., (2021) found that the effects of air pollution are more pronounced for younger firms with lower institutional ownership, while Jiang et al., (2021)

revealed that these negative effects are most significant during bullish market periods. Nguyen and Pham (2021) demonstrated that air pollution influences individuals' behavior, leading to biased trading decisions in the stock market. Ding et al., (2021) further highlighted that companies located in high pollution areas experience reduced stock returns. Kiihamäki et al., (2021) identified air pollution as a significant environmental issue with broad psychological, economic, and social impacts on individuals and businesses. Tainio et al. (2021) found that pollution reduces physical activity, while Giaccherini et al. (2021) linked it to higher hospitalization rates, particularly among the elderly. Additionally, air pollution's negative effect on cognitive function contributes to biased investor decision-making (Ding et al., 2021), emphasizing the wide-ranging consequences of pollution on both market dynamics and investor behavior.

What is more, air pollution has been shown to negatively affect consumers' decision-making, especially in scenarios requiring cognitive effort. Huang et al. (2020) found that air pollution correlates with impaired investor behavior, increasing susceptibility to biases such as the disposition effect and attention-driven buying. Teng and He (2020) observed that heightened pollution awareness reduces cognitive abilities, lowering investors' trading activity. Further studies by Wu et al. (2020) and Teng and He (2020) highlighted how pollution's physiological and psychological effects exacerbate biases and disrupt trading behaviors, leading to abnormal market fluctuations and reduced stock returns. Giudici et al. (2019) noted mixed effects of air pollution on stock returns in China from 2003 to 2015, emphasizing the complex relationship between environmental factors and financial market performance. These findings collectively demonstrate that air pollution influences both physical health and investor sentiment, significantly affecting financial market stability and performance. Wu et al., (2018) explored the impact of air pollution on fund managers' moods, finding that it induces depressive tendencies, which in turn reduce stock returns and trading frequency. The study highlighted that while air pollution does not directly affect firms' performance, it significantly influences investors' emotional states, thereby shaping their trading behaviors. Lu et al., (2018) further emphasized that air pollution leads to heightened anxiety and mood instability among investors, contributing to uncertain stock evaluations. In contrast, He and Liu (2018) found no significant long-term impact of air pollution on China's stock market performance. Zhang et al., (2017) observed a negative effect of air pollution on stock yields, suggesting that environmental factors can make stock performance more vulnerable. Lepori (2016) discussed how air pollution induces negative emotions, fostering risk-averse behaviors and decreasing trading activity, ultimately leading to lower returns. Similarly, Guo and Zhang (2016) found that air pollution reduces turnover rates, although it did not have a direct impact on stock returns. This sensitivity to external risk is particularly relevant in emerging markets like Kuwait, where high uncertainty avoidance and perceived security concerns dictate the psychological trust required for users to engage with digital financial platforms (Al-Shamali et al., 2025). Collectively, these studies underline the complex effects of air pollution on market dynamics, primarily through its influence on investor sentiment and trading behaviors, even when firm performance is unaffected.

To conclude, several studies have highlighted the negative impact of air pollution on individuals' disposable income, reducing their ability and willingness to invest in stocks. Air pollution contributes to increased medical expenses and health risks, which strain personal finances and hinder investment behavior (Santiago et al., 2022; Zhou and Li, 2021; Sager, 2019). Additionally, it affects firms' performance by lowering productivity, increasing absenteeism, and raising labor costs, which can diminish stock prices and investor confidence (Teng and He, 2020; Zhang et al., 2018). At the firm level, companies facing environmental challenges may struggle to attract investments (Gan et al., 2022). The broader implications of air pollution on both individual financial decisions and market dynamics are significant. Empirical evidence also shows that air pollution negatively influences investor behavior and stock returns (Li et al., 2021; Ding et al., 2021; Jiang et al., 2021; Xu et al., 2021; Huang et al., 2020). The adverse effects on firms' operations lead to investor pessimism, which depresses stock prices and prompts portfolio adjustments, ultimately impacting the stability of financial markets.

## 2.2. Stock Market Performance and Geopolitical Risk

The adverse macroeconomic implications of geopolitical risks (GPR) have increasingly attracted the attention of both policymakers and scholars. Geopolitical risks have significant effects on various macroeconomic and institutional factors. For instance, GPR influences the prices of assets such as oil (Bouoiyour et al., 2019), precious metals (Baur and Smales, 2020), gold (Gkillas et al., 2020), and commodities in general. Additionally, GPR can contribute to the likelihood of an economic recession (Clance et al., 2019; Francis et al., 2022) and undermine the stability and profitability of financial institutions (Alsagr and Almazor, 2020; Phan et al., 2022). Geopolitical risks also impact firms' financing decisions and long-term investment strategies (Alam et al., 2023; Caldara and Iacoviello, 2022; Zulfikar et al., 2025). In the face of heightened geopolitical threats, managers may be inclined to withhold negative information to preserve performance metrics and compensation plans, which can increase the risk of stock price declines.

Furthermore, the dissemination of negative information regarding geopolitical threats has a detrimental effect on investor sentiment, leading to declines in stock prices. Geopolitical uncertainty erodes investor confidence in capital markets (Habib and Huang, 2019) and increases the cost of equity financing, while simultaneously reducing the value of investors' portfolios (Carluccio et al., 2021; Gu et al., 2019; Liu and Ren, 2019). Empirical evidence from Zhang et al. (2023) underscores that geopolitical risk has a significant positive impact on stock market volatility. Lai et al. (2023) highlighted that geopolitical risk consistently exerts negative effects on economic activity, inevitably escalating uncertainties in financial market performance. These risks hinder credit demand by obstructing cross-border capital flows, leading to significant fluctuations in currency and commodity prices (such as crude oil), and prompting adjustments in asset prices, including stocks and real estate. In the context of financial market uncertainty, intensified geopolitical risk typically induces risk aversion among investors, thereby dampening both consumer and investor confidence. Additionally, heightened geopolitical

uncertainty may result in increased unemployment rates and lower production levels. Consequently, precautionary saving behaviors may be adopted, which inversely affects consumer spending and delays business investment decisions. Zhang et al. (2023) demonstrated that geopolitical risk influences stock market performance through three primary channels: first, an escalation in geopolitical risk prolongs the decision-making process of market participants; second, increased geopolitical risk diminishes global trade and capital flows between nations; and third, heightened geopolitical risk raises the overall risk associated with investing in financial markets.

In summary, the adverse effects of heightened geopolitical risk (GPR) on economic and financial markets drive investors to reduce their portfolio investments in financial markets, opting instead for safer investment alternatives. Adeleke (2023) found that GPR negatively impacts stock returns in three major North-East Asian countries: China, North Korea, and Japan. Agoraki et al., (2022) reported that GPR has a statistically significant and negative effect on stock returns across 22 countries from 1985 to 2020. Hoque and Zaidi (2020) concluded that GPR exerts an asymmetric effect on stock markets in different countries. Alqahtani et al., (2020) supported the notion that GPR possesses positive predictive power for stock markets. Cheng and Chiu (2018) provided evidence of economic contractions resulting from the differential responses of stock markets to GPR in 38 emerging countries. Finally, Balcilar et al., (2018) demonstrated that geopolitical turmoil negatively affects stock returns in BRICS nations.

## 2.3. Air Pollution and Geopolitical Risk

Geopolitical risks have wide-ranging effects that extend beyond economic and political concerns, significantly impacting environmental outcomes, particularly air pollution and climate change. Research by Acheampong et al. (2023) highlights that geopolitical risks can lead to increased reliance on fossil fuels, further exacerbating air pollution. Zhao et al. (2023) found that fluctuations in geopolitical risks could either increase or decrease pollution emissions, depending on the context, suggesting a nuanced relationship between geopolitical events and environmental outcomes. Similarly, Sohag et al. (2022) observed that geopolitical uncertainties often hinder investments and innovations crucial for mitigating air pollution and addressing climate change, as economic and political instability diverts attention and resources away from environmental progress. Caldara and Iacoviello (2022), along with Dogan et al. (2021), noted that heightened geopolitical risks often correlate with declines in real economic outcomes, which subsequently lead to increased carbon emissions and deteriorating air quality. This pattern is further exacerbated by geopolitical tensions that foster uncertainty, ultimately encouraging reliance on non-renewable energy sources rather than investing in clean technologies or renewable energy options. Astvansh et al., (2022) expanded on this by emphasizing that geopolitical risks contribute to worsening air pollution by disrupting innovation and promoting the use of fossil fuels.

In the context of specific countries, Syed et al., (2022) found that the impact of geopolitical risks on air pollution varied across the

BRICS countries and Turkey from 1990 to 2015. Their study identified that increased military spending, often a response to geopolitical tensions, typically involves greater fossil fuel consumption, thereby exacerbating air pollution. Wang et al. (2022) echoed these findings, linking militarization and fossil fuel dependence with higher air pollution levels.

Contrasting these views, Riti et al., (2022) argued that geopolitical risks might have a counterintuitive positive effect on the environment by curbing economic activity, reducing resource exploitation, and limiting production and consumption in response to heightened geopolitical uncertainty. This theory suggests that, in some instances, geopolitical risks could contribute to a temporary reduction in environmental degradation. However, longitudinal studies by Hashmi et al. (2022), which analyzed global data from 1970 to 2015, found that geopolitical risk initially leads to a reduction in air pollution in the short term, but over the long term, it results in an increase in pollution levels.

Overall, the bulk of the literature supports the notion that geopolitical risk generally contributes to higher carbon dioxide emissions, increased energy consumption, and ultimately environmental degradation (Anser et al., 2021; Gokmenoglu et al., 2020). These studies emphasize that while some short-term effects of geopolitical risk might temporarily benefit the environment, the long-term implications are more likely to exacerbate pollution and hinder environmental sustainability efforts.

### 3. DATA SOURCES AND PROXIES OF VARIABLES

#### 3.1. Data Sources

The paper focuses on China's economy over the sample period from 2012 to 2021. The data sources for the Vector Error Correction Model (VECM) analysis in this paper are diverse and robust. The dependent variable, adjusted closing price (Adj.Close), is based on historical daily stock data for the Shanghai Stock Exchange (SSE) Composite Index over a 10-year period, sourced from Yahoo Finance (Shanghai Stock Exchange Composite Index dataset stock data: [https://finance.yahoo.com/quote/000001.SS/history?p=000001.SS]). Air Quality Index (AQI) data, reflecting overall air quality, is derived from hourly concentrations of PM<sub>2.5</sub>, PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>2</sub>, CO, and O<sub>3</sub> collected by the China National Environmental Monitoring Center (CNEMC). The AQI uses a 24-h average for most pollutants and an 8-h average for O<sub>3</sub>, calculated per the Technical Regulation on Ambient Air Quality Index (HJ-633-2012); (Wang et al., 2018; Yin et al., 2019; Thach et al., 2018; HJ-633-2012). Geopolitical risk data is obtained from Caldara and Iacoviello's (2022) geopolitical risk index. Economic variables include Gross Domestic Product (GDP) per capita, representing total annual economic output from the World Bank (2023), and Return on Assets (ROA), sourced from the top 100 manufacturing companies by market capitalization listed on the Shanghai Stock Exchange from 2012 to 2021. Data manipulation included ensuring stationarity through differencing, cointegration testing using Johansen's method, and incorporating lagged terms and error correction mechanisms in the VECM framework to capture both short-term dynamics and long-term equilibrium relationships.

#### 3.2. Proxies of Variables

The firm's stock yield is used as explained variable. We utilized the stock yield of firms listed in the A-share market as a proxy for stock market performance, given its importance as a critical indicator of equity investment activity. Following the methodologies outlined by He et al. (2023) and Chen et al. (2018), we relied on the annual stock yield rate derived from the China Stock Market and Accounting Research (CSMAR) database. This yield rate is calculated as the ratio of the closing price of firm  $i$ 's stock on the final trading day of period  $t$  (denoted as  $P_{i,t}$ ) to the closing price on the final trading day of the preceding period (denoted as  $P_{i,t-1}$ ).

The explanatory variables consist of air pollution and geopolitical risk. Air pollution is utilized as an explanatory variable to quantify the severity of environmental pollution in a city. It is measured using the Air Quality Index (AQI), a widely recognized metric previously employed by He et al. (2023) and Wu et al. (2018).<sup>3</sup> The AQI provides a comprehensive assessment of air quality by aggregating data on key air pollutants, thereby offering an integrated evaluation of pollution levels. This index, which encompasses nearly all major air pollutants, serves as a reliable indicator of air pollution conditions. The AQI scale ranges from 0 to 500, with higher values reflecting deteriorating air quality. Such degradation has been shown to exert adverse effects on stock market performance. The Geopolitical Risk Index (GPR) is utilized to assess the likelihood of economic disruptions and increased downside risks associated with geopolitical events. Geopolitical threats consistently exert adverse effects on economic activities, creating uncertainties that hinder investment decisions in financial markets (Lai et al., 2023; Zhang et al., 2023). These risks have been shown to trigger economic recessions (Francis et al., 2022) and destabilize financial institutions (Phan et al., 2022). Furthermore, geopolitical risk undermines investor confidence in capital markets and raises the cost of equity financing (Carluccio et al., 2021; Gu et al., 2019). In summary, the GPR is closely linked to diminished stock returns and exhibits an asymmetric impact on stock market performance, ultimately leading to a decline in market yields. The geopolitical risk variable is quantified using the Geopolitical Risk Index (GPR), as developed by Caldara and Iacoviello (2022).

GDP per capita and Return on Assets (ROA) are used as control variables. The former (GDP per capita) is widely recognized as a key indicator of a country's economic growth and is often associated with stock market performance. It is intuitively expected that GDP growth and stock market returns exhibit a positive correlation, with GDP per capita serving as a leading indicator of domestic stock market dynamics. By capturing the income effect, GDP per capita is generally regarded as a strong predictor of stock market yields. However, Jason et al. (2022) found no statistically significant relationship between per capita GDP growth and stock returns in developed markets, reporting a negative correlation

3 AQI is the most widely used measure of air pollution since it comprised six different pollutants, namely ground-level ozone (O<sub>3</sub>), carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), Sulphur dioxide (SO<sub>2</sub>), particulate matter which is less than 10 microns (PM 10) and less than 2.5 microns (PM 2.5), see Lee et al. (2022).

of  $-0.31$  with a P-value of  $0.17$ . Similarly, Bhatt (2022) noted that while GDP growth and stock markets have historically been correlated, this relationship has weakened in recent years. In line with these findings, Boesler (2014) demonstrated a counterintuitive negative correlation between a country's stock market returns and the growth of its per capita GDP, challenging the assumption that higher economic growth rates necessarily lead to superior investment returns. Drawing on these insights, we hypothesize that in the context of China, GDP per capita may exert a negative influence on stock market yields. The later (Return on Assets) is a fundamental financial metric used to assess a firm's performance and its influence on stock prices (Yang et al., 2021). It evaluates a company's ability to generate profits relative to its total assets, serving as a measure of operational efficiency. A higher ROA signals strong profitability and financial health, which tends to attract investors, increasing demand for the company's shares. This heightened demand drives up stock prices, ultimately contributing to higher stock returns. Empirical evidence supports this relationship; Ramadhani and Ratnasari (2022) identified a positive and significant correlation between ROA and stock prices, which in turn enhances stock returns. Accordingly, we anticipate a positive effect of ROA on stock market yields. The ROA is calculated as the ratio of firm  $i$ 's net profit in period  $t$  relative to its total assets of period  $t$ .

## 4. RESEARCH MODEL

### 4.1. Model specification

The overall model integrating the direct and mediating effects in a single equation for the study can be expressed as follows:

Let:

- $Y_{i,t}$ : Stock yield for firm  $i$  at time  $t$
- $AP_t$ : Air pollution measure at time  $t$
- $GPR_t$ : Geopolitical Risk Index at time  $t$
- $GDP_t$ : Per capita Gross Domestic Product at time  $t$  (control variable)
- $ROA_{i,t}$ : Return on Assets for firm  $i$  at time  $t$  (control variable).

The overall model combining both direct and mediating effects is:

$$Y_{i,t} = \alpha + \beta_1 \cdot AP_t + \beta_2 \cdot GPR_t + \beta_3 \cdot (AP_t \times GPR_t) + \gamma \cdot GDP_t + \delta \cdot ROA_{i,t} + \epsilon_{i,t} \quad (1)$$

Where:

- $\beta_1$ : Coefficient for the direct effect of air pollution on stock performance.
- $\beta_2$ : Coefficient for the direct effect of geopolitical risk on stock performance.
- $\beta_3$ : Coefficient for the interaction (mediation) effect between air pollution and geopolitical risk on stock performance.
- $\gamma$  and  $\delta$ : Coefficients for the control variables (GDP per capita and ROA).
- $\epsilon_{i,t}$ : Error term for firm  $i$  at time  $t$ .

Equation (1) above captures:

- 1 The direct effect of air pollution ( $\beta_1 \cdot AP_t$ )
- 2 The direct effect of geopolitical risk ( $\beta_2 \cdot GPR_t$ ).

- 3 The mediating (interaction) effect of geopolitical risk on the relationship between air pollution and stock yield ( $\beta_3 \cdot (AP_t \times GPR_t)$ ).
- 4 The effects of control variables  $GDP_t$  and  $ROA_{i,t}$  on stock yield.

To align our model with the hypotheses outlined in the paper, equation (1) has been revised. Equation (2) layout keeps the equation concise while showing each part clearl.

$$Y_{i,t} = \alpha + \beta_1 \cdot AQI_t + \beta_2 \cdot GPRHC\_CHN_t + \beta_3 \cdot (AQI_t \times GPRHC\_CHN_t) + \gamma_1 \cdot CHN\ GDP\ per\ capita\ (current\ US\$)_t + \gamma_2 \cdot Weighted\ average\ return\ on\ net\ assets\ (\%)_{i,t} + \gamma_3 \cdot Total\ assets\ (yuan)_{i,t} + \epsilon_{i,t} \quad (2)$$

### 4.2. Methodology

This study employs a Vector Error Correction Model (VECM) framework to explore the dynamic relationships between stock yields, air pollution, geopolitical risks, and economic indicators. The analysis begins with stationarity testing, using the Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests to ensure that the variables meet the stationarity requirements necessary for cointegration analysis. The ADF test examines the null hypothesis of a unit root, while the KPSS test evaluates the null hypothesis of stationarity. Variables that exhibited non-stationarity in levels were differenced to achieve stationarity. Next, the Johansen cointegration test was conducted to identify long-term equilibrium relationships among the variables. The trace statistics significantly exceeded the critical values at the 5% significance level, indicating the presence of cointegration. This was done to validate the use of a VECM, as it captures both short-term fluctuations and long-term equilibrium dynamics within the system.

The optimal lag length for the VECM was determined using model selection criteria, such as the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The VECM was specified to include error correction terms (ECTs), which measure the speed at which deviations from long-term equilibrium are corrected, and lagged terms, which capture the short-term effects of explanatory variables on stock yields. Granger causality tests were performed to assess the directional predictive relationships among variables. Impulse-response functions (IRFs) were then used to evaluate the dynamic effects of one-standard-deviation shocks to each variable on the others over a 10-period horizon, providing insights into the temporal nature of these interactions (Alsaber et al., 2025).

## 5. EMPIRICAL ANALYSIS AND RESULTS

The Augmented Dickey-Fuller (ADF) test results reveal significant stationarity properties for both levels and first differences across all variables ( $P < 0.001$ ) (Table 1). In levels, all test statistics exceed the critical value of  $-2.8616$  in absolute terms, with GPRHC\_CHN showing the strongest rejection of the unit root hypothesis ( $t = -27.3449$ ), followed by Adjusted Close ( $t = -24.1840$ ) and AQI ( $t = -19.1114$ ). The first differences demonstrate even stronger stationarity, with substantially larger test statistics, particularly for GDP per capita ( $t = -307.2995$ ), weighted average return on net assets ( $t = -312.7835$ ), and total assets ( $t = -233.6062$ ). The consistently significant results across

both levels and first differences (all  $P < 0.001$ ) indicate that these variables are either trend-stationary in levels ( $I(0)$ ) or become stationary after first differencing ( $I(1)$ ), suggesting appropriate conditions for cointegration analysis and the application of a Vector Error Correction Model (VECM) to examine their long-run relationships and short-run dynamics.

Further, the KPSS test results assess the stationarity of variables by comparing test statistics to the critical value (0.463) at the 5% level (Table 2). In levels, Adj Close (0.4925,  $p = 0.0434$ ), CHN GDP per capita (3.6476,  $p = 0.01$ ), Weighted Average Return on Net Assets (27.949), Total Assets (4.8872), and SSE 100 Index (4.905) exceed the critical value, rejecting stationarity. Conversely, GPRHC\_CHN (0.2692) and AQI (0.0265) fall below the threshold, indicating stationarity.

After differencing, all variables exhibit strong stationarity, with test statistics significantly below the critical value (e.g., Adj Close:  $5e-04$ , CHN GDP per capita: 0.002, GPRHC\_CHN:  $4e-04$ ). Variables such as Weighted Average Return on Net Assets and Total Assets also show clear stationarity in first differences. These results confirm that differencing effectively addresses non-stationarity, ensuring the data meet the requirements for further econometric analysis, such as cointegration and VECM modeling.

The Johansen cointegration test results presented in Table 3 provide strong evidence for the presence of long-term equilibrium relationships among the variables under study. The trace statistics for all hypothesized cointegrating equations significantly exceed their respective critical values at the 5% significance level. Specifically, for the null hypothesis of no cointegration (None), the trace statistic is 3246.25, far surpassing the critical value of 34.91, with a probability value of 0, leading to the rejection of the null hypothesis. Similarly, for the null hypotheses of at most one and at most two cointegrating equations, the trace statistics are 1117.15 and 169.09, respectively, which also exceed their critical values of 19.96 and 9.24, both with probability values of 0.

These results indicate that the variables share common stochastic trends and are cointegrated, suggesting that they move together in the long run despite short-term fluctuations. This finding justifies the use of a Vector Error Correction Model (VECM) to capture both the long-term relationships and short-term dynamics among the variables.

The Vector Autoregression (VAR) Lag Order Selection Criteria results reveal that a lag length of two is optimal for the model, as indicated by the lowest values across multiple criteria: Akaike Information Criterion (AIC = 80.2388), Bayesian Information Criterion (BIC = 80.2494), Final Prediction Error (FPE =  $7.035E+34$ ), and Hannan-Quinn Information Criterion (HQIC = 80.2420) (Table 4). These criteria are essential for determining the appropriate number of lags to include in a VAR model, as they balance model fit with complexity. The asterisks (\*) next to the values for lag 2 highlight this as the preferred choice, suggesting that it provides the best trade-off between capturing the underlying data dynamics and avoiding overfitting.

The Granger causality test results (Table 5) indicate significant causal relationships among the variables Adj.Close, AQI, and GPRHC\_CHN. Specifically, the null hypothesis that Adj.Close does not Granger-cause AQI and GPRHC\_CHN is rejected with an F-Test statistic of 383.24 ( $P < 2.2e-16$ ), indicating that past values of Adj.Close provide significant information about future values of AQI and GPRHC\_CHN. Similarly, AQI Granger-causes Adj.Close and GPRHC\_CHN, with an F-Test statistic of 438.04 ( $P < 2.2e-16$ ), and GPRHC\_CHN Granger-causes Adj.Close and AQI, with an F-Test statistic of 254.3 ( $P < 2.2e-16$ ). The instantaneous causality tests also show significant relationships, with Chi-squared statistics of 5101.3, 169.37, and 5237.3 for Adj.Close, AQI, and GPRHC\_CHN, respectively (all  $P < 2.2e-16$ ). These results suggest that there are strong bidirectional causal relationships among these variables, highlighting their interconnectedness in the system.

**Table 1: ADF test results for levels and first differences**

Variable	Level test statistic	Level P-value	Level critical value (5%)	Diff test statistic	Difference P-value	Diff critical value (5%)
Adj Close	-24.1840	0.0000e+00	-2.8616	-47.3910	0.0000e+00	-2.8616
CHN GDP per capita (current US\$)	-12.0872	2.1636e-22	-2.8616	-307.2995	0.0000e+00	-2.8616
GPRHC_CHN	-27.3449	0.0000e+00	-2.8616	-47.1806	0.0000e+00	-2.8616
Weighted average return on net assets (%)	-11.2732	1.5187e0	-2.8616	-312.7835	0.0000e+00	-2.8616
Total assets (yuan)_y	-10.9758	7.6740e-20	-2.8616	-233.6062	0.0000e+00	-2.8616
SSE 100 Index	-10.9507	8.8116e-20	-2.8616	-234.0512	0.0000e+00	-2.8616
AQI	-19.1114	0.0000e+00	-2.8616	-40.9231	0.0000e+00	-2.8616

**Table 2: KPSS test results for levels and first differences**

Variable	Level test statistic	Level P-value	Level critical value (5%)	Diff test statistic	Diff P-value	Diff critical value (5%)
Adj Close	0.4925	0.0434	0.463	5e-04	0.1	0.463
CHN GDP per capita (current US\$)	3.6476	0.01	0.463	0.002	0.1	0.463
GPRHC_CHN	0.2692	0.1	0.463	4e-04	0.1	0.463
Weighted average return on net assets (%)	27.949	0.01	0.463	0.0019	0.1	0.463
Total assets (yuan)_y	4.8872	0.01	0.463	0.0023	0.1	0.463
SSE 100 Index	4.905	0.01	0.463	0.0023	0.1	0.463
AQI	0.0265	0.1	0.463	0.0012	0.1	0.463

The VECM results for Adj.Close, including lags t-1, t-2, and t-3, have been successfully extracted. The Vector Error Correction Model (VECM) results for Adjusted Closing prices reveal significant short-run dynamics and long-term equilibrium adjustments (Table 6). The error correction terms (ECT1:  $\beta = -0.0528$ ,  $P < 0.001$ ; ECT2:  $\beta = 0.034$ ,  $P < 0.001$ ; ECT3:  $\beta = -0.026$ ,  $P < 0.001$ ) indicate that deviations from the long-term equilibrium are corrected over time, with ECT1 and ECT3 suggesting a negative adjustment and ECT2 a positive one. Among the lagged variables, GDP per capita (t-1:  $\beta = -0.091$ ,  $P < 0.001$ ; t-2:  $\beta = -0.012$ ,  $P < 0.001$ ; t-3:  $\beta = -0.066$ ,  $P < 0.001$ ) consistently shows a significant negative impact on Adj.Close, highlighting its strong influence on market prices. Total assets also exhibit a significant positive effect at t-1 ( $\beta = 0.543$ ,  $P < 0.001$ ) and t-2 ( $\beta = 0.074$ ,  $P < 0.001$ ), while GPRHC\_CHN (t-1:  $\beta = -0.01$ ,  $P < 0.01$ ; t-2:  $\beta = 0.012$ ,  $P < 0.001$ ) and AQI (t-1:  $\beta = 0.015$ ,  $P < 0.001$ ) demonstrate varying impacts across different lags. These findings underscore the complex interplay of economic and geopolitical factors in shaping market dynamics, with significant implications for investment strategies that consider both short-term fluctuations and long-term trends.

**Table 3: Johansen cointegration test results**

Hypothesized_ CEs	Trace_ Statistic	Critical_ Value_ 5pct	Probability
None	3246.25	34.91	0
At most 1	1117.15	19.96	0
At most 2	169.09	9.24	0

**Table 4: VAR lag order selection criteria**

Lag	AIC	BIC	FPE	HQIC
0	105.8204	105.8211	9.061E+45	105.8206
1	80.5776	80.5832	9.872E+34	80.5793
2	80.2388*	80.2494*	7.035E+34*	80.2420*
3	80.3969	80.4123	8.24E+34	80.4016
4	81.2197	81.24	1.876E+35	81.2259
5	81.5476	81.5728	2.604E+35	81.5553
6	82.3729	82.4031	5.944E+35	82.3821
7	85.1756	85.2107	9.802E+36	85.1863
8	81.3687	81.4086	2.178E+35	81.3809
9	81.3882	81.4331	2.22E+35	81.4019
10	85.9406	85.9903	2.106E+37	85.9557

AIC: Akaike Information Criterion, BIC: Bayesian Information Criterion, FPE: Final Prediction Error, HQIC: Hannan-Quinn Information Criterion. An asterisk (\*) indicates the optimal lag length for each criterion

**Table 5: Granger causality test results**

Causality direction	F-statistic	df	P-value	$\chi^2$	$\chi^2$ df	Instant P
Adj. Close→AQI, GPRHC_CHN	383.24	4,278910	<0.001	5101.30	2	<0.001
AQI→Adj. Close, GPRHC_CHN	438.04	4,278910	<0.001	169.37	2	<0.001
GPRHC_CHN→Adj. Close, AQI	254.30	4,278910	<0.001	5237.30	2	<0.001

→ Indicates direction of Granger causality. Instant. P refers to instantaneous causality P value

The interaction between Air Quality Index (AQI) and Geopolitical Risk from Health Care (GPRHC\_CHN) demonstrated differential effects across temporal scales on adjusted closing prices in the Chinese market (Table 7). Short-term analysis revealed a significant negative interaction effect ( $\beta = -9.581e-05$ ,  $P < 0.001$ ), suggesting that daily market responses are sensitive to the combined influence of air quality and healthcare-related geopolitical risks. However, this interaction effect dissipated in the long-term monthly analysis ( $\beta = 0.002$ ,  $P = 0.236$ ), indicating that the market's immediate reactions to these combined environmental and geopolitical factors tend to stabilize over longer periods. The short-term model explained a small but significant portion of daily return variance ( $R^2 = 0.003685$ ,  $F(3, 92974) = 114.6$ ,  $P < 0.001$ ), while the long-term model showed no significant explanatory power ( $R^2 = 0.03147$ ,  $F(3, 77) = 0.834$ ,  $P = 0.4793$ ). These findings suggest that while investors react to the combined impact of AQI and healthcare-related geopolitical risks in their day-to-day trading

**Table 6: Vector error correction model (VECM) results for Adj.Close**

Variable	Estimate ( $\beta^{\wedge}$ )	SE	t	p	Sig.
ECT1	-0.0528	0.0012	-44	<2e-16	***
ECT2	0.034	0.0015	22.67	<2e-16	***
ECT3	-0.026	0.0014	-18.57	<2e-16	***
Adj.Close (t-1)	0.005	0.0033	1.52	0.129734	
GDP per capita (t-1)	-0.091	0.0012	-75.83	<2e-16	***
GPRHC_CHN (t-1)	-0.01	0.0035	-2.86	0.004275	**
Return on assets (t-1)	-0.022	0.0013	-16.92	<2e-16	***
Total assets (t-1)	0.543	0.0017	319.41	<2e-16	***
AQI (t-1)	0.015	0.0015	10	<2e-16	***
Adj.Close (t-2)	-0.002	0.0033	-0.61	0.544475	
GDP per capita (t-2)	-0.012	0.0012	-10	<2e-16	***
GPRHC_CHN (t-2)	0.012	0.0035	3.43	0.000607	***
Return on assets (t-2)	0.001	0.0013	0.77	0.441756	
Total assets (t-2)	0.074	0.0017	43.53	<2e-16	***
AQI (t-2)	-0.001	0.0015	-0.67	0.504985	
Adj.Close (t-3)	0.037	0.0033	11.21	<2e-16	***
GDP per capita (t-3)	-0.066	0.0012	-55	<2e-16	***
GPRHC_CHN (t-3)	-0.003	0.0035	-0.86	0.391366	
Return on assets (t-3)	0.004	0.0013	3.08	0.002091	**
Total assets (t-3)	-0.006	0.0017	-3.53	0.000416	***
AQI (t-3)	0.002	0.0015	1.33	0.182422	

\*\*\*P<0.001, \*\*P<0.01, \*P<0.05. Results show the short-run dynamics and error correction terms for Adj.Close

**Table 7: Vector error correction model results with AQI and GPRHC\_CHN interaction**

Variable	Estimate	Std. Error	t value	P value
ect1	-0.01	0	-28.41	<0.001
Adj.Close.dl1	-0.032	0.003	-9.247	<0.001
GPRHC_CHN.dl1	-29.947	2.945	-10.17	<0.001
Return on assets.dl1	-0.712	0.088	-8.103	<0.001
AQI.dl1	-0.154	0.008	-18.778	<0.001
Adj.Close.dl2	-0.035	0.003	-10.119	<0.001
GPRHC_CHN.dl2	-6.867	2.95	-2.328	0.02
Return on assets.dl2	0.099	0.088	1.12	0.263
AQI.dl2	-0.38	0.01	-39.725	<0.001
Adj.Close.dl3	-0.009	0.003	-2.659	0.008
GPRHC_CHN.dl3	-22.269	2.95	-7.55	<0.001
Return on assets.dl3	0.055	0.088	0.626	0.531
AQI.dl3	-0.284	0.011	-25.571	<0.001

decisions, these effects are transient and do not persist in monthly trading patterns.

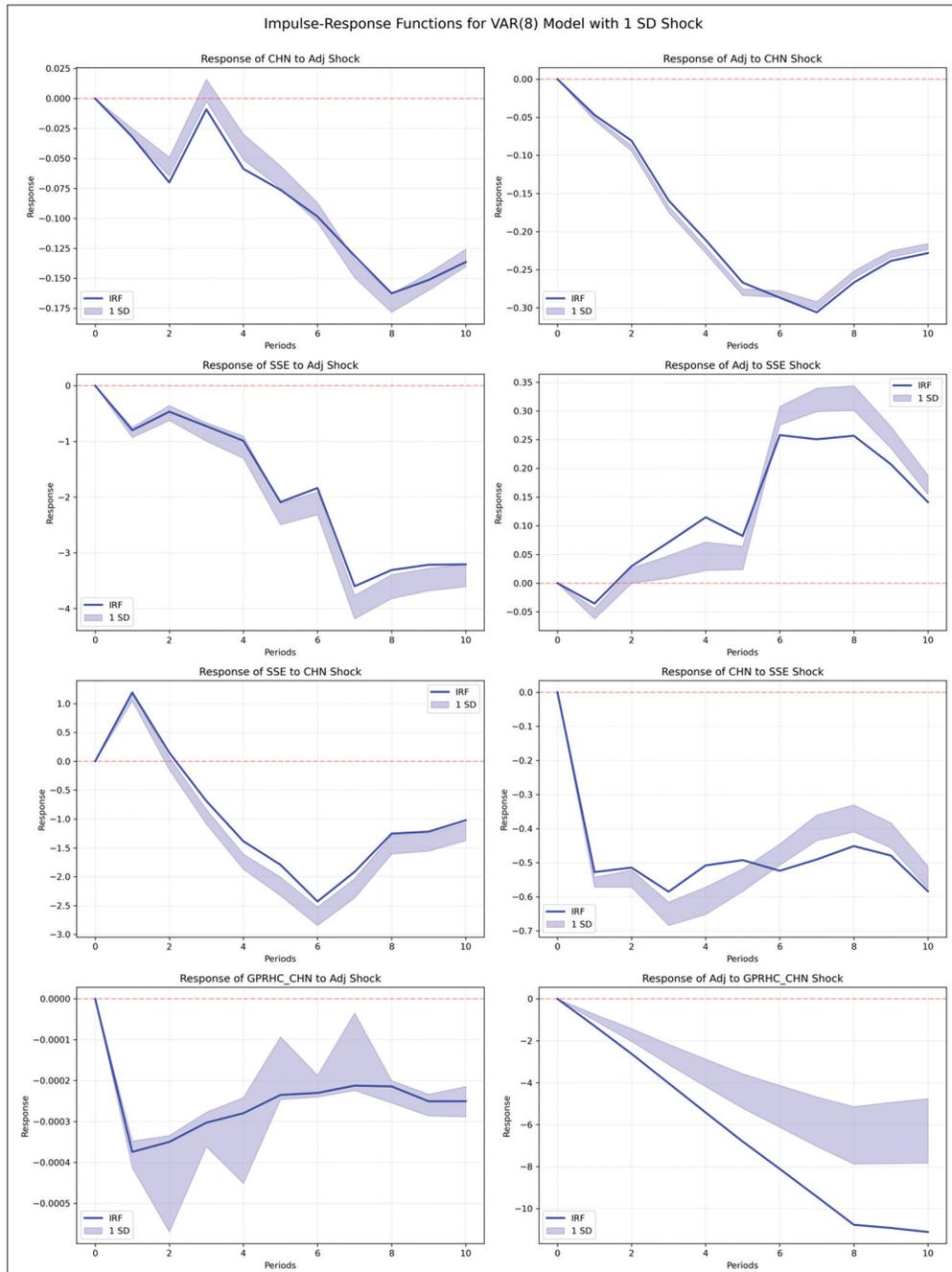
Figure 1 presents the impulse-response functions (IRFs) derived from the Vector Autoregression (VAR) model, illustrating how key variables respond over a 10-period horizon to one-standard-deviation shocks in other variables within the system. The IRFs provide valuable insights into the dynamic interactions among adjusted closing prices (Adj.Close), the Chinese economy (CHN), the Shanghai Stock Exchange Index (SSE), and geopolitical risk indicators (GPRHC\_CHN).

A significant finding is that a positive shock to the adjusted closing price leads to a notable negative response in the Chinese

economic indicator (CHN), reaching its maximum impact within the initial periods before gradually returning to equilibrium. This suggests that sudden increases in stock prices may initially signal overvaluation or speculative bubbles, prompting concerns about economic sustainability, which in turn negatively affect economic performance in the short term.

Conversely, a shock to the Chinese economy (CHN) results in a declining trend in Adj.Close, indicating that adverse economic conditions lead to decreases in stock prices. This bidirectional relationship underscores the strong linkage between macroeconomic fundamentals and stock market performance, highlighting how economic downturns can erode investor confidence and reduce market valuations.

**Figure 1:** Impulse-response functions from the VAR(8) model



The impulse responses also reveal that a shock to the Shanghai Stock Exchange Index (SSE) induces a positive and sustained increase in Adj.Close. This reflects the overall market sentiment influencing individual stock performance, where bullish market conditions elevate stock prices across the board due to heightened investor optimism and increased trading activity.

Geopolitical risk, represented by GPRHC\_CHN, exhibits a complex interaction with stock prices. A positive shock to geopolitical risk leads to an immediate and persistent negative response in Adj.Close, indicating that heightened geopolitical tensions and uncertainties adversely impact stock market performance. Investors may perceive increased risk, leading to capital outflows and declining stock valuations. The sustained nature of this effect emphasizes the long-term implications of geopolitical instability on financial markets.

Furthermore, the response of GPRHC\_CHN to shocks in Adj.Close shows a mild but statistically significant positive effect, suggesting that declining stock prices may exacerbate perceptions of economic vulnerability, potentially elevating geopolitical risk concerns. This highlights a feedback mechanism where market downturns contribute to broader risk assessments.

Overall, the impulse-response analysis demonstrates that shocks to stock prices, economic indicators, and geopolitical risks have significant and enduring effects on each other. The stock market is highly sensitive to both economic fundamentals and geopolitical developments, with implications for investors and policymakers. These dynamics underscore the importance of incorporating a multifaceted approach when assessing market conditions, considering not only financial metrics but also macroeconomic and political factors that can influence market stability and performance over time.

Figure 2 illustrates the variance decomposition results, showing the proportion of forecast error variance for the dependent variable explained by its own past values and the contributions of other variables over multiple time horizons. Initially, the forecast error

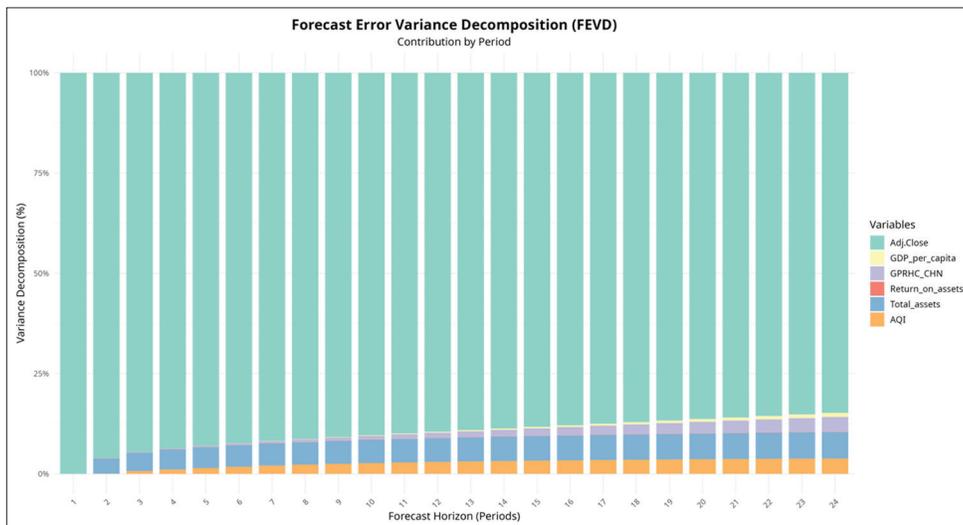
variance is predominantly driven by the variable’s own lags, reflecting a strong autoregressive structure. However, as the time horizon increases, the contributions of other variables gradually increase, indicating the development of interdependencies and the influence of external factors.

The largest contributor across time remains the variable’s own historical values, highlighting its self-reinforcing nature. Nonetheless, external factors such as economic indicators, air quality, or geopolitical risk begin to play a more significant role over longer periods, albeit to a limited extent. This dynamic indicates that short-term variability is largely self-driven, while external factors gain explanatory power as time progresses, showcasing the interconnected nature of the system.

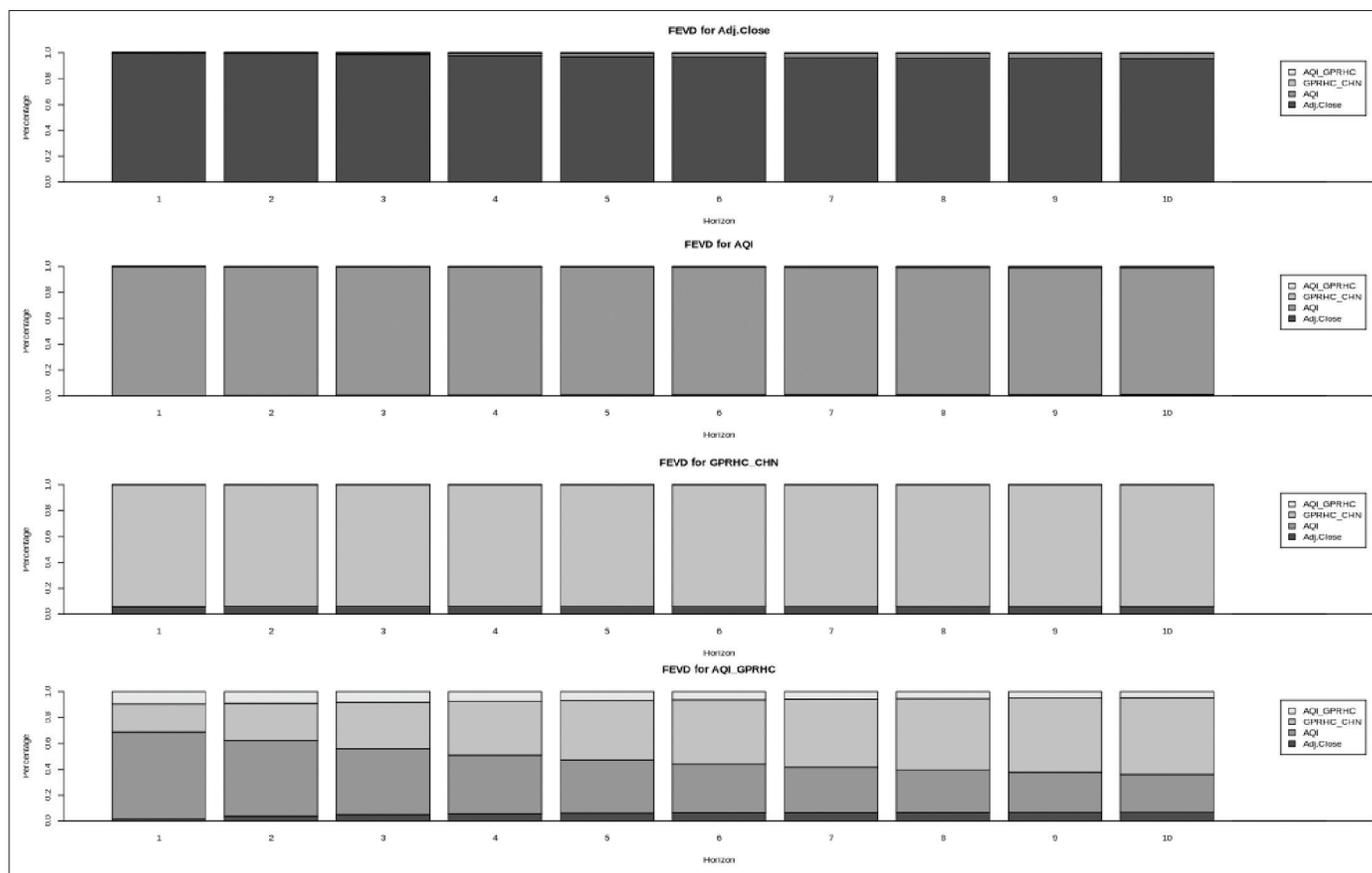
These results provide valuable insights into the temporal dynamics of the relationships between the variables. They suggest that the immediate impact of shocks is contained within the variable itself, but systemic interactions and cross-variable influences become more evident in the long term. This emphasizes the importance of considering both short-term self-dependence and long-term intervariable linkages in econometric modeling and policy formulation.

Figure 3 illustrates the Forecast Error Variance Decomposition (FEVD) results for the variables Adj.Close, AQI, GPRHC\_CHN, and their interaction term (AQI\_GPRHC) over a 10-period horizon. The decomposition reveals that the forecast error variance for Adj.Close is predominantly explained by its own past values, indicating that stock yield dynamics are largely self-driven across the observed horizon. Similarly, the forecast error variances for AQI and GPRHC\_CHN are also primarily explained by their respective historical values, with minimal influence from other variables, suggesting that air quality and geopolitical risks operate largely autonomously within the system. However, the forecast error variance for the interaction term (AQI\_GPRHC) demonstrates a more balanced contribution from multiple factors. While the interaction term’s own historical values account for a significant portion of the variance, the contributions of Adj.Close, AQI, and

**Figure 2:** Forecast error variance decomposition illustrating the contributions of each variable over different time horizons



**Figure 3:** Short-term and long-term effects in VECM



GPRHC\_CHN become more prominent over longer horizons, highlighting the interconnectedness of these variables. These results suggest that while the individual variables exhibit strong autoregressive behavior, the interaction between environmental and geopolitical factors introduces a degree of mutual influence that becomes more evident over time. This highlights the importance of considering both individual and combined effects of air quality and geopolitical risks when assessing their impact on stock yields and broader market dynamics.

## 6. CONCLUSION AND POLICY IMPLICATIONS

This study focuses on forecasting stock yield for firms, particularly through the adjusted closing price (Adj.Close), using variables such as air pollution, geopolitical risk, gross domestic product (GDP) per capita, and return on assets (ROA). Utilizing a comprehensive model, the study integrates direct, indirect, and mediating effects to analyze the dynamic relationships between these variables, providing valuable insights into how external factors shape stock performance over time. The model employed a Vector Error Correction Model (VECM) to assess both short- and long-term impacts, supported by rigorous stationarity and cointegration tests.

According to the model summary and key findings, the model’s design allows for capturing both direct effects of individual variables on stock yield and interaction effects between air quality and geopolitical risk, reflecting the complex environment

influencing stock performance. The Augmented Dickey-Fuller (ADF) and KPSS tests confirm the stationarity of the variables, meeting essential preconditions for time-series modeling. Cointegration testing further establishes a long-term equilibrium relationship among variables, demonstrating that although each variable may fluctuate in the short term, they collectively trend together over the long run. The optimal lag length of two, determined by multiple criteria, ensures the model appropriately captures temporal dependencies while preventing overfitting.

The short-term results reveal significant Granger causality between Adj.Close and both AQI and geopolitical risk, highlighting the intertwined impact of environmental and geopolitical changes on stock performance. The model indicates that deviations from the long-term equilibrium are corrected over time, with air quality and geopolitical risks exerting notable influence on stock returns in the short term. For example, AQI exhibited a consistent positive impact, suggesting that pollution levels influence stock yield sensitivity, potentially due to investor concerns regarding regulatory actions or economic slowdowns associated with poor air quality.

According to the VECM results and economic interpretation, the VECM results for Adj.Close confirm that GDP per capita and ROA are influential determinants of stock performance, particularly in their lagged forms, reflecting the delayed economic impact on market prices. The error correction terms (ECTs) demonstrate that market prices adjust gradually back to equilibrium, with negative and positive adjustments in response to deviations from the expected trajectory. The interaction between AQI and geopolitical

risk, a central component of this study, reveals significant short-term effects that diminish over longer periods. This suggests that while day-to-day trading decisions are highly responsive to combined environmental and geopolitical signals, these influences stabilize over extended intervals.

For the implications for forecasting and investment strategy, the study underscores that economic, environmental, and geopolitical factors collectively shape stock yield dynamics, offering a multifaceted approach to forecasting stock performance. The findings highlight that investors should consider both the immediate and prolonged impacts of these external factors, recognizing that while the market quickly incorporates such information in the short term, the effects may not persist monthly. For investment strategies, this suggests that adaptive responses to environmental and geopolitical risks may yield better outcomes in volatile periods, whereas focusing on fundamentals like GDP and ROA provides more reliable insights for long-term positioning.

Drawing on the empirical findings of this study and reflecting global sustainability imperatives, it is recommended that both corporations and regulatory bodies integrate Environmental, Social, and Governance (ESG) principles into their strategic frameworks. The evidence presented in this paper, particularly the significant impact of air pollution (AQI) and geopolitical risk on stock yield volatility, underscores the growing importance of non-financial factors in shaping financial performance and investor behavior. This aligns with the United Nations Sustainable Development Goals (UN SDGs), especially SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

Supporting this recommendation, Broadstock et al. (2021) demonstrate that firms in China with robust ESG performance experience greater firm value, lower stock price volatility, and improved earnings resilience—particularly during periods of market stress. In this context, companies are urged to adopt transparent environmental practices, such as disclosing emissions data, setting air pollution targets, and aligning national carbon neutrality commitments. In parallel, ESG governance should be institutionalized at the board level, where dedicated committees assess both environmental and geopolitical risk exposure. Socially responsible practices—such as ethical labor policies, community engagement, and data governance—should be tracked through formal ESG reporting mechanisms.

Ultimately, embedding ESG into corporate strategy not only enhances reputational and regulatory standing but also contributes to financial stability and long-term value creation (Aldousari and Alsabah, 2025). As this study illustrates, ESG integration is no longer optional—it is a strategic necessity in navigating the complex interplay between environmental change, geopolitical uncertainty, and market performance.

In summary, this model provides a robust framework for predicting stock yield by capturing the nuanced relationships between environmental conditions, political stability, and economic indicators. These insights not only aid investors and analysts in

refining their forecasting models but also reinforce the importance of considering diverse factors in understanding market trends and informing strategic investment decisions.

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