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Araştırma Makalesi / Research Article

The Impact of Air Pollution on the Stock Market*

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Abstract

The purpose of this study is to examine the relationship between air pollution and the BIST stock market over 10 years between March 1, 2013 and July 7, 2023. This study draws attention to the gap in the literature on air pollution and stock market performance in Türkiye. Previous studies have examined the negative effects of fine particulate matter pollution on investor psychology. These studies emphasize that air pollution reduces investor optimism, which leads to more cautious investment decisions. Decreased optimism leads to a decline in the demand for risky assets, resulting in lower returns in stock markets. In this study, to examine the relationship between air pollution and stock market performance in Türkiye, Dickey-Fuller unit root tests were applied to test the stationarity of the variables and the suitability of the data for time series analysis was evaluated. The Air Quality Index (AQI) and dummy variables representing good/bad air quality days are used as independent variables in the model. The model also includes additional dummy variables to control for seasonal and calendar anomalies (such as the January effect and Monday effect) that may affect stock returns. As a result, this study analyzes the hypothesized negative relationship between air pollution and stock returns revealing that policies to improve air quality can provide both environmental and economic benefits. The findings emphasize that governments should increase incentives to improve air quality to mitigate the negative effects of air pollution on investor sentiment and enhance market stability.

Keywords: *Air Pollution, Stock Market, Investor Mood, Regression Analysis.*

Hava Kirliliğinin Borsaya Etkisi

Öz

Bu araştırmanın amacı, 1 Mart 2013 ile 7 Temmuz 2023 tarihleri arasındaki 10 yıllık dönemde BIST hisse senedi piyasası ile hava kirliliği arasındaki ilişkiyi incelemektir. Bu çalışma, Türkiye özelinde hava kirliliği ve borsa performansına ilişkin literatürde bulunan boşluğa dikkat çekmektedir. Önceki çalışmalar, ince partikül madde kirliliğinin yatırımcı psikolojisi üzerindeki olumsuz etkilerini incelemiştir. Bu çalışmalar, hava kirliliğinin yatırımcı iyimserliğini azalttığını ve buna istinaden yatırım kararlarının daha temkinli hale geldiğini vurgulamaktadır. Azalan iyimserlik, riskli varlıkların talebinde düşüşe yol açarak hisse senedi piyasalarında getirilerin azalmasına neden olmaktadır. Bu çalışmada, Türkiye'de hava kirliliği ve hisse senedi piyasası performansı arasındaki ilişkiyi incelemek amacıyla değişkenlerin durağanlığını test etmek için Dickey-Fuller birim kök testleri uygulanmış ve verilerin zaman serisi analizi için uygunluğu değerlendirilmiştir. Modelde bağımsız değişken olarak Hava Kalitesi İndeksi (AQI) ve iyi/kötü hava kalitesi günlerini temsil eden kukla değişkenler kullanılmıştır. Model, aynı zamanda hisse senedi getirilerini etkileyebilecek mevsimsel ve takvimsel anomalileri (Ocak ayı etkisi ve Pazartesi etkisi gibi) kontrol etmek için ek kukla değişkenleri de ekleyerek etkilerini gözlemlemektedir. Sonuç olarak, bu çalışma, hava kirliliği ile hisse senedi getirileri arasındaki varsayılan negatif ilişkiyi analiz ederken, hava kalitesinin iyileştirilmesine yönelik politikaların hem çevresel hem de ekonomik faydalar sağlayabileceğini ortaya koymaktadır. Çalışmanın bulguları, hava kirliliğinin yatırımcı duyarlılığı üzerindeki olumsuz etkilerini hafifletmek ve piyasa istikrarını artırmak amacıyla, hükümetlerin hava kalitesini artırmaya yönelik teşvikleri artırması gerektiğini vurgulamaktadır.

Anahtar Kelimeler: *Hava Kirliliği, Borsa, Yatırımcı Ruh Hali, ARIMA Modeli.*

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INTRODUCTION

The Industrial Revolution made significant contributions to countries economically, socially, and politically. However, rapidly increasing industrialization and urbanization since the Industrial Revolution have put great pressure on the environment and have been a major factor in the formation of types of environmental pollution. The type of pollution that causes the greatest harm to environmental quality and human health is air pollution. Harmful substances generally consisting of waste from vehicles or industries cause air pollution (Huynh, 2020). The most common air pollutants are sulfur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), ozone, particulate recall (PM2.5) with a diameter of 2.5 micrometers or less, particle count (PM10) with a diameter of 10 micrometers or much less, and particulate recall (PM10) with a diameter of 10 micrometers or much less (Wang et al., 2021). Numerous psychological studies have found that long-term exposure to these pollutants can have effects not only on physiology but also on psychology. These studies have shown that it can lead to high levels of depression, anxiety, tension, helplessness, and anger (Guo et al., 2021; Levy & Yagil, 2011; Teng & He, 2020). Accordingly, air pollution can impair cognitive function, heighten anxiety, and cause unique psychological effects (Guo & Fu, 2019). Research has been conducted on the project in the field of finance, with the theory that air pollutants not only cause physical and psychological harm but also negatively affect financial and industrial activities, changing the overall performance of the company and the risk perceptions of traders (Giudici et al., 2019; He & Liu, 2018).

The field of traditional finance is primarily based on the idea of "Homo Economicus". Homo Economicus: It is expressed as an individual who acts with the aid of making rational decisions, can attain all applicable information, goals to maximize advantages as a purchaser and earnings maximization as a producer (Akyıldız, 2008; Müldür, 2019; Tekin, 2016). Although it is argued in the standard finance idea that traders are rational in the markets, it has been viewed that psychological elements play a necessary function in funding choices in the actual buying and selling world (Xu et al., 2021). Researchers in the field of finance have reported that people exhibit irrational behaviour in capital markets, influenced by emotional, psychological, sociological and behavioural reasons. Thus, behavioural finance science began to develop with the analysis of rational and irrational behaviours in markets (Çetiner et al., 2019). Behavioural finance no longer focuses on the assumption that buyers make rational decisions, unlike ordinary finance theories. Instead, behavioural finance researchers argue that investment decisions are made based on individuals' emotions and moods rather than being rational. Investors' moods can be affected by environmental factors and change investor behaviour in financial markets (Eyüboğlu & Eyüboğlu, 2018; Tufan & Sarıçiçek, 2013). In this context, there are studies in the literature investigating the effects of environmental factors such as heat, daylight duration, moon phases and humidity on stock markets. These studies highlight the importance of environmental factors on trading behaviour (Gao et al., 2020). There are findings that air pollution, especially one of the environmental stress factors, can trigger mood changes and affect investment decisions (Gao et al., 2020; Teng & He, 2020; Xu et al., 2021). Therefore, air pollution can be considered an important factor that can affect the stock market, and it does this through two channels.

The first channel is the physiology and psychology of investors (Song et al., 2023). According to research, air pollution disrupts mood even after short-term exposure due to its negative psychological effects. Thus, cortisol secretion, known as the stress hormone, concentrates in the body of individuals and reduces the likelihood of risk-taking behaviour

(Qifang et al., 2020). In other words, there is a negative relationship between air pollution and stock returns. Air pollution causes investors to avoid risk and reduces stock purchases (Guo et al., 2021). In addition, studies indicate that exposure to air pollutants affects the stock market by causing complexity in investors' trading decisions, as it causes effects such as reduced cognitive ability and impaired concentration (Liu et al., 2021). Therefore, severe air pollution can affect investor sentiment, making the stock market feel pessimistic in terms of earnings prospects. This may cause stock returns to decrease (Wu et al., 2018). The basis of these studies is the perception that investors tend to sell stocks during periods of high-risk aversion, and this results in negative returns. In this context, the literature emphasizes that air pollution is two channels that affect investors' risk-taking behaviour and commercial decisions. These channels show that both cortisol levels and mood channels are inversely related to air quality and risk-taking (Guo et al., 2021).

The second channel is political management and government intervention. Bernauer and Koubi (2009) mentioned in their study that the more democratic a country is, the lower its SO2 value. At the same time, it has been stated that SO2 is readily available and can be controlled with effective methods, although it is costly, this depends on the will of political leaders. On the other hand, there are studies in the literature arguing that polluting businesses in some developing countries increase local environmental pressures, often by bribing policymakers and practitioners.

The newfound insight into how air pollution affects the stock market adds valuable knowledge to the current understanding of the various factors influencing financial markets. Conventional financial theories have mainly concentrated on economic indicators like interest rates, inflation, and corporate earnings as the primary factors influencing stock market fluctuations. Nevertheless, by including environmental elements, especially air pollution, in the examination, a fresh viewpoint is offered, enhancing the current research. This method recognizes the wider environment in which financial markets function, understanding that environmental factors can greatly impact investment activities, business results, and overall market trends.

This study adds to a developing branch of research that combines environmental economics and finance by analyzing how air pollution affects stock market performance. It disputes the common belief that environmental factors are insignificant to financial markets, suggesting they are crucial elements that can impact market volatility and investor sentiment. This input is especially important when considering global environmental issues, as the economic consequences of pollution are becoming more apparent. The research expands financial analysis and demonstrates the significance of incorporating environmental sustainability in financial decision-making through empirical evidence. Moreover, studying the effects of air pollution on the stock market has practical significance for policymakers and investors alike. This research emphasizes the financial repercussions of inadequate environmental management for policymakers, indicating that enhancing air quality may benefit financial markets. Investors could use knowledge of the connection between air pollution and market performance to develop sustainable investment strategies that combine financial gain with environmental stewardship. Therefore, this addition to the body of knowledge not just enhances scholarly comprehension but also provides practical recommendations to inform upcoming policy and investment choices.

Additionally, these studies were conducted only for developed countries, and developing countries were ignored (Ebaid, 2010). Therefore, it is thought that this study will contribute to the literature by examining the impact of air pollution on the developing Borsa Istanbul Türkiye with current data. Since the current period of 10 years is to be considered in this study, data starting from 1 March 2013 is used. The next section of the study provides a chronological list of studies examining the link between air pollution and the stock market. The next section includes the data set and econometric method used for empirical analysis. Finally, the conclusion is presented in the light of the data.

1. LITERATURE REVIEW

The intricate relationship between the environment and human behaviour has garnered considerable attention in academic discourse, particularly in the context of environmental degradation and its broader societal impacts. Among the various environmental factors, air pollution stands out as a critical concern due to its pervasive influence on public health, economic activities, and behavioural patterns. The growing awareness of air pollution's far-reaching consequences has led to an increasing body of research that examines its implications across multiple disciplines, including finance. While the health and economic effects of air pollution have been extensively studied, there has been a notable surge in interest since 2015 in understanding how air pollution impacts financial markets, a field that previously received comparatively less attention.

The seminal work of Saunders (1993) marked an early exploration into the intersection of environmental conditions and financial markets. Saunders' research, which analysed the relationship between local weather conditions in New York and stock returns on the New York Stock Exchange from 1927 to 1989, revealed a significant correlation between weather and market performance. Specifically, the study found that stock returns tended to be lower on cloudy days compared to sunny days, suggesting that atmospheric conditions can influence investor behaviour and market outcomes. This pioneering study laid the groundwork for subsequent investigations into the effects of environmental factors, including air pollution, on financial markets.

Building on this foundation, Levy and Yagil (2011) conducted a pivotal study that extended the inquiry into the mood effects of air pollution on economic activities. Their research focused on the relationship between air pollution, as measured by the Air Quality Index (AQI), and stock returns across four major stock exchanges in the United States during the period from 1997 to 2007. The findings revealed a negative correlation between air pollution levels and stock returns, indicating that higher pollution levels were associated with lower stock market performance. Furthermore, Levy and Yagil observed that the strength of this relationship diminished as the geographical distance between the stock exchange and the polluted area increased, suggesting a spatial dimension to the impact of air pollution on financial markets.

In a subsequent study, Levy and Yagil (2013) expanded their analysis by incorporating additional explanatory variables, such as moon phases, cloud cover, and seasonal effects, to explore the effects of air pollution on stock markets across different continents, including the USA, Canada, the Netherlands, China, and Australia. Their empirical results confirmed the negative relationship between air pollution and stock returns across these diverse geographical contexts, further substantiating the global relevance of this phenomenon.

Lepori (2016) contributed to the burgeoning literature by investigating the relationship between air pollution and stock returns in the Italian stock market from 1989 to 2006. His findings corroborated the earlier studies, demonstrating that air pollution negatively affects stock returns, possibly through its influence on investor mood. Lepori's work emphasised the psychological pathways through which environmental conditions can impact financial decision-making, highlighting the importance of considering non-economic factors in financial market analyses.

In the context of emerging markets, Demir and Ersan (2016) examined the impact of air pollution on the Turkish stock market, specifically focusing on Borsa Istanbul. Their analysis encompassed data from the provinces of Istanbul, Ankara, and Izmir, given their significance in terms of investor numbers and account values. Covering the period from 2008 to 2013, the study found a statistically significant and negative relationship between air pollution levels and stock returns, reinforcing the notion that environmental degradation can have tangible economic consequences even in developing economies.

Li and Peng (2016) extended the exploration of this relationship to China, investigating the effect of depressive moods induced by air pollution on stock returns using daily air pollution data from 2005 to 2014. Their empirical research uncovered a complex relationship, with a simultaneous negative and a two-day-lagged positive correlation between air pollution levels and stock returns. This nuanced finding suggests that while the immediate impact of air pollution on stock markets may be negative, subsequent adjustments in investor behaviour may partially mitigate this effect over time.

An et al. (2018) examined the impact of air quality on the stock market through investor sentiment using the daily closing prices of the Shanghai Composite Index and Shenzhen Component Index in China in the 2014-2015 period. In the findings, it was determined that while air quality did not have a significant effect on stock market volatility, investor sentiment had a significant effect. Eyüboğlu and Eyüboğlu (2018) analyzed the effect of air quality, which may affect investor behaviour, on stock returns in the 2007-2016 period by using four Borsa Istanbul indices. According to the findings, it has been determined that air pollution has a statistically significant and negative effect on the returns of the Services Index but also has a delayed effect on the returns of the BIST-100, Industrial and Financial Indexes. Wu et al. (2018) used data from listed enterprises in six heavy pollution industries in China in 2014-2016 to investigate the impact of air pollution on the stock yield of these industries. According to empirical results, it has been determined that heavy air pollution has a significant negative impact on stock yield.

Andrikopoulos et al. (2019) investigated the impact of weather-induced mood changes on stock and foreign exchange markets. For this, they analyzed the stock indices of New York and London between 2002 and 2018 according to seven weather variables. According to the results of the analysis, they found that weather conditions did not significantly affect foreign exchange and stock returns. Teng and He (2020) examined the effects of the difference between air quality and environmental awareness on investor trading behaviour and stock price using pollution and stock market data in China for the period 2005-2017. As a result, they determined that increased pollution awareness caused a negative mood, which in turn led to a decrease in investors' desire to trade. Ullah and Öztürk (2020) examined the impact of stock market and exchange rate volatility on environmental pollution in Pakistan during the period 1985-2018. According to the findings, short-term results revealed that positive and negative shocks in stock markets reduce carbon emissions. They also concluded that while positive shocks in exchange rate volatility reduce carbon emissions in Pakistan, negative shocks in exchange rate volatility have a positive and significant effect on carbon emissions.

Ding et al. (2021) examined the relationship between air pollution and stock returns in China between 2009 and 2016. In the analysis, daily weather conditions such as temperature, precipitation, sunshine duration, wind speed, and humidity for 1929 days and data from 1719 companies in 221 cities were used. As a result of the study, they found that companies located in cities with higher levels of air pollution had lower stock returns. Kirk-Reeve et al. (2021) examined the effects of air pollution in China on the stock returns of companies traded on both the Shanghai Stock Exchange and the Shenzhen Stock Exchange in the 2015-2018 time period. They found that stocks most sensitive to air pollution produce lower risk-adjusted returns than stocks less sensitive to air pollution. Meza et al. (2021) analyzed the impact of the stock market on carbon emissions in Asian economies in the period 1995-2019. According to the findings of the research, it has been observed that the stock market has a positive impact on carbon emissions in Asia in the short and long term. They also found that positive changes in the stock market significantly increase carbon emissions in the long run.

Xu et al. (2021) examined the impact on public awareness of pollution and stock returns using hourly PM2.5 data from 25 monitoring sites in Beijing and 10 monitoring sites in Shanghai in 2013-2016. The analysis concluded that when air pollution spreads over large areas, the weather of that day and successive air pollution days have a significant impact on stock returns, thanks to investors' awareness of air pollution. Therefore, investors argued that on hazy days, their decisions were biased. Guo et al. (2021) empirically examined the relationship between air pollution and investor trading behaviour using data from more than 3000 investors and a total of 372310 individual transactions in China between 2016 and 2018. As a result, they determined that there is a significantly negative relationship between air pollution and investor trading behaviour. In this regard, they found that while air pollution reduces investors' purchasing tendency, it increases investors' selling tendency. Wang (2022) analyzed the relationship between air quality and stock returns by selecting 8 different sectors in Beijing and Shanghai between the 2014-2021 period. The study first examined whether air pollution is political or economic. As a result of the analysis, people who are politically exposed to air pollution attribute this to industries that pollute the environment; In economic terms, it has been determined that there are heterogeneous responses from industrial stock returns to air quality within the same city.

He et al. (2023) investigated the relationship between air pollution and stock market performance using panel data of 1344 A-share companies in China during the 2013-2019 period. According to the findings, it has been determined that air pollution has a different effect on stock market performance depending on the number of analysts, company size, ownership type and industry type. It has been concluded that air pollution has a greater negative impact on stock performance, especially in small and non-state-owned companies. Song et al. (2023) examined the relationship between air quality and stock returns using daily trading data between 2014 and 2021. As a result of the analysis, the coefficient values between air quality and stock for the tourism, iron and steel and automobile industries turned from positive to negative with the deterioration of air quality; It has been determined that the coefficients in the wind energy, hydropower, thermal energy, environmental protection and medical equipment sectors have changed from negative to positive. In this context, it has been determined that there are asymmetric and heterogeneous relationships between air quality and stock returns.

In summary, the extant literature provides robust evidence of the negative impact of air pollution on stock market returns across various geographical regions and market contexts. These studies underscore the importance of considering environmental factors in financial analyses and highlight the need for continued research to unravel the complex mechanisms through which air pollution influences investor behaviour and market outcomes. The present study builds upon this growing body of knowledge by investigating the specific relationship between air pollution, as measured by the Istanbul Air Quality Index (AQI), and stock returns in Borsa Istanbul, offering new insights into the intersection of environmental degradation and financial market performance.

This work advances the integration of environmental concerns, particularly air pollution, into financial market analysis, which adds to the body of literature. Economic variables like inflation and interest rates have long been emphasised in financial literature as the main forces influencing stock market performance. This study does, however, draw attention to the behavioural and psychological effects of environmental stressors, such as air pollution, on stock market volatility, returns, and investor decision-making. This work broadens the scope of financial analysis and offers insightful empirical and policy-related information by tying environmental economics and financial markets together.

2. METHODOLOGY

In the study, daily return data on Istanbul's air quality index (AQI) and BIST 100 (XU100), BIST Service (XUHIZ) and BIST Financial (XUMAL) indices between the period of 01.03.2013-07.07.2023 were used. In the analysis, data on air quality are taken from the National Air Quality Monitoring Network of the Ministry of Environment, Urbanization and Climate Change of the Republic of Türkiye BIST index data was obtained from the Central Bank of the Republic of Türkiye EVDS

In the study, return rates are calculated separately for each index according to the formula in equation (1) by using the daily closing prices of each index.

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \tag{1}$$

R_t is the logarithmic return of an index in period t; P_t refers to the closing value of an index in period t and P_{t-1} refers to the closing value of an index in period t-1. After the return calculation, the days must be determined as healthy or unhealthy according to the air quality index values for each trading day. Air quality in Türkiye is calculated with the parameters PM10, $PM_{2.5}$, SO_2, CO, NO_2, NOX, NO and O_3. For PM_{10}, a value between 0-50 is considered healthy air, and a value between 51-500 is considered unhealthy air. In this study, PM_{10} was preferred as the parameter in air quality index measurement.

In the study, the relationship between weather-related connections was also discussed with the help of regression analysis. The reason why the regression method is preferred is that this method is advantageous compared to other econometric methods. Time series regression is particularly useful for forecasting future values based on past trends and patterns. Therefore, provides more reliable and effective results than other methods.

The model used to examine the relationship between air pollution and stock returns is shown in equation (2).

$$R_t = \beta_0 + \beta_1 AQI_t + \varepsilon_t \tag{2}$$

The model used to examine the relationship between air pollution and stock returns is shown in equation (2).

In the equation, R is the stock return; Pol is a pollution effect with two alternatives: AQI_d and AQI_k. AQI_k, original air quality; AQI_d refers to the dummy variable that takes the value of 1 on healthy days and 0 on unhealthy days. t is the time. The coefficient in this model is predicted to be statistically significant and negative. When creating equation 3, we took into account various important studies from the literature that have investigated how air quality impacts stock market returns. An example is the study by Heyes et al. (2016), which shows that environmental elements, like air pollution, can have a notable influence on financial markets by influencing investor emotions and thinking skills, resulting in changes in stock outcomes. Another relevant study is done by Li and Peng (2016), indicating that high levels of air pollution have a noticeable effect on stock market volatility, especially on days with significantly polluted air. These studies, along with others, offer a strong empirical basis for incorporating AQId and AQIk into the model, guaranteeing that the selected variables are firmly supported by prior academic research. Therefore, the equation is supported not only in theory but also by an increasing amount of research that highlights the importance of air quality in influencing stock market behaviour. Referencing previous studies confirms alignment with existing research findings and introduces new perspectives by examining the impacts of both continuous and dichotomous air pollution measurements on stock returns.

$$R_t = \beta_0 + \beta_1 AQI_t + \beta_2 DMon + \beta_3 DJan + \beta_4 DSum + \beta_5 R_{t-1} + \varepsilon_t \tag{3}$$

DMon, DJan, and DSum are dummy variables in this equation. It has a value of 1 on Mondays, in January, and throughout the summer, and 0 otherwise. The delayed period, t-1, is represented. The coefficients in the equation are predicted to have the signs and $\beta_4 = 0$, respectively.

The analysis in this case concentrated on three models. The models in equations (4), (5), and (6) are displayed.

$$R_{XU100t} = \beta_0 + \beta_1 AQI_t + \beta_2 DMon + \beta_3 DJan + \beta_4 DSum + \beta_5 R_{t-1} + \varepsilon_t \tag{4}$$

$$R_{XUHIZt} = \beta_0 + \beta_1 AQI_t + \beta_2 DMon + \beta_3 DJan + \beta_4 DSum + \beta_5 R_{t-1} + \varepsilon_t \tag{5}$$

$$R_{XUMALt} = \beta_0 + \beta_1 AQI_t + \beta_2 DMon + \beta_3 DJan + \beta_4 DSum + \beta_5 R_{t-1} + \varepsilon_t \tag{6}$$

3. EMPIRICAL RESULTS

Table 1 includes the descriptive analysis of dummy variables included in the model to examine potential effects such as BIST indices, air quality index, Monday effect, and January and summer seasons. When looking at the skewness values, it is interpreted that all variables are skewed to the right because they are greater than 0. Kurtosis values of all variables except AQIk and K3 are greater than 3, indicating that they follow a leptokurtic distribution. In addition, the

Jarque-Bera test statistic is significant at the 1% level and shows that not all variables comply with normal distribution.

Table 1: Descriptive statistics of the variables

Variable	Maximum	Minimum	Std.Dev.	Skewness	Kurtosis	Jarque-Bera
XU100	11554.46	875.8100	2115.588	2.533987	8.637458	5787.233***
XUHIZ	9620.150	653.1700	1723.443	2.614962	9.099408	6501.215***
XUMAL	9186.720	1053.200	1589.323	2.677245	9.291945	6874.264***
AQI_d	330.1300	7.100000	30.90029	1.821699	8.617357	4514.659***
AQI_k	1.000000	0.000000	0.485131	0.500717	1.250718	409.1638***
K1	1.000000	0.000000	0.395863	1.544005	3.38950	975.1808***
K2	1.000000	0.000000	0.277428	2.999682	9.998093	8556.752***
K3	1.000000	0.000000	0.428902	1.199296	2.438312	611.1728***

Note: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

There are three alternative regression analysis models were used to assess the BIST 100, service, and financial indices calculated in Borsa Istanbul independently. But before applying the coefficient estimation, to ensure stationary we applied the Dickey-Fuller unit root test.

The Dickey-Fuller test is a statistical test used in time series analysis to test for the presence of a unit root, which is an indication of non-stationarity in a time series dataset. The test checks the null hypothesis that a unit root is present against the alternative hypothesis that the time series is stationary (no unit root). According to the null hypothesis, there is a unit root (non-stationary).

Table 2: Dickey-Fuller Test Results for Unit Root (Stationary Test)

Variable	Df Test p-value	Differenced DF Test	Results	Unit Root
XU100	0.9835	0.0000***	Stationary	No Unit Root
XUHIZ	0.9964	0.0000***	Stationary	No Unit Root
XUMAL	0.9383	0.0000***	Stationary	No Unit Root
AQI_d	0.0000***	0.0000***	Stationary	No Unit Root
AQI_k	0.0000***	0.0000***	Stationary	No Unit Root

Note: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

To examine equation 2, the relationship between air pollution and indices was also discussed with the help of regression analysis. To do that we need to separate it into two parts as AQId and AQIk.

Table 3: Forecasting Results of the Equation 2

AQI_K
R_{XU100t}=7.634065-0.2813095AQI_K+ε_t (512.89) (-11.63)
R_{XUHIZt}=7.316463-0.3084085AQIK+ε_t (457.77) (-11.87)
R_{XUMALt}= 7.63159 -0.1890533AQIK+ε_t (649.36) (-9.90)
AQI_D
R_{XU100t}=7.767757-0.0046258AQI_D+ε_t (339.43) (-12.21)
R_{XUHIZt}= 7.463178-0.0050742AQI_D+ε_t (303.75) (12.48)
R_{XUMALt}= 7.722345-0.0031263AQI_D+ε_t (427.16) (-10.45)

According to Table 3 regression analysis, all the models are statistically significant due to their t-tests and for the real value of AQI (AQI_K). There is an inverse relationship between air quality and XU100, XUHIZ, and XUMAL.

While we are analyzing the relationship of the dummy of the AQI (AQI_D) and indices, there is an inverse relationship between air quality and XU100, XUHIZ, and XUMAL.

In Table 4, we can see that there is a unit root for some of the series, like XU100, XUHIZ, and XUMAL. Thus, we need to make them stationary to avoid bias or spurious regression. One or more differentiating operations can be performed to make the series stationary. Differentiated series are generally stationary. As you can see, when differentiation occurred, all the series have turned to stationary. If all the series are stationary, we can apply the ARIMA. ARIMA models are powerful tools for forecasting and analyzing non-stationary time series, as long as they are correctly specified and validated. According to the analysis results, we have six different outcomes to investigate. Three of them belong to the original air quality variable amongst the others, and the rest of them belong to the dummy air quality variable.

Table 4: Regression Equations 4, 5 and 6 (In the Context of Original Air Quality (AQI_d) Equation)

Dependent Variable: R_{XU100}		
Variable	**Coefficient**	**Probability**
XU100(-1)	1.008888	0.268
AQIk	-0.0048744***	0.000
K1 (Monday Effect)	2.6136	0.482
K2 (January Effect)	0.0532346	0.278
K3 (Summer Effect)	-0.1051008***	0.000
R^2	0.0654	
F	31.79	
Dependent Variable: R_{XUHIZ}		
Variable	**Coefficient**	**Probability**
XUHIZ(-1)	1.500723	0.158
AQI_k	-0.005301***	0.000
K1 (Monday Effect)	3.544046	0.213
K2 (January Effect)	0.0592488	0.261
K3 (Summer Effect)	-0.1174352***	0.001
R^2	0.0678	
F	33.05	
Dependent Variable: R_{XUMAL}		
Variable	**Coefficient**	**Probability**
XUMAL(-1)	0.599089	0.344
AQI_k	-0.0033525***	0.000
K1 (Monday Effect)	1.15716	0.724
K2 (January Effect)	0.0538764	0.164
K3 (Summer Effect)	-0.0792959***	0.002
XUMAL(-1)	0.599089	0.344
AQI_k	-0.0033525***	0.000
R^2	0.0516	
F	24.72	

Note: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

According to Table 4, there is an inverse relationship between original air quality and the Summertime effect with all indices (R_{XU100}, R_{XUHIZ} and R_{XUMAL}) and this relationship is statistically significant. We can say in the summertime R_{XU100}, R_{XUHIZ} and R_{XUMAL} are decreasing. On the other hand, if there is an increase in the air quality index which is referred to as "bad quality" there is a decrease in the return of XU100, XUHIZ and XUMAL.

Table 5: Regression Prediction Results For Equations 4,5 and 6 (In the context of Dummy Air Quality (AQI_d) Equation)

Dependent Variable: R_{XU100}		
Variable	**Coefficient**	**Probability**
XU100(-1)	1.296278	0.153
AQI_d	-0.031801***	0.000
K1 (Monday Effect)	2.7000097	0.471
K2 (January Effect)	0.0567721	0.246
K3 (Summer Effect)	-0.1123749***	0.001
R_2	**0.688**	
F	**33.58**	

Dependent Variable: R_{XUHIZ}		
Variable	**Coefficient**	**Probability**
XUHIZ(-1)	1.960773*	0.064
AQI_d	-0.3490229***	0.000
K1 (Monday Effect)	3.544046	0.213
K2 (January Effect)	0.0631948	0.229
K3 (Summer Effect)	-0.1261113***	0.000
R_2	**0.0727**	
F	**35.59**	
Dependent Variable: R_{XUMAL}		
Variable	**Coefficient**	**Probability**
XUMAL(-1)	0.7402816	0.241
AQI_D	-0.2154608***	0.000
K1 (Monday Effect)	1.238721	0.707
K2 (January Effect)	-4.040178	0.145
K3 (Summer Effect)	-0.0835817***	0.001
R_2	**0.0528**	
F	**25.30**	

Note: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

In Table 5, all the analyses were conducted in the frame of air quality as a dummy variable. For R_{XU100}, R_{XUHIZ} and $R_{XUMAL,}$ the air quality index and summer effect are statistically significant. The direction of the relationship is inverse for these variables. It means in the bad air quality all the indices that we took into consideration are decreasing. Also, summertime negatively returns. For all three indices, in the summertime, there is a negative relationship with the returns. On the other hand, the lagged value of XUHIZ is also statistically significant and has an inverse relationship with the dependent variable.

4. CONCLUSION

The intricate relationship between environmental conditions and human behaviour has long been a subject of scholarly inquiry. This study contributes to the burgeoning literature by exploring the correlation between stock returns in Borsa Istanbul and air pollution, specifically as measured by the Istanbul Air Quality Index (AQI). The investigation focuses on the BIST 100, BIST Service, and BIST Financial indices over ten years, from March 1, 2013, to July 7, 2023. The data utilised in this analysis were sourced from reliable institutions, namely, the National Air Quality Monitoring Network and the Central Bank of the Republic of Türkiye EVDS. By categorising days based on PM10 readings into those with healthy or unhealthy air quality, the study sought to discern the impact of air pollution on the daily return rates of the aforementioned indices.

The methodological approach employed in this research was rigorous, utilising time series regression analysis to examine the connection between stock returns and air pollution. The model incorporated lagged periods and dummy variables for specific temporal factors, including Monday, January, and the summer months, alongside pollution variables. Stationarity of the data was ensured through the application of Dickey-Fuller unit root tests, and the regression models were independently applied to each index, allowing for a comprehensive analysis of the relationships in question.

The empirical findings, although exhibiting modest statistical significance, consistently indicate an inverse relationship between the indices studied (RXU100, RXUHIZ, and RXUMAL) and air quality. Specifically, poor air quality, as captured by the AQI and its dummy variables, was found to exert a significant negative effect on the returns of these indices. The results suggest that as air quality deteriorates, there is a corresponding decrease in stock market returns, a pattern that holds across all three indices analysed. This negative correlation underscores the influence of environmental factors on investor behaviour, suggesting that worsening air quality may lead to more cautious or adverse stock purchasing decisions.

Further analysis revealed a potential lagged effect of air pollution on stock returns, particularly concerning the XUHIZ index. The study found that an increase in air pollution (as indicated by a higher AQI) on a given day was associated with a statistically significant decrease in the stock returns of the XUHIZ index on the following day. This finding suggests that investors may adjust their portfolios in response to air quality changes, potentially leading to profit opportunities based on anticipated market reactions to environmental conditions.

The results of this study align with previous research by Levi and Yagil (2011), Lepori (2016), Eyüboğlu and Eyüboğlu (2018), Teng and He (2020), Ding et al. (2021), Xu et al. (2021), and Guo et al. (2021), as well as He et al. (2023), which have similarly identified a relationship between environmental factors and financial market performance. The negative association between air quality and stock returns observed in this study reinforces the notion that environmental degradation can have tangible economic consequences, influencing investor sentiment and market dynamics.

However, the overall lack of statistical significance in some instances suggests that the relationship between air pollution and stock returns may be more complex and context-dependent than initially anticipated. While the study provides valuable insights through the application of robust statistical techniques, including Dickey-Fuller tests and regression coefficients, it also highlights the limitations of the current analysis. Notably, this research does not fully disentangle whether the observed relationship—whereby index returns increase with improving air quality and decrease with deteriorating air quality—is driven by the physical health of investors or by the psychological well-being associated with cleaner air. Future studies should aim to clarify this distinction to better understand the underlying mechanisms at play.

In conclusion, this study underscores the importance of considering environmental factors, such as air pollution, in financial market analyses. The findings suggest that air quality can significantly influence stock returns, thereby offering new avenues for research into the economic impacts of environmental degradation. Moreover, these results have important policy implications, indicating a need for greater attention to the economic costs of air pollution in the context of financial markets. Future research should continue to explore these dynamics, particularly in different geographical and market contexts, to develop a more nuanced understanding of the intersection between environmental and economic factors.

YAZAR BEYANI

Araştırma ve Yayın Etiği Beyanı

Bu çalışma bilimsel araştırma ve yayın etiği kurallarına uygun olarak hazırlanmıştır.

Etik Kurul Onayı

Bu araştırma için etik kurul onayı gerekmemektedir.

Yazar Katkıları

Yazarlar çalışmaya eşit oranda katkıda bulunmuştur.

Çıkar Çatışması

Yazarlar açısından ya da üçüncü taraflar açısından çalışmadan kaynaklı çıkar çatışması bulunmamaktadır.

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