Journal of Cleaner Production 454 (2024) 142294

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Stock market response to natural disasters: Does corporate sustainability performance make difference?

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ARTICLE INFO

Handling editor: Xin Tong

Keywords:
Abnormal returns
Earthquake
Stock market
Sustainability performance
Türkiye

ABSTRACT

This study aims to examine the short-term price reactions of the stocks listed on Borsa Istanbul (BIST) after the severe earthquake of February 6, 2023, that happened in the southeastern region of Türkiye covering 11 provinces and causing more than 50,000 fatalities. Using a sample of 450 companies listed on the BIST All Index, this study estimates the abnormal returns (ARs) of stocks by employing an event study methodology. Using BIST 100 companies as a sub-sample, this study also explores whether sustainability performance creates resilience against downside risk after the earthquake. The results of the market model and the mean-adjusted model show that on the event day, most of the sectors had negative and significant ARs, while only the non-metal mineral products had positive and significant ARs. Most of the sectors continued to decline in the following 10 days except basic metal and non-metal mineral products sectors. The telecommunications sector was the most negatively affected sector in both models after the event day as it has underperformed in ensuring uninterrupted access to communication. The findings also indicate that firms in the financial sector that have higher sustainability performance are more resilient in responding to the disaster.

1. Introduction

Many countries have witnessed dramatical damages caused by natural disasters over the last decades. These catastrophes act as non-financial shocks and cause severe destruction that lead to remarkable impacts on financial markets, and economic units across sectors (Pagnottoni et al., 2022). Among natural disasters, earthquakes have special characteristics. It is difficult to predict them, and they occur suddenly, causing substantial economic harm and loss of life and triggering sizeable damages not only to individuals and communities, but also to firms depending on the seismic scale of the earthquake, its magnitude, and distance to the epicenter (Wanga et al., 2020).

On financial markets perspective, many earthquake studies focus on the nexus between the disaster and stock returns, discussing the reflection of natural hazards on short-run stock price reactions based on the view that stock markets are efficient (Tao et al., 2019; Tao, 2015; Yamori and Kobayashi, 2002; Worthington and Valadkhani, 2004). Most of these studies employed event study to measure the effects of earthquakes on stock market indices or specific-sectors, revealing that the negative sentiment due to bad mood affects the behavior of market participants, and influences asset pricing (Bourdeau-Brien and Kryzanowski, 2017; Ferreira and Karali, 2015). Many of these works claim that abnormal returns (ARs) provide an expression of the expected variations in the profitability of firms that may arise from the occurrence of the earthquake.

Most of the prior studies examine the impact of earthquakes, focusing mainly on developed markets i.e., Japan, US, Australia. There are relatively few studies held on emerging markets (Bolak and Süer, 2008; Javid, 2007). In this context, Türkiye offers an interesting setting for exploring the impact of earthquakes since it is situated in a region where seismic waves are common, and it suffered severe earthquakes in the past. Most of these earthquakes caused a high number of fatalities and significant losses in the country. However, the twin earthquakes that occurred on the southern and southeastern regions of Türkiye on February 6, 2023, were the strongest one ever recorded in the last century with a moment magnitude scale of 7.7 and 7.6 on the Richter scale and more than 50,000 people lost their lives. The earthquakes severely hit 11 provinces as shown in Fig. 1, where around 14 million people reside including 2 million Syrian refugees. These provinces account for 17% of Türkiye's population, 15% of its agricultural output and 9% of its industrial output (United Nations, 2023). According to the official figures, 110,000 people were injured, 173,000 houses were

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https://doi.org/10.1016/j.jclepro.2024.142294
Received 20 June 2023; Received in revised form 17 March 2024; Accepted 20 April 2024
Available online 21 April 2024
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destroyed, 200,000 severely, and 300,000 partially damaged. Direct damage is officially estimated at USD 103.6 billion (Turkish Presidency, 2023).

Turkish capital markets, particularly Borsa Istanbul (BIST), was also affected from the earthquake. The prices of many stocks dropped after the disaster. BIST-100 Index fell nearly 5% on February 6, extending sharp losses in the aftermath of the earthquake. Circuit breakers were issued for many stocks, including large-caps, suspending trading in those shares. Stock market officials suspended trading on February 8 for five days, until the evening of February 14. BIST 100 Index fell 16% from February 6 to 8, with almost half of that decline coming early February 8 before the trading was halted. After the earthquake, the prices of many stocks dropped, while the prices of some shares increased due to the multiple expectations of the investors.

This study aims to examine the impact of the twin devastating earthquakes in Türkiye on the stock returns of companies listed on BIST to measure how the effect of the disaster is reflected in the short-run stock price changes. There are relatively few studies that investigates the reaction of stock markets to earthquakes in emerging markets, and most of these studies mainly estimate the effect of earthquakes on insurance, construction, and real estate sectors (Shelor et al., 1992; Tao, 2015; Yamori and Kobayashi, 2002). This research makes contributions in three-folds. First, it identifies the most affected sectors in the earthquake on the event day, and after the event day to allow firms to make a proper risk assessment for seismic risk management. By being aware of this relationship, investors could take better decisions. Second, the research explores whether the earthquake affects ARs of the firms by using an event window to assess the immediate and delayed impact of the disaster on different sectors. Finally, the study compares the ARs of the firms that are members of the BIST Sustainability Index and those that are not. This evidence provides insights for firms to decide on whether they should enhance their sustainability performance.

The remaining part of the study is organized as follows: The next section reviews the relevant literature and develops the hypotheses. Section Three presents the data and methodology, while Section Four provides the empirical findings. The paper concludes with a discussion of the practical implications of the study, and avenues for future research.

2. Literature review and hypotheses development

2.1. Theoretical framework and literature review

Natural disasters have significant impacts on the changes in stock market behavior. Policymakers and market players are highly concerned about the impact of these disasters on capital markets, and this concern stimulates academic studies on the nexus between natural disasters and capital markets. In this context, most of the studies held on the impact of large earthquakes focus on the US and Japanese stock markets. There are relatively few studies on emerging markets that have more volatile market conditions (Bolak and Süer, 2008; Javid, 2007).

There are two prominent theories that support sustainable business practices as empowering conditions for companies to navigate turbulent times such as natural disasters: crisis theory and stakeholder theory. Crisis theory asserts that individuals have to adapt to crises and this adaption requires high skills in making decisions to avoid risks (Shrivastava, 1993). Crises highlight the aspirations of shareholders, and investors. They try to avoid any losses during the crises. Proactive thinking play a vital role during these episodes, particularly natural disasters, to reduce the severe consequences of the event (Al-Dabbagh, 2020). To create a favorable perception on the preferences of investors, companies take actions to enhance sustainability performance during normal times, resulting in lower financial and market losses during the crises. This philosophy provides a golden opportunity for firms to protect their resilience during the disasters.

The stakeholder theory provides a perspective on the behavior of companies toward the demands of stakeholders. It argues that companies must prioritize the interests of stakeholders by committing to social and environmental matters for executing their responsibility towards society (Gallego-Álvarez and Pucheta-Martínez, 2020). On this respect, firms are primarily concerned with dominant stakeholders i.e., shareholders and investors. They seek to meet their aspirations to reduce agency costs and lead to improved investor confidence through sustainability activities (El Ghoul et al., 2011; Sharfman and Fernando, 2008). This approach helps firms manage the severity of disaster and its negative effects on financial performance, enhancing the expectations of investors for the market performance and recovery of firms during the disaster (Velte, 2022).

The earthquakes have different devastating effects on companies. These effects are more pronounced for certain industries, leading to divergent swings in investor sentiments on capital markets across sectors depending on the intensity of the hazard. Most of the prior studies held on the developed markets have shown that large earthquakes have detrimental effects particularly on real estate and insurance companies. Shelor et al. (1990) examined the impact of the 1989 California earthquake on real estate and insurance firms. They reported a significant negative and a positive stock price response, respectively, due to riskiness of property ownership and financing in the earthquake-prone areas.

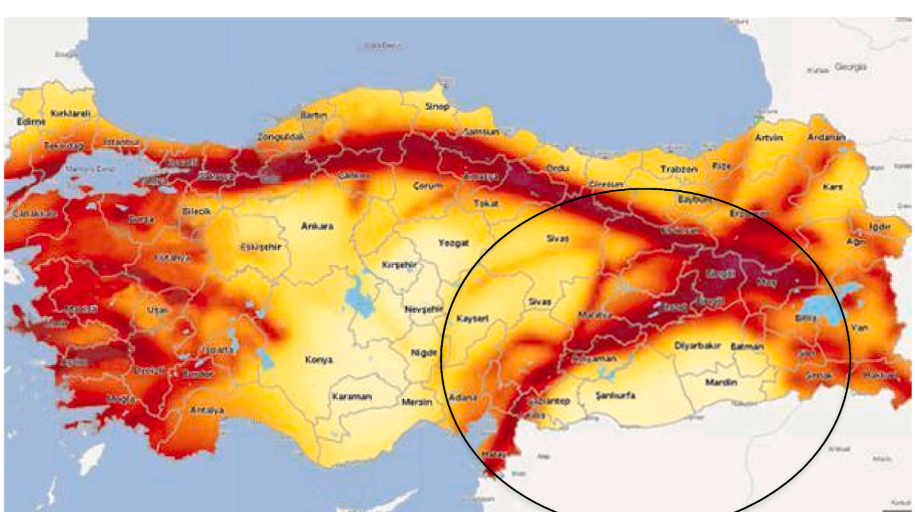

Fig. 1. The earthquake-affected provinces in Türkiye (AFAD, 2018).

Yamori and Kobayashi (2002) investigated the effects of the 1995 Tokyo earthquake on 13 insurance firms. They find negative AR of −2.7% on the event day and significant cumulative abnormal returns (CARs) up to four days after the event. They indicated that investors had serious concerns about the potential impact of the expected earthquakes on the financial condition of the insurance firms. Tao (2015) measured the effect of the 2011 Tohoku earthquake on the Japanese market and found a significant negative effect on the Nikkei 225 at the event day of 2.77%, negative CAR of 5.85% on the following four days after the disaster and −3.52% ARs on the event period [0; +10]. However, Tao (2013) found insignificant ARs on Chinese stock market indices for the Lushan earthquake. He claimed that the market is confident for the emergency response capability of the government. Worthington and Valadkhani (2004) examined the impact of natural disasters on the Australian stock market. They argue that natural disasters have a significant negative impact (average abnormal returns of 0.38%) on stock prices on the event day with some adjustment on the subsequent days. They claimed that it may take some days before a fuller information set is obtained after the natural disaster. Lamb and Kennedy (1997) examined the impact of the 1994 Northridge earthquake on the insurance companies. They revealed significant positive ARs for exposed insurers and insignificant negative ARs for unexposed insurers after the disaster.

Some studies measure the impact of the earthquakes on stock markets by using a large coverage to reflect the diverge evidence across emerging and developed markets. Scholtens and Voorhorst (2013) examined the effects of 100 earthquakes that occurred in 21 countries from 1974 to 2011 on the stock markets. They found that the earthquakes had significant negative effects on the value of stocks. They also indicated that there is no difference in the responses to the most and least severe earthquakes or to those in high-income and low-income countries. Ferreira and Karali (2015) explored the effects of the major earthquakes on the returns of aggregate stock market indices in 35 markets over the last two decades and they identified that global financial markets are resilient to shocks caused by earthquakes even if these are domestic. The evidence in these studies suggest that large earthquakes in either developed or emerging markets have an immediate, but not prolonged impact on capital markets. The impact of the earthquakes is usually reflected in short-run stock price changes but does not have a pervasive negative impact on capital markets in the long-run. However, the negative impact of the large earthquakes on stock markets is relatively higher in emerging markets due to volatile market conditions in these countries.

Drawing on this fact, emerging markets offer a distinctive setting for analyzing the impact of large earthquakes on stock markets due to their peculiar market structure. Studies held on emerging countries provide insightful evidence on the responsiveness of the market players to natural disasters. Javid (2007) explored the impact of the October 8, 2005, earthquake on the sixty companies listed on Karachi Stock Exchange, revealing that the disaster had both positive and negative effects. He stated that there is an increase in the stock return of the cement, steel, food, and banking sectors, indicating that the investors have expectations of the upcoming demand of investment in these sectors. There is also no significant increase in volatility, as the investors are certain about the future outlook. Bolak and Süer (2008) examined the influence of Marmara earthquake on the returns of the financial companies listed on BIST, indicating that the earthquake produced negative and significant ARs for insurance firms, while the response of the banks is negative but insignificant. They asserted that the rapid depletion of surplus accounts fostered by the earthquake caused investors to discount the stock value of the insurance firms in the market.

Considering the geographical and economic importance of Turkiye in emerging markets, this study draws on the behavioral strand of finance and analyzes the impact of the large earthquake occurred on February 6, 2023, on investor sentiments and stock market outcomes to provide new evidence into the dynamic connectedness between asset prices and investor sentiment in the wake of natural disasters.

2.2. Hypotheses development

2.2.1. Earthquake and abnormal returns

Natural disasters and their severe damage to the economy lead companies to assess the impact of the disasters on the stock markets. The psychological impact of an unexpected disaster may also trigger the rationality that characterizes investors and leads them to react immediately, causing price volatility (Carter and Simkins, 2004). On this respect, individual and institutional investors are interested in knowing how their portfolio will behave when it faces a severe natural disaster. Most of the studies discussed in the previous section provide evidence that stock markets usually respond negatively to natural disasters on the event day, and they usually have a significant and negative AARs. However, some authors indicate that after a devastating disaster ARs did not stay significant on the following days (Lamb and Kennedy, 1997; Yamori and Kobayashi, 2002). Thus, cumulative average abnormal returns (CAARs) may be expected to be statistically equal to zero in the next 5–10 days after the disaster. Therefore, we propose the following hypotheses.

H1a. The earthquake does not affect the AARs of companies.

H1b. The earthquake does not affect the CAARs of companies.

2.2.2. Earthquake and corporate sustainability performance

Sustainability performance of companies provides a competitive advantage that enhances financial and market performance, particularly in tightened economic situations. On this respect, it may provide resilience for firms in turbulent times such as natural disasters in protecting their valuation. Earthquakes have detrimental effects on people and companies. Although the influence of natural disasters on the preferences of investors have been investigated, the role of corporate sustainability performance (CSP) on these preferences has not yet been explored. How companies perform on sustainability matters indicates their survival ability after the disaster. Thus, it is important to understand how CSP influences investor confidence at the post-disaster period, and whether it provides insurance-like protection against social and economic downturns during the disaster. In this sense, CSP may serve as a promoter in shaping the post-earthquake investor behavior in the normalization of ARs. Thus, we propose the following hypothesis.

H2. Corporate sustainability performance creates resilience against downside risk in earthquake.

3. Data and methodology

3.1. Data

Our sample covers 450 companies listed on the BIST All Index. Table 1 shows the distribution of the firms across industries. We collected the daily prices of companies listed on BIST from February 1 to 24, 2023. To make a deeper analysis, we grouped 330 of 450 stocks into 19 sectors to reach a more refined outcome. We aim to identify the most influenced sectors to get an overview after the earthquake. Furthermore, we analyzed BIST 100 Index companies as a sub-sample since most of the firms included in the BIST SI are listed on this benchmark index that represents 70% of the market capitalization in BIST.

Broadstock et al. (2021) indicates that during the market-wide financial crisis, stocks with higher CSP are less affected. The main reason may be the perception of investors to see CSP as a sign of potential market success and/or risk aversion in times of crisis. Building on this argument, we analyze whether CSP decreases the risk during the disaster led by the earthquake by playing a smoothing role in managing the impact of the disaster. Following prior studies (Aksoy et al., 2020; Ates, 2020), we used BIST Sustainability Index (BIST SI) calculated by Refinitiv to measure the CSP of the Turkish companies.

The BIST SI serves as an indicator for institutional investors to show

Table 1
The AARs, CAARs, and t-statistics (Market Model).

Sector	Number of firms	AARs	t_{AAR}	CAARs	t_{CAAR5}	CAARs	t_{CAAR10}	Critical t-values
Banks	12	0.29	0.55	0.20	0.13	−3.26	−1.40	2.20
Basic Metal	18	1.66	1.63	3.86	1.38	11.82	4.64*	2.11
Chemical, Petrol, Plastic	31	−1.00	−1.58	−4.72	−3.60*	−0.49	−0.28	2.04
Construction	12	−1.77	−1.27	−10.92	−7.14*	−6.47	−2.41*	2.20
Electricity	19	−1.14	−2.44*	−8.92	−5.98*	−4.53	−2.64*	2.10
Food, Beverage	24	0.56	0.77	−8.13	−7.26*	−3.55	−2.30*	2.07
Information Technology	27	−0.86	−1.61	−8.61	−6.84*	−3.19	−1.92	2.06
Insurance	6	−3.28	−2.31*	−14.45	−3.65*	−11.41	−3.10*	2.57
Metal Products, Mach.	30	−1.78	−5.23*	−6.65	−5.00*	−1.68	−0.77	2.05
Non-Metal Min. Product	17	7.00	5.30*	24.26	4.20*	31.64	5.70*	2.12
Real Estate Inv. Trust	36	−1.31	−3.25*	−9.09	−8.35*	−1.60	−1.10	2.03
Retail Trade	20	−0.77	−1.02	−7.77	−4.31*	−3.67	−2.29*	2.09
Technology	28	−0.69	−1.28	−8.43	−6.86*	−3.38	−2.10*	2.05
Telecommunications	2	1.69	5.97*	−9.29	−31.05*	−17.68	−17.75*	12.71
Textile, Leather	17	−1.82	−3.37*	−11.04	−4.98*	−7.28	−2.29*	2.12
Tourism	9	−2.76	−3.62*	−7.70	−2.83*	−8.57	−3.16*	2.31
Transportation	9	−0.37	−0.28	−10.79	−3.61*	−5.26	−1.61	2.31
Wood, Paper, Printing	13	−2.17	−1.68	−11.48	−4.74*	−7.57	−2.13	2.18
Other	147	−1.67	−5.73*	−7.87	−9.55*	−4.09	−5.41*	1.98

Note: The critical z-value = 1.96.

their dedication to companies that effectively manage ESG issues with exemplary performance. In 2013, BIST entered into an agreement with Ethical Investment Research Services Limited (EIRIS) to establish BIST SI. EIRIS was responsible for screenings BIST-listed firms according to the international sustainability criteria. The BIST SI was launched in 2014. EIRIS initially assessed companies in the BIST 30 Index in 2014 and then firms in the BIST 50 Index in 2015. Starting from 2016, EIRIS extended its coverage to encompass both firms in the BIST 50 Index and voluntary participants from the BIST 100 Index. BIST signed a new agreement in 2021 and switched from EIRIS to Refinitiv to get service for the BIST SI. Since our dataset covers only the year 2023, we used the data of Refinitiv in this study.

3.2. *Methodology*

3.2.1. *Event study*

In the literature, one of the widely used approaches to examine the effect of natural disasters on the stock markets is event study. Following prior studies (Shelor et al., 1990; Tao et al., 2019), we conducted event study to measure the impact of the earthquake on the stock price reactions in BIST. To calculate ARs, we used two different models, i.e., market model and mean-adjusted model. Between different models, both the bias and precision of the expected return measure may differ, and this may affect the characteristics of ARs (Yilmaz et al., 2020). For robustness check, we ran the mean-adjusted model, and we reported the results in the Appendix.

The event timeline is presented in Fig. 2. The earthquake occurred on February 6, 2023, at 4:17 a.m. The stock market was closed from February 8 to 14. The event date is represented by *t*. We use shorter event window so that other firm-specific events do not affect the results. A review of the literature shows that in the studies where daily data are used, the estimation period tends to range from 100 to 300 days, while the event period is between 2 and 121 days (Chang et al., 2018).

We first measure ARs by the market model. In the market model, we regress stock returns of each firm to the returns of the market portfolio, i.e., BIST 100 Index. Then, we use estimated α_i, and β_i values to predict the expected returns of the firm on a given day as a function of the market performance on that day. After that, we calculate AR as per Equation (1):

$$AR_{it} = R_{it} - E(R_{it}) \tag{1}$$

$$R_{it} = \alpha_i + \beta_i R_{mt} \tag{2}$$

Where, R_{mt} is the return of the BIST 100 Index, and α_i, and β_i are the estimated parameters of the Ordinary Least Squares (OLS) regression over 250 trading days, from t = −260 (T2) to t = −10 (T1), relative to the event date.

In the mean-adjusted model, we calculate the ARs according to Equation (3).

$$AR_{it} = R_{it} - \overline{R} \tag{3}$$

$$\overline{R} = \frac{1}{(T2 - T1 + 1)} \sum_{t=T1}^{T2} R_t \tag{4}$$

Since we have N firms, the ARs are averaged across all firms in one sector for each separate day t during the event window as in Equation (5):

$$AAR_t = \frac{1}{N} \sum_{i=1}^{N} AR_{it} \tag{5}$$

Following Brown and Warner (1985), we then apply a conventional test statistic based on the standardised abnormal return. The test statistic for testing the null hypothesis that the AAR (across the N firms) on day t is zero is given by Equation (6):

$$t_{AAR} = \frac{AAR_t}{(\sigma_{AAR})/\sqrt{N}} \tag{6}$$

$$\sigma^2_{AAR} = \frac{1}{N-1} \sum_{i=1}^{N} (AR_i - AAR_t)^2 \tag{7}$$

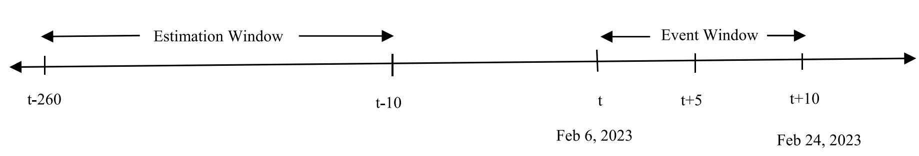

Fig. 2. Event timeline.

Cumulative abnormal returns (CARs) summarize the impact of the earthquake over the five-day (+5) and ten-day (+10) period following the event day. K is the number of the ARs. We calculated the firm-specific CARs, the cumulative average abnormal returns (CAARs) and their test statistics as in Equations (8)–(10), respectively.

$$CAR_i = \sum_{t=1}^{K} AR_{it} \tag{8}$$

$$CAAR = \frac{1}{N} \sum_{i=1}^{N} CAR_i \tag{9}$$

$$t_{CAAR} = \frac{CAAR_t}{(\sigma_{CAAR})/\sqrt{N}} \tag{10}$$

$$\sigma^2_{CAAR} = \frac{1}{N-1} \sum_{i=1}^{N} (CAR_i - CAAR)^2 \tag{11}$$

For Hypothesis 1, we tested whether the AAR_t and $CAAR_t$ at time t is equal to zero. If the test statistic is greater than its corresponding critical values (for $N \geq 30$, z-value; $N < 30$, t-value), we reject the null hypothesis, indicating that there is a non-zero AR associated with the event and the earthquake affects the ARs and CARs of the companies. To test Hypothesis 2, we created two groups; companies included in the BIST SI and companies not included in the BIST SI. We compared the AARs and CAARs of these two groups.

4. Empirical findings

The AARs that are calculated for 19 sectors by using the market model are presented in Table 1. We first interpreted the results of the sectors having a sample size of less than 30 by comparing the test statistics with the critical t-values. On the event day ($t = 0$), four sectors, i. e., electricity, insurance, textile, and tourism, experienced negative AARs that were significantly different from zero at the 0.05 level. Only two sectors, non-metal mineral products and telecommunications, had significant and positive AARs. Then, we compared the test statistics of the chemical, petroleum, plastic, metal products and machinery, real estate investment trust, and other sectors with the critical z-values since the sample size for these sectors is above 30. On the event day ($t = 0$), metal products and machinery, real estate investment trusts, and others experienced negative AARs that were significantly different from zero at the 0.05 level. The results do not support Hypothesis 1a, indicating that the earthquake affects the AARs of companies in different sectors. This outcome is in line with findings of Sakariyahu et al. (2023).

To explore how quickly the market absorbed the news, two longer event windows, from the event date to 5 days following the event ($t = +5$) and from the event date to 10 days following the event ($t = +10$) were defined. For these event windows, we calculated the CAARs. Table 1 shows that over the 5-day and 10-day windows, most of the sectors experienced negative CAARs that were significantly different from zero at the 0.05 level. On the other hand, the non-metal mineral products sector continuously had positive and significant CAARs, while the basic metal sector had a positive CAAR only on 10-day event window. The results do not support Hypothesis 1b, indicating that the earthquake affects the CAARs of the companies. The results also indicate that the stock prices of the firms in the telecommunications sector significantly declined following the event day. One reason for the negative CAARs in the telecommunications sector is that GSM mobile operators responsible for ensuring uninterrupted access to communication and the internet were unable to maintain reliable service, further hindering rescue and relief efforts during the disaster (Turkish Presidency, 2023). The earthquake destroyed or damaged many buildings, resulting in a serious need for cement and iron to rebuild those places. This need led to a sharp increase in the basic metal and non-metal mineral products sectors. Although the firms in these sectors are expected to show the same reaction to the earthquake, we witnessed a delayed reaction of basic metal sector. One explanation for this finding is that some of the factories in the basic metal sector are in the earthquake provinces, i.e., Hatay and Osmaniye. Due to the earthquake, production in these provinces was temporarily stopped for a short period of time.

The AARs of firms in the BIST 100 Index during the event window are shown in Table 2. To test whether the effect of the earthquake on the stock prices makes any difference if the firm is a member of the BIST SI, we created two groups. On the event day ($t = 0$), 43 firms that are not listed on the BIST SI experienced negative AARs that were significantly different from zero ($t_{AAR} = -1.980$, $p < 0.05$). On the other hand, 49 firms listed on the BIST SI had positive AARs that were insignificant ($t_{AAR} = = 0.74$, $p > 0.05$). For longer event windows, the CAARs of the companies listed on the BIST SI were negative and insignificant. These results indicate that the firms that are included in the BIST SIare resilient in terms of stock price responses to the disaster on the event day, supporting our second hypothesis (H2).

The stock price behavior of financial and non-financial companies included in the BIST SI can be different after the disaster. Therefore, we created two groups i.e., financial companies and non-financial companies. We first compared the test statistics with the critical z-values for non-financial companies ($N \geq 30$). Then, we compared the test statistics with the critical t-values since the sample size is below 30 for financial companies in Table 2. Among the firms in the BIST SI, 9 financial companies experienced negative AARs ($t_{AAR} = -0.10$, $p > 0.05$) and 40 non-financial companies had positive AARs ($t_{AAR} = 0.79$, $p > 0.05$) that were all insignificant. On the other hand, among the BIST 100 firms that are not in the BIST SI, financial firms experienced significant and negative AARs ($t_{AAR} = -6.06$, $p < 0.05$), while non-financial firms had negative but insignificant AARs ($t_{AAR} = -0.82$, $p > 0.05$). These results support our second hypothesis (H2), indicating that the companies that adopt sustainability practices are more resilient in absorbing the detrimental effects of natural disasters. Table A4 shows the exemplary activities of the selected firms that are in the BIST SI in 2022.

For our second hypothesis (H2), we also conducted a one-way ANOVA analysis to test whether there exists any difference for ARs, CAR5s and CAR10s between two groups i.e., firms that are included in the BIST SI and others. The assumption of normality and the assumption of homogeneity of variance must be met before running an ANOVA. The normality test results asserted that the distributions were not normal. The Levene statistics showed that the data did not violate the assumption of homogeneity of variances. Despite the non-normal nature, a one-way ANOVA test was performed since there is an adequate number of observations, particularly for non-financial group. The results for the non–parametric Kruskal–Wallis test were also provided for robustness check. Table 3 shows the results for the one-way ANOVA and Kruskal-Wallis tests.

One-way ANOVA revealed that there is a statistically significant difference in the mean AR ($F(1,17) = 12.038$, $p = 0.003$) and CAR5 ($F(1,17) = 29.962$, $p = 0.000$) results between two groups for financial companies. A Kruskal-Wallis test was also performed on the results of AR, CAR5 and CAR10. The differences between the rank of AR ($H(1, n = 18) = 7.587$, $p = 0.006$), and CAR5 ($H(1, n = 18) = 12.008$, $p = 0.001$) results were significant. For financial companies, we obtained similar results by using the non-parametric Kruskal–Wallis test which suggests that our findings are robust to the method chosen. We also performed a one-way ANOVA and Kruskal-Wallis tests for non-financial firms. Only the differences between the rank of AR ($H(1, n = 73) = 4.529$, $p = 0.033$) results were significant for Kruskal-Wallis test. This finding shows a difference in ARs between two groups i.e., non-financial firms that are included in the BIST SI and others. These results support our second hypothesis (H2), indicating that the companies that adopt sustainability practices are more resilient in absorbing the detrimental effects of natural disasters.

There are many studies that examine the impact of natural disasters on insurance companies in the literature. In the previous analysis, we

Table 2
The AARs and CAARs of the BIST 100 companies (Market Model).

		Number of firms	AARs	t_{AAR}	CAARs	t_{CAAR5}	CAARs	t_{CAAR10}	Critical t-values
Firms included in the BIST SI	Financial	9	−0.06	−0.10	1.27	0.77	−3.22	−1.45	2.31
	Non-financial	40	0.38	0.79	−2.99	−1.78	−0.31	−0.16	2.02
	All firms	49	0.30	0.74	−2.21	−1.56	−0.84	−0.52	2.01
Firms not included in the BIST SI	Financial	10	−2.93	−6.06*	−10.73	−8.22*	−4.76	−2.68*	2.26
	Non-financial	33	−0.57	−0.82	−3.13	−1.31	2.10	0.74	2.04
	All firms	43	−1.12	−1.98*	−4.90	−2.55*	0.51	0.22	2.02

Note: The critical z-value = 1.96.

Table 3
One-way ANOVA and Kruskal-Wallis tests results of the BIST 100 companies (Market Model).

	One-way ANOVA	Kruskal-Wallis
Financial Companies		
AR	F (1,17) = 12.038, p = 0.003***	H (1, n = 18) = 7.587, p = 0.006**
CAR5	F (1,17) = 29.962, p = 0.000***	H (1, n = 18) = 12.008, p = 0.001***
CAR10	F (1,17) = 0.116, p = 0.737	H (1, n = 18) = 0.000, p = 1.000
Non-Financial Companies		
AR	F (1,72) = 1.317, p = 0.255	H (1, n = 73) = 4.529, p = 0.033**
CAR5	F (1,72) = 0.002, p = 0.962	H (1, n = 73) = 0.551, p = 0.458
CAR10	F (1,72) = 0.516, p = 0.475	H (1, n = 73) = 0.111, p = 0.740

Note: *p < 0.10, **p < 0.05, ***p < 0.01. F, Sig.

identified that the earthquake affects the AARs of insurance companies (Table 1). In this part, we searched for whether the CSP creates resilience against downside risk after the earthquake for the insurance companies. The AARs in the event window for insurance companies that are both included in the BIST SI and not included in the BIST SI are presented in Table 4. On the event day (t = 0), all insurance companies experienced negative AARs. When we compared t_{AAR} with the critical t-values since the sample size is below 30 for the insurance companies, we found that the earthquake negatively but insignificantly affected the AARs of these companies and the BIST SI membership does not make any difference.

4.1. Cross-sectional model

It is possible that the results for ARs and CARs may be due to other factors such as firm size, firm leverage, sector, and BIST SI membership for the BIST 100 companies. To measure the sensitivity of the results, we used the cross-sectional model shown in Equations (12)–(14) to explain the size of AR and CARs.

$$AR_i = \beta_0 + \beta_{SIZE}D_{SIZE} + \beta_{LEV}D_{LEV} + \beta_{FIN}D_{FIN} + \beta_{BISTSI}D_{BISTSI} + \beta_{FIN}D_{FIN} * \beta_{BISTSI}D_{BISTSI} + \varepsilon_i \tag{12}$$

$$CAR5_i = \beta_0 + \beta_{SIZE}D_{SIZE} + \beta_{LEV}D_{LEV} + \beta_{FIN}D_{FIN} + \beta_{BISTSI}D_{BISTSI} + \beta_{FIN}D_{FIN} * \beta_{BISTSI}D_{BISTSI} + \varepsilon_i \tag{13}$$

$$CAR10_i = \beta_0 + \beta_{SIZE}D_{SIZE} + \beta_{LEV}D_{LEV} + \beta_{FIN}D_{FIN} + \beta_{BISTSI}D_{BISTSI} + \beta_{FIN}D_{FIN} * \beta_{BISTSI}D_{BISTSI} + \varepsilon_i \tag{14}$$

The variables for the regression equation are as follows.

AR_i: Abnormal return on event date for firm *i*
$CAR5_i$: Cumulative abnormal return over a 5-day window from day 0 through day 5.
$CAR10_i$: Cumulative abnormal return over a 10-day window from day 0 through day 10.
SIZE: Firm size calculated as the natural logarithm of the total assets of the firm.
LEV: Financial leverage of the firm calculated as the total liabilities divided by total assets.
FIN: A binary variable that equals 1 if the company is in the financial sector, and 0 otherwise.
BISTSI: A binary variable that equals 1 if the company is included in BIST SI, and 0 otherwise.

The interaction term (*FIN * BISTSI*) is also included in the model to test whether the effect of CSP on ARs and CARs are different for financial companies.

The ordinary least squares (OLS) regression results are reported in Table 5. The LEV and FIN have negative and significant effects on AR, CAR5 and CAR10. The BIST SI has positive and insignificant effects on AR and negative and insignificant effects on both CAR5 and CAR10. On the other hand, the interaction term has positive and significant effect on AR, CAR5 and CAR10. These results show that for financial companies, CSP, which is proxied by the BIST SI membership, created resilience against downside risk during the earthquake on the event day, over a 5-

Table 5
The cross-sectional model results of the BIST 100 companies (Market Model).

Variables		AR	CAR5	CAR10
SIZE	Firm Size	−0.002	1.099	0.394
		(0.286)	(0.945)	(1.100)
LEV	Financial	−3.236	−14.524	−19.998
	Leverage	(1.370) **	(4.536) ***	(5.276) ***
FIN	Sector	−2.815	−10.105	−9.836
		(1.172) **	(3.879) ***	(4.512) **
BISTSI	BIST SI	1.295	−0.311	−1.013
	Membership	(0.915)	(3.028)	(3.522)
InteractionTerm	FIN * BISTSI	3.306	15.893	11.708
		(1.824) *	(6.037) ***	(7.023) *
Constant		1.120	−13.256	5.997
		(4.605)	(15.243)	
F (5, 86)		2.90	3.59	3.50
Adj R-squared		0.095	0.125	0.121
Number of obs		92	92	92

Note: Standard errors are in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

Table 4
The AARs and CAARs of the insurance companies (Market Model).

Insurance Companies	Number of firms	AARs	t_{AAR}	CAARs	t_{CAAR5}	CAARs	t_{CAAR10}	Critical t-values
Insurance companies included in the BIST SI	3	−1.47	−0.86	−9.85	−3.10	−6.34	−1.52	4.30
Insurance companies not included in the BIST SI	3	−5.09	−2.59	−19.06	−2.77	−16.48	−3.33	4.30

day and 10-day period. These findings support our second hypothesis (H2) and are in line with the results obtained by using ANOVA and Kruskal-Wallis tests.

4.2. Robustness check

For robustness check, we calculated the AARs for 19 sectors by using the mean-adjusted model that assumes the mean return of a given security is constant through time (MacKinlay, 1997). Although the mean-adjusted model is simple, Brown and Warner (1985) found that it often yields similar results to those of more sophisticated models. On the other hand, the estimated values of ARs by the market model and the mean-adjusted model may differ for a couple of reasons. First, the market model assumes a linear relationship between the stock returns and the market index (MacKinlay, 1997). If the actual relationship is nonlinear, the model may not accurately capture the stock behavior. Second, omitted variables in the model can result in specification errors. Finally, the calendar time effect is a potential problem with the market model.

Table A1 in the Appendix reports the results of the mean-adjusted model. We first interpreted the results of sectors having a sample size of less than 30, by comparing the test statistics with the critical t-values. Then, we compared the test statistics of chemical, petroleum, plastic, metal products and machinery, real estate investment trust, and other sectors with the critical z-values as the sample size is above 30. The results show that, on the event day ($t = 0$), thirteen sectors experienced negative AARs that were significantly different from zero at the 0.05 level. Only one sector, i.e., non-metal mineral products, had positive AARs that were significantly different from zero. These results do not support Hypothesis 1a, indicating that the earthquake affects the AARs of firms except five sectors i.e., basic metal, food and beverage, telecommunications, construction, and transportation on the event day. The results in Table A1 do not support Hypothesis 1b, indicating that the earthquake affects the CAARs of the companies.

We also calculated the AARs of firms listed on the BIST 100 Index by employing the mean-adjusted model. The results are shown in Table A2 in the Appendix. On the event day ($t = 0$), both the firms in the BIST SI and the firms not included in the BIST SI experienced negative AARs that were significantly different from zero at the 0.05 level. On the other hand, for longer event windows ($t = +10$), CAARs were negative but insignificant for all companies. These results do not support our first and second hypothesis.

The results for the AARs of the insurance companies that are in the BIST SI and those that are not in the BIST SI are presented in Table A3 in Appendix. On the event day ($t = 0$), all insurance companies experienced negative AARs. When we compared t_{AAR} with the critical t-values since the sample size is below 30 for the insurance companies, we found that the earthquake negatively but insignificantly affected the AARs of these companies and the BIST SI membership does not make any difference. These results are consistent with the market model.

5. Conclusions and discussions

Large earthquakes cause immense hardship to individuals and businesses in terms of casualties and immediate economic damages, usually leading to a correction to the local stock markets. Thus, there are often gainers and losers out of these devastating events. This study examines how the effects of one of the largest earthquakes ever recorded in the eastern and southeastern regions of Türkiye on February 6, 2023, at 4:17 a.m. spread across various sectors in the stock market. It merely provides evidence on the short-run market reaction of the stock prices of the Turkish companies listed on Borsa Istanbul to the earthquake on 19 sector indices. The study also explores whether corporate sustainability performance creates resilience against downside risk in the earthquake. We used event study and the market model, and the mean adjusted model to measure AARs and CAARs at the event day and over a ten-day event window following the disaster.

The results of the market model show that on the event day, out of 19 sectors, seven of them had negative and significant AARs while the mean-adjusted model reveals that on the event day, out of 19 sectors, 13 of them had negative and significant ARs. Non-metal mineral products is the only sector that reacted positively to the disaster on the event day in both models. The magnitude of the negative AARs varies across sectors. Most of the sectors continued to decline in the following 10 days except basic metal and non-metal mineral products sectors. The telecommunications sector was the most negatively affected sector in both models after the event day. One reason is that GSM mobile operators responsible for ensuring uninterrupted access to communication were unable to maintain reliable service, further hindering rescue efforts during the disaster.

Finally, the stock price behavior of companies that are included in the BIST SI show different patterns after the disaster. The findings for the market model indicate that BIST 100 firms included in the BIST SI were not significantly affected by the earthquake, while the results for the mean-adjusted model show that all BIST 100 firms were significantly and negatively affected. The insurance companies were negatively but insignificantly affected by the disaster in both models and BIST SI membership did not make a difference. The cross-sectional model shows that the joint effect of the BIST SI membership and being in the financial sector has significant and positive effect on AR, CAR5 and CAR10. This finding indicates that the firms in the financial sector that adopt sustainability practices are more resilient in managing the destructive effects of the disaster.

5.1. Implications of the study

This research has important implications for companies and investors. Türkiye faces a high probability of earthquakes, and the frequency of natural disaster increases. First, the commitment of companies to sustainability can have a range of implications during and after a disaster. Sustainable companies enjoy stable valuations due to the preference of investors for the ESG-conscious stocks that have less investor exit during the disaster due to the better risk-adjusted return. This implication confirms the assertion of the stakeholder theory. Second, the findings indicate that firms that execute sustainability practices are more resilient than those firms that do not, suggesting that managers should invest in sustainability to be more stable during inevitable future crises. Sustainability practices can enhance financial resilience. Firms with strong sustainability performance may be better equipped to navigate financial challenges caused by the disaster, as they are often perceived more stable and responsible by investors. Finally, although sustainability practices do not provide immediate economic benefits to firms, it reduces risk and provides insurance-like protection against natural disasters. On this respect, our findings provide valuable insights for firms, as they may invest more resources towards improving sustainability performance to maintain their viability in economies where the frequency and intensity of natural disasters are increasing.

5.2. Limitations and future research

This study has some limitations. First, although the earthquake in the eastern and southeastern regions of Türkiye is the most disruptive disaster over the last century in the country, it is a single event. However, given the severity of the event in an industrialized region, it provides evidence for the effects of natural disasters. Future studies of similar disasters in emerging markets would help in generalizing the results. Second, the analyses provide some explanation of the heterogeneity of the abnormal returns across sectors. However, the consideration of the geographic and business diversification of companies in each sector on abnormal returns would be interesting. This study does not consider the distance of firms to the disaster location, as the economic recovery process may be weaker for firms at a shorter distance to the location of the earthquake. With increasing disaster distance, the prospects for the improved investor confidence may look better. This issue needs future research.

CRediT authorship contribution statement

Mine Aksoy: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mustafa K. Yilmaz:** Project administration, Investigation, Conceptualization, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix

Table A1
The AARs, CAARs, and t-statistics (Mean-Adjusted Model)

Sector	Number of firms	AARs	t_{AAR}	CAARs	t_{CAAR5}	CAARs	t_{CAAR10}	Critical t-values
Banks	12	−1.58	−2.69*	−1.24	−0.83	−5.91	−2.47*	2.20
Basic Metal	18	0.13	0.13	2.65	0.96	9.65	3.84*	2.11
Chemical, Petrol, Plastic	31	−2.23	−3.47*	−5.71	−4.39*	−2.30	−1.30	2.04
Construction	12	−2.99	−2.16	−11.85	−7.71*	−8.23	−3.07*	2.20
Electricity	19	−2.40	−4.97*	−9.86	−6.59*	−6.35	−3.68*	2.10
Food, Beverage	24	−0.51	−0.70	−8.96	−7.94*	−5.12	−3.26*	2.07
Information Technology	27	−1.98	−3.69*	−9.46	−7.48*	−4.81	−2.92*	2.06
Insurance	6	−4.43	−3.20*	−15.30	−3.87*	−13.07	−3.54*	2.57
Metal Products, Mach.	30	−3.05	−9.59*	−7.65	−5.76*	−3.55	−1.61	2.05
Non-Metal Min. Product	17	5.76	4.47*	23.33	4.07*	29.92	5.45*	2.12
Real Estate Inv. Trust	36	−2.54	−6.28*	−10.03	−9.27*	−3.38	−2.37*	2.03
Retail Trade	20	−1.88	−2.58*	−8.64	−4.82*	−5.31	−3.34*	2.09
Technology	28	−1.84	−3.44*	−9.29	−7.56*	−5.05	−3.15*	2.05
Telecommunications	2	−0.26	−0.53	−10.82	−22.40*	−20.41	−16.25*	12.71
Textile, Leather	17	−3.02	−5.45*	−12.00	−5.49*	−9.03	−2.91*	2.12
Tourism	9	−3.85	−4.97*	−8.58	−3.14*	−10.20	−3.77*	2.31
Transportation	9	−1.71	−1.23	−11.88	−4.00*	−7.29	−2.20	2.31
Wood, Paper, Printing	13	−3.15	−2.53*	−12.23	−5.05*	−8.97	−2.55*	2.18
Other	147	−2.77	−9.56*	−8.72	−10.59*	−5.69	−7.56*	1.98

Note: The critical z-value = 1.96.

Table A2
The AARs and CAARs of the BIST 100 companies (Mean-Adjusted Model)

		Number of firms	AARs	t_{AAR}	CAARs	t_{CAAR5}	CAARs	t_{CAAR10}	Critical t-values
Firms included in the BIST SI	Financial	9	−2.29	−3.79*	−0.44	−0.27	−6.35	−2.99*	2.31
	Non-financial	40	−1.21	−2.54*	−4.25	−2.54*	−2.60	−1.34	2.02
	All firms	49	−1.41	−3.46*	−3.55	−2.52*	−3.29	−2.01	2.01
Firms not included in the BIST SI	Financial	10	−4.20	−8.99*	−11.74	−9.22*	−6.69	−3.94*	2.26
	Non-financial	33	−2.00	−2.88*	−4.23	−1.77	0.04	0.01	2.04
	All firms	43	−2.51	−4.49*	−5.97	−3.13*	−1.53	−0.68	2.02

Note: The critical z-value = 1.96.

Table A3
The AARs and CAARs of the insurance companies (Mean-Adjusted Model)

Insurance Companies	Number of firms	AARs	t_{AAR}	CAARs	t_{CAAR5}	CAARs	t_{CAAR10}	Critical t-values
Insurance companies included in the BIST SI	3	−6.24	−3.27	−19.91	−2.92	−18.14	−3.70	4.30
Insurance companies not included in the BIST SI	3	−2.63	−1.59	−10.69	−3.30	−8.01	−1.86	4.30

Table A4
Exemplary activities of the selected companies that are included in the BIST SI in 2022

Company	ESG Dimension	Sustainability Activity
Arçelik	Environmental	To minimize the plastics pollution on water stemming from its products Arçelik developed FiberCather technology as a built-in microfiber filtration system for washing machines to prevent microplastics from entering the seas and oceans from wasteway.
Ereğli	Social	An AFAD-trained Ereğli Search and Rescue Team, consisting of 50 volunteer personnel is in place at Erdemir, with professional equipment to perform rescue operations in the disasters that may occur in the country. Ereğli supported the aid campaign organized by Disaster and Emergency Management Directorate after the flood disaster in Pakistan in 2022.
Enka	Environmental	In 2022, ENKA conducted afforestation projects to protect the forests in İstanbul and Ankara, create new forests for the benefit of society and nature and to preserve biodiversity and natural life.
Turkish Airlines	Social	As the official transport sponsor of the Turkish Red Crescent, Turkish Airlines provides support for the transport of 500 tonnes of blood, blood products, and transfusion boxes and 100 tonnes of disaster, emergency, and aid materials every 2 years. In 2022, 1500 families and 4000 children were provided with aid in the form of food parcels and shopping cards.
Ford Otosan	Social	To raise awareness in the Oltenia Region of Romania, Ford Otosan provided oral and dental health services for those in need. In the scope of the project, it offers oral health checks and free treatment at the mobile oral and dental health unit by working with the volunteering dentists.
Vestel	Social, Environmental	In the scope of the Domestic Recycling Project, starting from on April 22, 2022, old and disused white goods and electronic goods are brought back into the economy. The recycling fee will be donated within the scope of cooperation with the NGOs to support the efforts to protect the natural life. In addition, for consumers who support the project by giving their old product, seed balls will be thrown with unmanned aerial vehicles in hard-to-reach areas that need to be afforested in cooperation with Ecording.
Ak Sigorta	Social, Environmental	Ak Sigorta reviews its portfolio in terms of natural disaster risks by modeling twice a year and analyzes the adequacy of reinsurance coverage. It also maintains a balancing reserve that can be used in an earthquake.
Anadolu Sigorta	Social, Environmental	Anadolu Sigorta ran a project in 2022 to improve the preparedness of the bank for the expected Marmara earthquake. It still runs its projects on pre- and post-earthquake planning, building safety, awareness/training, and communication infrastructure by making modeling studies in reinsurance.
Türkiye İş Bankası	Social, Environmental	For highway projects, the bank developed social responsibility projects such as upgrading roads, schools and water pipelines in villages located along the highway, donating agricultural machinery, providing seed support, offering art training programs for women, and supporting education via annual budgets for villages that rely on agriculture.
Türkiye Garanti Bankası	Environmental	Within the Blue Breath project carried out in cooperation with Turkish Marine Environment Protection Association, sea sweepers collected 109 tonnes of solid waste, that were sent for recycling, since September 2021.
TSKB	Environmental	The bank implemented afforestation by aerial seeding in cooperation with the social enterprise Ecording to restore the forests lost by the fires. The bank planted 86,000 seeds on hard-to-reach lands by ecodrones in 2022.
Şekerbank	Social, Environmental	Şekerbank implements Social and Environmental Management System in its lending activities. It provides no resources to sectors that are harmful to the environment and social life in international norms.

Note: The information in this table was compiled from the 2022 sustainability reports of the selected companies on their official websites.

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