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Quantile connectedness between social network sentiment and sustainability index volatility: Evidence from the Moroccan financial market[1]

Ahmed El Oubani[2]

Abstract

The goal of this paper is to investigate the connectedness between investor sentiment and volatility on the environmental, social, and governance index (ESG) in Morocco. Therefore, on the basis of an investor sentiment index constructed from the X platform, and using quantile and frequency connectedness approaches, the findings reveal a significant connectedness between sentiment and ESG volatility, particularly during turbulent events. Although sentiment acts most of the time as a net receiver of shocks, notably during the COVID-19 pandemic and geopolitical crises, it sometimes becomes a net sender of shocks. Furthermore, the spillovers between sentiment and ESG volatility are determined mainly by the long-term component, especially during extreme events, implying the persistence of shock transmission due to high uncertainty. The results also illustrate the impact of market conditions on the spillovers

Keywords

- COVID-19
- ESG
- frequency spillovers
- quantile connectedness
- sustainability

[1] This article is a complementary version of the paper entitled 'Investor sentiment and sustainable investment: evidence from North African stock markets' accessible at: https://doi.org/10.1186/s43093-024-00349-x. The main contributions of this manuscript with respect to the previous manuscript are as follows. Firstly, while the previous manuscript develops an aggregate sentiment index from three sentiment proxies, the present manuscript focuses only on the social media sentiment index. This allows us to compare the results from these sentiment indices used and to assess the robustness of social media sentiment as a representative indicator of investor sentiment and, consequently, its relevance in predicting investor behaviour and its impact on market risk. Secondly, while the previous manuscript integrates the frequency connectedness approach with the time connectedness approach, the present paper integrates the frequency connectedness approach with the quantile connectedness approach. Finally, the present manuscript discusses in detail the practical implications of the findings for investors, companies and policy makers.

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between sentiment and ESG volatility. The conclusions of this study provide useful guidance for pro-ESG investors, policymakers, and companies.

JEL codes: G11, G15, G41, N27, N57.

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Introduction

The growing awareness of climate change and sustainability issues has prompted many stock markets to introduce sustainability indices. These indices cover only companies that comply with specific environmental, social, and governance (ESG) criteria. Recently, many investments have been reallocated to ESG assets (Gao et al., 2022; Zhan & Santos-Paulino, 2021), representing a high proportion of global equity portfolios (Daugaard, 2020). Therefore, investors' increasing attention to ESG-related stocks might have a positive effect on companies' financial performance (Vuong, 2022; Zhang & Zhang, 2023) and on the returns of ESG indices on financial markets (El Ouadghiri et al., 2021; López-Cabarcos et al., 2019).

Although ESG indices are derived from general indices, they might be more sensitive to market fluctuations than general indices are (Ortas et al., 2014). This is explained by investors' sensitivity to sustainable investment. Some studies have analysed the relationship between sentiment and sustainability indices on the basis of different investor sentiment proxies (El Ouadghiri et al., 2021; Giannarakis et al., 2016; López-Cabarcos et al., 2019; Pitoska et al., 2017). Giannarakis et al. (2016) and Pitoska et al. (2017) revealed that consumer sentiment has a positive effect on sustainability indices. On the basis of the Google search volume index, El Ouadghiri et al. (2021) reported that investors' attention to climate change and pollution has a significant and positive effect on sustainability index returns. López-Cabarcos et al. (2019) indicated that social network sentiment has a stronger effect on the S&P 500 Environmental & Socially Responsible Index than on the S&P 500 Index. Using

event study analysis, Nyakurukwa and Seetharam (2023a) found that investors react strongly to positive ESG news, whereas there is no statistically significant reaction to negative ESG news sentiment.

Investors' overreaction to ESG news could have a significant effect on ESG volatility and risk. However, the relationship between ESG performance and the volatility of ESG returns remains unclear: some studies have shown that ESG performance reduces risk (Li et al., 2022; Shakil, 2021), whereas others have revealed that it increases risk (Khan et al., 2024; Nofsinger et al., 2019). Thus, examining the connectedness between investor sentiment and ESG index volatility can provide a better understanding of this relationship. Furthermore, limited effort has been devoted to investigating the quantile, time, and frequency connectedness between sustainability sentiment and ESG index volatility. Moreover, despite the growing interest in ESG stock indices, little research exists on the connectivity between ESG sentiment and volatility in emerging markets. On the basis of a systematic literature review, Daugaard (2020) noted that there is very little literature on ESG investment in emerging markets. In addition, no research has addressed this connectivity in the Moroccan context, where it is unclear whether the results of previous research apply.

To fill these gaps, this article aims to investigate the dynamic connectedness between the X-based sustainable investment sentiment index and the volatility of the ESG index in the Moroccan financial market. Using quantile and frequency connectedness approaches, the main empirical results show that the connectedness between investor sentiment and ESG index volatility varies over time and depends on certain events. Furthermore, the results reveal that sentiment is a net receiver of shocks from ESG index volatility most of the time, but sometimes becomes a net transmitter of shocks, implying a feedback effect between sentiment and ESG index volatility. The net receipt of shocks is more pronounced during periods of extreme events. Moreover, most of the time long-term spillovers dominate short-term spillovers, especially during distress events such as COVID-19 and geopolitical tensions. With respect to market conditions, the findings show that spillover effects are greater in the upper quantiles than in the other quantiles, and that sentiment is a net transmitter of shocks to ESG index volatility in the upper quantiles, particularly in times of crisis.

We make four main contributions to the literature. Firstly, most research examining ESG investment issues has focused primarily on the US and Europe, where the ESG concept first emerged (Demers et al., 2021; Engelhardt et al., 2021). Nevertheless, related research on certain emerging markets is in noticeably short supply, including countries that are highly vulnerable to climate change and where ESG investment is an extremely critical issue. Morocco is an emerging country that is highly vulnerable to climate change, and where authorities are striving to encourage ESG investments and achieve sustain-

ability goals. Against this backdrop, the Casablanca Stock Exchange recently introduced the ESG index. It is therefore relevant to examine the relationship between investor behaviour and ESG investment in Morocco to determine whether the findings of previous studies apply to Morocco, where the ESG concept has gained momentum in recent years. This study is the first to explore the dynamic and complex interplay between social media sentiment and ESG index volatility in the Moroccan ESG market. We thereby examine whether investors in emerging markets, particularly in Morocco, are committed to sustainable investment and how their behaviour may affect the ESG market. Moreover, this study provides a better understanding of the progress of sustainable markets on the African continent, as the Moroccan financial market is one of the largest in Africa and attracts foreign investors, which can offer investors opportunities for geographic diversification. Secondly, to the best of our knowledge, this is also the first study to examine the bidirectional effect between social media sentiment and volatility on the ESG index, providing a comprehensive examination of this relationship. Thirdly, the sample in this study includes the most recent major events, namely, the COVID-19 epidemic, and the most recent major geopolitical events, such as the Russian-Ukrainian and Israeli-Palestinian conflicts, allowing us to better understand how these turbulent events influence the relationship between sentiment and the sustainability index, and thus help manage the risk propagated by these events. Fourthly, this study extends the literature on the relationship between ESG sentiment and volatility by using a fairly novel connectedness method, the dynamic *QVAR* model proposed by Ando et al. (2022), and by including frequency connectedness in our analysis. This enables us to capture connectivity in the frequency and time domains, as well as the quantile connectivity representing different market states. This is founded on the idea that the extent of connectivity can vary depending on whether markets are bearish, bullish or normal, depending on the time horizon (short or long term), and can also vary over time owing to extreme events. As a result, this allows us to understand the impact of the interaction between heterogeneous investor behaviour (short-term versus long-term investors) on the ESG market, as well as the ESG market risk at different quantiles (bearish, bullish and normal market conditions), which is more beneficial for the management of portfolios and the supervision of financial systems (Liao & Pan, 2022; Londono, 2019). This is especially important as financial markets exhibit structural breaks in return series (Cunado et al., 2023; Suleman et al., 2024) and nonlinearity caused by investor psychology (Lekhal & El Oubani, 2020).

The remainder of this paper is organised as follows. Section 1 reviews recent related literature. Section 2 outlines the methodology and data. Section 3 presents and analyses the empirical results of the paper. Section 4 performs robustness tests. Section 5 discusses the implications of the study. The last section presents conclusions.

1. Literature review and hypothesis development

With a market capitalisation of $35.30 trillion in 2020, ESG investments are expected to reach $50 trillion by 2025 (Lei et al., 2023). This reflects investors' preference for socially responsible investments that focus more on social or ethical utility (Gao et al., 2022; Garel & Petit-Romec, 2021), especially as such investments might be more resilient to turbulent events. Indeed, sustainable investment might continue to increase even in times of crisis, suggesting that investors and companies can be rewarded during crises for environmental sustainability (Garel & Petit-Romec, 2021). This can be explained by the fact that the ESG strategy might strengthen the brand image and loyalty of responsible companies (Pedini & Severini, 2022), helping attract loyal managers, investors, and customers (Boubaker et al., 2022; Isaak & Lentz, 2020). Loyal managers possess desirable capabilities for managing businesses, employees and customer relationships, which could facilitate improved productivity and profitability (Pedini & Severini, 2022). Loyal investors are motivated by nonpecuniary incentives to invest in ESG assets and are therefore unlikely to sell their investments, even in times of crisis (Hartzmark & Sussman, 2019). Loyal customers offer socially responsible companies financial support to overcome the crisis, resulting in higher cumulative abnormal returns (Boubaker et al., 2022). Moreover, firms that report ESG information benefit from financial support (Raimo et al., 2021). In fact, rating agencies have adhered to the principle of responsible investment, where ESG issues are included in their rating methodologies, implying that companies with higher ESG performance receive higher ratings (Bannier et al., 2022) and therefore benefit from lower interest rates. For instance, Phillips has received a EUR 1 billion loan from a syndicate of banks on the basis of sustainability (Klink & Gonciarenko, 2017). As a result, ESG performance could improve companies' resistance to risks. In this vein, Wang et al. (2023) argued that increasing environmental uncertainty drives companies to undergo a green transformation, improving their resistance to risks while enhancing their ESG performance. Li et al. (2022) revealed that ESG ratings reduce a firm's default risk. Murata and Hamori (2021) reported that ESG disclosures lower the risk of future stock price crashes. Thus, the high value placed on ESG assets is explained by their ability to hedge against downside risk during periods of market volatility (Albuquerque et al., 2020; Broadstock et al., 2021).

On the other hand, investor psychology might cause mispricing and high market volatility, which calls into question the efficiency market hypothesis. According to this hypothesis, prices instantly incorporate all available information, because investors can process all this information rationally (Fama, 1970). Nonetheless, investors' rationality is limited (Simon, 1982), and in-

vestors are affected by psychological biases that can influence their decision-making (El Oubani, 2023; Tversky & Kahneman, 1974; Willett, 2024). Behavioural finance studies have shown that investor sentiment can affect stock prices and explain many market anomalies, such as excessive volatility (Chiu et al., 2018; El Oubani & Lekhal, 2022; Lekhal & El Oubani, 2020; Paramanik & Singhal, 2020; PH & Rishad, 2020; Shiller, 1981; Wang et al., 2021).

Consequently, investor sentiment has a major impact on financial markets, and ESG markets might not be an exception or immune to this impact. In fact, investor sentiment could influence the ESG market, leading to market inefficiency and thus price deviation from the intrinsic value. Khan et al. (2024) reported that improvements in ESG profiles increase market prices relative to their true value and that market sentiment plays a moderating role in the link between ESG performance and mispricing, suggesting that ESG performance is a frictional factor for market efficiency. Bofinger et al. (2022) noted that socially responsible stocks tend to be overvalued. Liu et al. (2022) reported that ESG sentiment is positively associated with the volatility risk premium, particularly the impact of environmental and social factors.

The challenge in these studies lies in the fact that investor sentiment is unobservable and must thus be estimated from proxies. These proxies can be divided into three categories, namely, market-based measures, survey-based measures, and text-based measures. Market and survey-based measures are the most traditional methods, but their weaknesses arise from the fact that they indirectly attribute investor sentiment to a particular asset and are measured at low frequencies, which might not explain stock prices determined at high frequencies. The textual method is a relatively new way of extracting sentiment from news texts or social media posts. Accordingly, a large body of research uses social media and news-based sentiment in connection with ESG returns, trading volume and volatility. Through bibliometric analysis, Nyakurukwa and Seetharam (2023b) revealed that social media has emerged as an important facet of financial market understanding. Several measures of social media sentiment have been used in this context, including sentiments derived from the X platform (Abdollahi et al., 2024; Shutes et al., 2016), Facebook (Siganos et al., 2017) and Reddit (AlZaabi, 2021). Many studies confirm the impact of social media sentiment on returns and volatility. Indeed, Nyakurukwa and Seetharam (2024) reported a more powerful effect of social media sentiment on stock market returns in the US than did news media. Using textual analysis from news and social media, Abdollahi et al. (2024) found that media sentiment induces market volatility. Haroon and Rizvi (2020) showed that media-generated panic is correlated with increased volatility in global stock markets. This evidence suggests that part of financial market volatility is connected to media sentiment. As a result, the following hypothesis is formulated:

Hypothesis 1. There is a significant connectedness between social media sentiment and ESG volatility.

Within this connection, ESG volatility can transmit shocks to investor sentiment, which in turn can transmit shocks to ESG volatility. Dhasmana et al. (2023) asserted that the ESG index influences investor sentiment. In fact, as the ESG index increases, investor sentiment weakens; in contrast, poor ESG index performance strengthens investor sentiment. Ford et al. (2022) revealed that optimistic investor sentiment is driven by the highest-rated ESG portfolio. Chen and Yang (2020) found that investors are optimistic (pessimistic) about companies with higher (lower) ESG scores. Therefore, ESG performance or risk could influence investor sentiment.

Reciprocally, investor sentiment can play a dominant role in the ESG market. Indeed, Sabbaghi (2022) observed that the volatility of ESG companies is greater for bad news than for good news. Yu et al. (2023) reported a significant negative relationship between ESG news sentiment and stock market crash risk, suggesting that higher sentiment of ESG news could mitigate the risk of stock market crashes. Specifically, ESG sentiment impacts stock market crash risk by lowering negative ESG incidents, information asymmetry and agency costs. In addition, Liu et al. (2022) noted that news-based ESG sentiment influences the equity volatility risk premium. Wan et al. (2024) noted that high attention to ESG results in high volatility because greater attention to ESG information can lead to a diversity of opinions and disagreements between investors in ESG investment, thus inducing an increase in volatility connectedness. Cheng et al. (2024) pointed out that companies with better-quality sustainability reports receive greater coverage from analysts and positive reactions from investors on stock prices, which is likely to lead to greater volatility. Abdollahi et al. (2024) observed a bidirectional connection between social media sentiment and volatility.

On the basis of the aforementioned literature, we propose the following hypothesis:

Hypothesis 2. There is a feedback channel between investor sentiment and ESG index volatility.

The link between sentiment and ESG volatility can be more pronounced in times of crisis. Indeed, in times of crisis, investors prefer to switch from conventional to sustainable investments, which can cause large movements in stock markets (Wan et al., 2024). Consequently, ESG investments might not hedge against the market shocks propagated by distress events, such as the COVID-19 pandemic and geopolitical risk. Nofsinger and Varma (2014) demonstrated that risk contagion is likely to be more severe during periods of turbulence, including in the ESG market. Döttling and Kim (2022) reported a high sensitivity of sustainable investments to return shocks during crises, especially the

COVID-19 outbreak. In fact, exposure to COVID-19 positively and significantly impacts stock market volatility (Liu et al., 2023). This can be explained by investor perceptions and sentiment, as greater exposure to COVID-19 can be seen as a risk factor, resulting in greater selling pressure and volatility, especially as social media coverage of the COVID-19 outbreak (Umar et al., 2021) increased the sentiment of fear. In this context, Chen and Lin (2022) argued that ESG investment does not hedge against the risks that financial markets commonly experience, as their performance and volatility can be influenced by a variety of extreme events. This contradicts the findings of Albuquerque et al. (2020), who documented that stocks which are better rated in terms of ESG performance showed significantly lower volatility during the spike of the COVID-19 epidemic, because of investor and customer loyalty to sustainability. This also disagrees with Rubbaniy et al. (2022), who concluded that during the pandemic, investors might have shifted their portfolios from risky assets to ESG assets considered to be safe assets.

In addition to COVID-19, geopolitical risks can also have a significant effect on sustainable investment. These risks include the potential disturbance of normal international relations caused by several factors, such as shocks and tensions between nations (Ren et al., 2023), military conflicts, and war and terrorism threats (Caldara & Iacoviello, 2022). Yang et al. (2024) reported that changes in the geopolitical risk index bring about changes in ESG stocks. Sohag et al. (2022) highlighted the negative impact of geopolitical risk shocks on green equity. In this context, investor sentiment can explain the relationship between geopolitical risk and volatility. Guo and Shi (2024) examined the impact of investor sentiment and China-US geopolitical risk on Chinese stock market volatility and found that the interplay effects of China-US geopolitical risk and investor sentiment can further influence industry stock market volatility.

Building on this foundation, we posit the following:

Hypothesis 3. Disruptive events can amplify the connectedness between sentiment and ESG index volatility, creating increased risk in the sustainable market.

Volatility tends to be highly persistent (Wei et al., 2022), a property that is considered a stylised fact of financial markets known as long memory (Shi & Ho, 2015). Investor sentiment could be responsible for this volatility persistence. In fact, the uncertainty that prevails in distressed situations can transmit shocks from investor sentiment to market volatility over longer periods, which can result in low-frequency connectivity. Wu et al. (2023) showed that low-frequency connectedness tends to dominate during conflicts. Abdollahi et al. (2024) found that social media sentiment has a stronger lasting effect than news sentiment for some markets. Wan et al. (2024) found that high attention primarily impacts volatility connectedness at low frequencies. These results are in line with those found in the ESG market. Indeed, Gao et al. (2022) found that medium-frequency volatility connectivity between ESG stock in-

dices from eight regions dominates. This might be explained by the fact that ESG stock indices generate less sudden short-term risk and take longer to absorb risk in the risk transmission process (Wan et al., 2024). El Oubani (2024) found significant connectedness between sentiment and ESG market volatility, and this connectedness is due mainly to the long-term component, especially during extreme events.

On the basis of this discussion, the following hypothesis is formulated:

Hypothesis 4. The connectedness between sentiment and ESG index volatility is created at low frequencies, particularly during extreme events leading to high persistent volatility.

The connectedness between ESG sentiment and volatility might depend on market conditions, which can be captured by calculating this connectedness at different quantiles. In this respect, using the quantile connectedness approach to examine the relationship between sentiment and ESG volatility across different quantiles can be highly relevant. Indeed, conditional mean connectedness may provide limited information on the connectedness between sentiment and ESG volatility as financial markets can experience structural breaks (Cunado et al., 2023). Specifically, the most essential information on negative and positive shocks in financial time series is available in the lower and upper extreme quantiles (Londono, 2019). On the basis of quantile connectedness estimates, Sheikh et al. (2024) showed that the overall connectedness between daily trade policy uncertainty, geopolitical risk, the global financial stress index and the three Australian financial markets (i.e. conventional, sustainable and Islamic stock markets) increases at extreme bearish and bullish quantiles relative to normal market conditions. Guo and Shi (2024) reported that the impact of the interaction effects of Chinese and US geopolitical risk and investor sentiment on market volatility is highly heterogeneous, and that its magnitude lies mainly in the upper and lower tails. El Khoury et al. (2024) found that dynamic spillover effects are greater under extreme market conditions than normal conditions. With respect to the ESG market, Yang et al. (2024) noted that the predictability of ESG returns by geopolitical risk is asymmetric across different ESG return distributions. Dhasmana et al. (2023) found that the relationship between investor sentiment and the ESG index is asymmetric and influenced by extreme market conditions. Therefore, studying the impact of different market conditions can provide in-depth information on the link between sentiment and ESG index volatility, and provide investors with valuable information that could improve their decision-making by trading according to different market conditions, including upper and lower quantiles.

On the basis of the above literature review, we posit the following:

Hypothesis 5. The magnitude of the spillover effects between investor sentiment and ESG index volatility depends on market conditions.

2. Methodology and data

2.1. Methodology

Some approaches consider the mean-based *VAR* (Diebold & Yilmaz, 2012; Baruník & Křehlík, 2018) to examine connectedness between variables, but these approaches do not allow us to assess whether co-movement between variables in the network depends on the extreme quantiles and whether the shock is positive or negative. Furthermore, as the most essential information on negative and positive shocks in financial time series is available at the lower and upper extremes (Londono, 2019), these approaches do not provide sufficient information on the connectedness between sentiment and ESG volatility, especially as financial markets can experience structural breaks (Cunado et al., 2023). Accordingly, in our study we use the quantile connectedness approach developed by Ando et al. (2022), which is an improvement over the mean-based measures version. Quantile connectedness considers both extreme positive structural shocks (upper quantiles) and extreme negative structural shocks (lower quantiles). This allows us to see how normal (median), bullish (right-tail) and bearish (left-tail) market conditions affect spillover effects between variables.

To compute the connectedness measures at each quantile τ, we first estimate a quantile vector autoregression, *QVAR*(p), which is as follows:

$$y_t = \mu(\tau) + \sum_{j=1}^{p} \Phi_j(\tau) y_{t-j} + u_t(\tau) \tag{1}$$

in which y_t and y_{t-j}, $j = 1, ..., p$ are $N \times 1$ dimensional endogenous variable vectors, τ denotes the quantile of interest and lies within [0,1], p is the lag length of the *QVAR* model, $\mu(\tau)$ stands for the $N \times 1$ dimensional conditional mean vector, $\sum_{j=1}^{p} \Phi_j(\tau)$ is an $N \times N$ dimensional *QVAR* coefficient matrix, and $u_t(\tau)$ represents the $N \times 1$ dimensional error vector that has an $N \times N$ dimensional error variance—covariance matrix $\sum(\tau)$. To transform the *QVAR*(p) into its quantile vector moving average representation, *QVMA*(∞), we employ Wold's theorem:

$$y_t = \mu(\tau) + \sum_{j=1}^{p} \Phi_j(\tau) y_{t-j} + u_t(\tau) = \mu(\tau) + \sum_{i=0}^{\infty} \Psi_i(\tau) u_{t-i} \tag{2}$$

Then, we calculate the generalised forecast error variance decomposition (GFEVD) at the forecast horizon H (Koop et al., 1996; Pesaran & Shin, 1998).

The GFEVD indicates the impact of a shock in variable *j* on variable *i* with respect to its forecast error variance share. The GFEVD is given by the following formula:

$$\theta_{ij}^{g}(H)=\frac{\sum(\tau)_{jj}^{-1}\sum_{h=0}^{H-1}\left(e_i'\Psi_h(\tau)\sum(\tau)e_j\right)^2}{\sum_{h=0}^{H-1}\left(e_i'\Psi_h(\tau)\sum(\tau)\Psi_h(\tau)'e_i\right)} \tag{3}$$

in which e_i represents a zero vector with unity at the i^{th} position. In the decomposition matrix, the normalisation of elements is as follows:

$$\tilde{\theta}_{ij}^{g}(H)=\frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{k}\theta_{ij}^{g}(H)} \tag{4}$$

The normalisation is expressed by the following equations:

$$\sum_{j=1}^{K}\tilde{\theta}_{ij}^{g}(H)=1 \quad \text{and} \quad \sum_{i,j=1}^{K}\tilde{\theta}_{ij}^{g}(H)=K \tag{5}$$

Subsequently, according to Diebold and Yilmaz (2012), all GFEVD-based connectedness metrics are estimated as follows. The total connectedness index (TCI) provides the average level of total spillover and is written as follows:

$$TCI=K^{-1}\sum_{i,j=1,i\neq j}^{K}\tilde{\theta}_{ij}^{g}(H) \tag{6}$$

This measure can be seen as an indicator of market uncertainty.

The total directional connectedness TO is defined as:

$$TO_i=\sum_{j=1,i\neq j}^{K}\tilde{\theta}_{ji}^{g}(H) \tag{7}$$

The total directional connectedness $FROM$ is as follows:

$$FROM_i=\sum_{j=1,i\neq j}^{K}\tilde{\theta}_{ij}^{g}(H) \tag{8}$$

The NET total directional spillover is written in the following form:

$$NET_i(H)=TO_i-FROM_i \tag{9}$$

If $NET_i>0$, this indicates that variable i influences all the other variables more than it is influenced by them. The variable *i* is therefore a net transmitter of shocks. It is a net receiver of shocks when $NET_i<0$.

The net pairwise connectedness ($NPDC$) is computed as follows:

$$NPDC_{ij}(H) = \tilde{\theta}^{g}_{ij}(H) - \tilde{\theta}^{g}_{ji}(H) \tag{10}$$

If $NPDC_{ij}(H) > 0$, variable *j* has a greater effect on variable *i* than variable *i* has on variable *j*. Consequently, the variable *j* dominates the variable *i*. If $NPDC_{ij}(H) < 0$, the variable *i* dominates the variable *j*.

We integrate the frequency domain connectedness approach of Baruník and Křehlík (2018) with Ando et al.'s *QVAR* approach (2022). The frequency domain separates spillovers into high-frequency (short-term) and low-frequency (long-term) spillovers. The former indicates that connectedness results from shocks that have a short-term effect on the system, whereas the latter suggests that connectedness results from shocks that have a long-term effect on the variables in the system.

According to Baruník and Křehlík (2018), $\Psi(e^{-i\omega}) = \sum_{h} e^{-i\omega h}\Psi_h$ is the frequency response function generated from the Fourier transform of the coefficient Ψ_h with $i = \sqrt{-1}$. The generalised causation spectrum over frequencies $\omega \in (-\pi, \pi)$ is determined as:

$$\theta_{ij}(\omega) = \frac{\sigma_{jj}^{-1}\left|\Psi(e^{-i\omega})\sum_{ij}\right|^2}{\left(\Psi(e^{-i\omega})\sum\Psi'(e^{+i\omega})\right)_{ii}} \tag{11}$$

in which $\Psi(e^{-i\omega}) = \sum_{h} e^{-i\omega h}\Psi_h$ is the Fourier transform of the impulse response Ψ_h, and $\theta_{ij}(\omega)$ denotes the fraction of the i^{th} variable at a specified frequency ω resulting from shocks to the j^{th} variable.

The generalised variance decomposition at a given frequency band $d = (a, b)$ is as follows:

$$\theta_{ij}(d) = \frac{1}{2\pi}\int_{a}^{b} \Gamma_i(\omega)\,\theta_{ij}(\omega)\,d\omega \tag{12}$$

where $\Gamma_i(\omega)$ denotes the power of the i^{th} variable at a specified frequency and is described as:

$$\Gamma_i(\omega) = \frac{\left(\Psi(e^{-i\omega})\sum\Psi'(e^{+i\omega})\right)_{ii}}{\frac{1}{2\pi}\int_{-\pi}^{\pi}\left(\Psi(e^{-i\lambda})\sum\Psi'(e^{+i\lambda})\right)_{ii}\,d\lambda} \tag{13}$$

The normalised generalised variance decomposition at the frequency band d can be calculated as follows:

$$\tilde{\theta}_{ij}(d) = \frac{\theta_{ij}(d)}{\sum_{j} \theta_{ij}(\infty)} \tag{14}$$

where $\theta_{ij}(\infty)$ represents the contribution over all frequencies.

All measures of connectedness are calculated as in (6)–(10) at a frequency band "d". These connectivity measures are established via a particular quantile τ.

2.2. Data

To measure the spillover effect between investor sentiment and ESG investment volatility in Morocco, we use weekly data from the MASI ESG index, which was introduced in 2018. The goal of this index is to highlight companies performing well in terms of environmental, social, and governance factors relative to their market peers. The data are obtained from the Moroccan stock market website (https://www.casablanca-bourse.com/en/live-market/indices/ESGI) and cover the period from January 2018 to December 2023. This period is instructive in terms of extreme events because it includes the COVID-19 outbreak and subsequent years, as well as the most recent geopolitical conflicts (The Russian-Ukrainian and Israeli-Palestinian conflicts).

The volatility of the ESG index is estimated on the basis of the conditional variance from the univariate *GARCH* model (Bollerslev, 1986). In addition to the ESG index, we introduced the general market index, the Moroccan All Shares Index (MASI), to monitor general market conditions. The standard *GARCH* (p, q) model can be expressed as follows:

$$y_t = x_t\beta + \varepsilon_t,\ \varepsilon_t = h_t e_t,\ h_t^2 = \phi + \sum_{i=1}^{p} \lambda_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \gamma_j h_{t-j}^2 \tag{15}$$

where p represents the order of the moving average $ARCH$ term, q denotes the order of the autoregressive *GARCH* term, y_t stands for the conditional mean, h_t^2 expresses the conditional variance, ε_t^2 is the squared residual, λ_i represents the $ARCH$ parameters, γ_j represents the *GARCH* parameters, e_t denotes a white noise process, and ϕ is a constant.

We use the X (Twitter) sentiment as a proxy for investor sentiment. To construct this sentiment index, we applied the following procedure. We collected daily posts (tweets) related to "sustainable investment in Morocco" from the X platform for the period under investigation. In this context, we employed various related keywords, such as "Sustainable investment in Morocco", "Environmental, social, and governance criteria in Morocco", "Sustainability in Morocco ", and "ESG in Morocco". Once we had cleaned

the raw posts, we attributed a sentiment score to each post on the basis of natural language processing via Python. We obtained the opinion polarity from a total of 11,346 posts indicating whether a person has a neutral, positive or negative opinion toward sustainability. We then calculated the weekly average sentiment to construct a time-series of the weekly sentiment index with the following formula:

$$Tsent_t = \sum_{i=1}^{n} \frac{Sent_{it}}{N_t} \tag{16}$$

where $Tsent_t$ represents the weekly sentiment at time t, $Sent_{it}$ represents the sentiment score of message i posted at time t, and N_t denotes the number of messages posted at time t. The sentiment index ranges from –1 to 1, in which –1 is considered extremely pessimistic, 1 is considered extremely optimistic, and zero is considered neutral.

Table 1. Descriptive statistics of the series

	Sentiment	ESG return	MASI return	ESG_Vol	MASI_Vol
Mean	0.106	–0.0004	–0.0001	0.016	0.015
Median	0.097	0.0013	0.0010	0.013	0.012
Max	0.480	0.0466	0.042	0.062	0.066
Min	–0.156	–0.0973	–0.09	0.009	0.009
Relative Std. dev.	1.037	48	179	0.521	0.549
Kurtosis	3.011	8.7355	10.144	13.130	18.038
Skewness	0.727	–1.4070	–1.6622	2.9781	3.557
JB	23.158***	549.68***	831.97***	1801.2***	3609.7***
ADF	–6.64***	–13.58***	–12.80***	–4.49**	–5.34***
ARCH–LM		56.18***	50.54***		

Notes: JB represents the Jarque and Bera (1980) test for normality; ADF represents the augmented Dickey and Fuller unit root test; ARCH-LM represents Engle's (1982) ARCH-LM test. (***) and (**) denote significance at the 0.01 and 0.05 levels, respectively. Returns are calculated via the following formula: $R_t = \ln(p_t/p_{t-1})$, where p_t is the closing price of the index at time t and p_{t-1} is the closing price of the index at time $t-1$.

Source: own elaboration.

Table 1 shows summary statistics for the sentiment, return, and volatility series. The ESG and MASI returns have a negative mean, indicating that the indices are losing value on average. However, the positive mean of the sentiment series implies that investors are, on average, optimistic about sustain-

able investment. Furthermore, we note that the relative standard deviation[3] of the sentiment series is lower than that of the ESG and MASI returns, indicating that sentiment is less volatile than returns. We also notice that the returns are negatively skewed due to their negative variations. The sentiment index is positively skewed, which means that the distribution is skewed to the right due to positive sentiment variations. The kurtosis is greater in all series than in the normal distribution. The distributions are therefore non-Gaussian. The nonnormality of all variables is also validated by the Jarque-Bera normality test. All these characteristics support the adoption of the *QVAR* connectedness approach.

To verify the stationarity of the variables, we employ the ADF test. All the series exhibit stationarity, as the ADF unit root test is highly significant. Finally, the significant ARCH-LM test suggests the presence of heteroscedasticity in the return series, supporting the use of the *GARCH* model in volatility estimation.

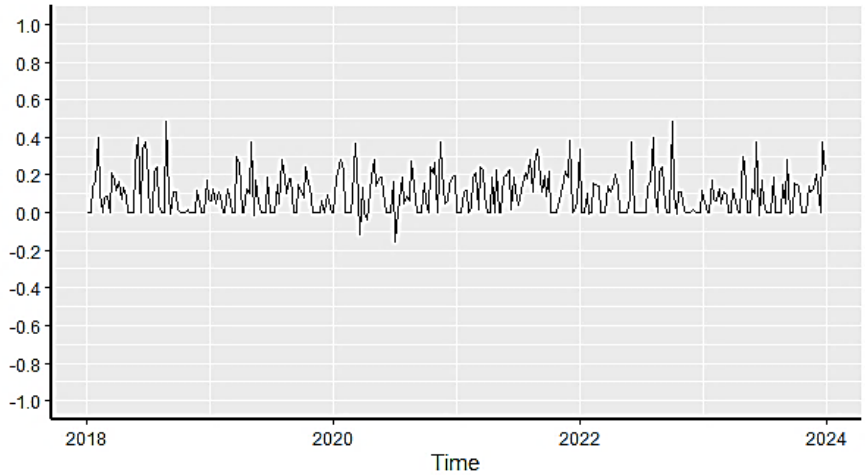

Figure 1. Dynamics of the investor sentiment index

Source: own elaboration.

Figure 1 illustrates the dynamics of the investor sentiment index. The results indicate that social media sentiment varies over time, ranging from –0.2 to 0.5. A negative value means that people are pessimistic about ESG investments, a positive value means that they are optimistic, and a zero means they are neutral. Specifically, we observe positive values most of the time, with important levels during crises, notably at the start of COVID-19, after the beginning of the war between Russia and Ukraine, and at the end of 2023,

[3] The relative standard deviation stands for the standard deviation divided by the absolute mean.

which corresponds to the Israeli-Palestinian conflict. Nevertheless, during the COVID-19 pandemic, there were a few brief periods of negative sentiment, implying that during the crisis period, negative sentiment can occur due to significant negative shocks and uncertainty (Zribi et al., 2024). However, negative shocks in sentiment are short-lived, and people quickly switch to optimistic sentiments as the crisis raises awareness of the need for sustainability-related investments.

3. Results and discussion

In this section, we examine the static and dynamic connectedness between sentiment and ESG index volatility. Table 2 shows the static connectedness at three quantiles, namely, the median ($\tau = 0.5$), the lower quantile ($\tau = 0.05$), and the upper quantile ($\tau = 0.95$).

The results show that the total connectedness index (*TCI*) is 37.42% at the median (normal market conditions), 41.06% at the lower quantile (bearish market conditions) and 64.10% at the upper quantile (bullish market conditions), which means that the *TCI* is higher under extreme quantiles than under the median, and that it is greater at the upper tail than at the lower tail. Furthermore, the findings show a significant feedback channel between ESG sentiment and volatility, particularly at the 95th quantile (where spillover effects range from 30.25% to 30.73%). This confirms that the risk in the upper tails is greater than that in the lower tails.

However, the static measurement of spillovers assumes that the coefficients of the model remain constant for the entire study period, which does not allow us to capture the structural breaks that occur because of extreme events. Moreover, numerous studies show that the impact of investor behaviour on financial markets evolves over time (El Oubani, 2022; Lekhal & El Oubani, 2020; Lo, 2004). To overcome this drawback, we re-estimate the time-varying connectedness between ESG sentiment and volatility.

Figure 2 shows the *TCI* in the time and frequency domains between investor sentiment toward sustainability, ESG index volatility, and MASI index volatility. The findings indicate that the *TCI* varies over time and depends on certain events. Indeed, notable peaks are observed in March 2020 (67%), February 2022 (66%), and October 2023 (60%), coinciding with the COVID-19 pandemic, the Russian-Ukrainian conflict, and the Israeli-Palestine conflict, respectively. Thus, during the crisis, the shocks created additional uncertainty, which was then transmitted to the entire system, leading to significant spillover into the system and thereby extremely high market risk. These results confirm those of Mensi et al. (2021), who argue that intense economic

Table 2. Sentiment and ESG volatility connectedness at the median, 5th quantile and 95th quantile

	Sent.	ESG	MASI	*FROM*
Panel A: Connectedness at the median				
Sent.	83.50	8.58	7.92	16.50
ESG	2.35	52.83	44.82	47.17
MASI	1.93	46.67	51.40	48.60
TO	4.28	55.25	52.74	112.27
NET	–12.22	8.08	4.14	**37.42**
Panel B: Connectedness at the 5th quantile				
Sent.	79.05	11.08	9.88	20.95
ESG	6.69	48.58	44.73	51.42
MASI	6.02	44.80	49.18	50.82
TO	12.71	55.88	54.60	123.19
NET	–8.24	4.46	3.78	**41.06**
Panel C: Connectedness at the 95th quantile				
Sent.	37.18	30.73	32.09	62.82
ESG	30.25	34.60	35.15	65.40
MASI	30.13	33.94	35.93	64.07
TO	60.37	64.67	67.24	192.29
NET	–2.45	–0.73	3.18	**64.10**

Notes: The variance decomposition is based on the *QVAR* approach, estimated at the median, lower quantile, and upper quantile, with a lag order of 1 chosen according to the Bayesian Information Criterion (BIC). The total connectedness index (*TCI*) in bold in the lower right corner is calculated via Eq. (6). The *TO*, *FROM*, and *NET* are calculated via Eq. (7), Eq. (8) and Eq. (9), respectively. The ij^{th} value is the directional connectedness from variable *j* to variable *i* and is calculated via Eq. (3). The results are expressed as percentages.

Source: own elaboration.

periods create feelings of fear and uncertainty, which results in strong spillover effects. The results also support the findings of Liu et al. (2023) that exposure to COVID-19 increases stock market volatility. Nevertheless, they do not confirm some earlier studies suggesting that companies with better ESG scores have lower stock price volatility in times of crisis, such as COVID-19 (Albuquerque et al., 2020; Broadstock et al., 2021) or that ESG stocks have a safe-haven property (Rubbaniy et al., 2022).

A decline in spillover effects was observed during stable periods coinciding with the recovery of the economy from the COVID-19 epidemic (at the end

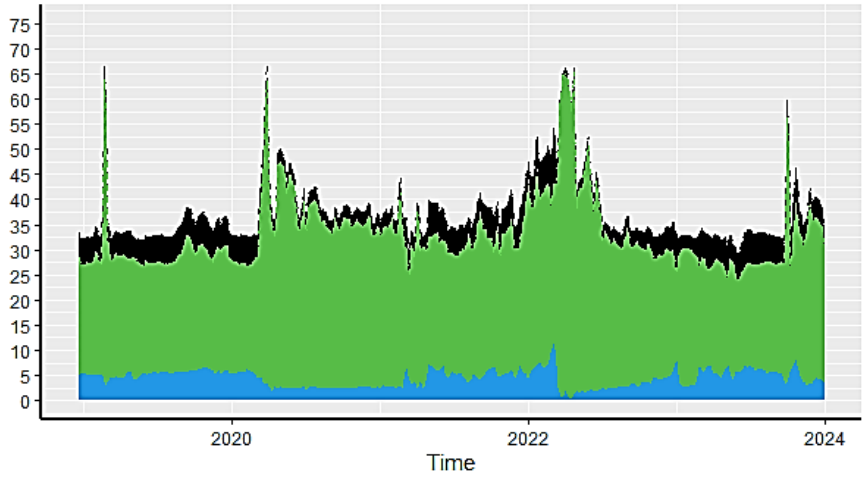

Figure 2. Short-term, long-term, and overall dynamic total connectedness

Notes: The results are estimated via the median *QVAR* model with a 52-week rolling window, a lag length of order 1 (BIC) and a generalised forecast error variance decomposition at 100 steps forward. The black area represents the time dynamic connectedness, the green area represents the long-term connectedness, and the blue area represents the short-term connectedness.

Source: own elaboration.

of 2021). This is due to lower uncertainty transmission, leading to low connectivity. Our results thus support Hypotheses 1 and 3.

To understand how the time horizon of investments can explain the origin of spillovers in the system, we investigate the frequency dynamics of connectivity. Market participants have heterogeneous expectations and therefore heterogeneous frequency responses to shocks. Ferrer et al. (2018) argue that diverse market participants have distinct goals, priorities, risk appetites and institutional constraints. While institutional investors prioritise long-term market returns, individual traders and hedge funds focus on short-term returns on assets, which results in heterogeneity in their frequency responses. Thus, asset prices, driven by fluctuations in demand involving multiple cyclical components, trigger shocks with different frequency responses, producing both short- and long-term spillovers.

The results in Figure 2 show that dynamic spillovers are induced by heterogeneous frequencies, in line with investors' heterogeneous perceptions and preferences. Nevertheless, spillovers are driven mainly by the long-term component, as they are concentrated at low frequencies, implying that the connectivity between ESG sentiment and volatility occurs mainly in the long term. These results are consistent with the fact that volatility connectedness is generally more persistent than return connectedness is (Wan et al., 2024; Wei et al., 2022), and that volatility often shows strong persistence, which is

a stylised fact in financial markets. This characteristic was more pronounced during the COVID-19 epidemic and during the Russian-Ukrainian and Israeli-Palestinian conflicts. This can be explained by the fact that investors react very slowly to news, due to the important level of uncertainty during the crisis period, resulting in the shock being transmitted over a longer period and hence longer-term spillover effects. These results are consistent with those of Baruník and Křehlík (2018). They also align with the results of Wan et al. (2024), according to which attention to ESG has a significantly positive effect on the *TCI* of volatility in the low-frequency domain, suggesting that high attention to ESG results in strong volatility connectivity in the long term. These findings support Hypothesis 4.

To focus on the relationship between investor sentiment and ESG index volatility, we calculated the net pairwise spillover effect between these variables. The results in Figure 3 show a feedback channel between sentiment and ESG index volatility, in which investor sentiment toward sustainability acts as a net receiver of ESG volatility shocks most of the time, but becomes a net sender of shocks during certain periods. Interestingly, the net reception of shocks by investor sentiment is more pronounced during periods of extreme events, namely, the COVID-19 health crisis and geopolitical crises such as the Russian-Ukrainian and Israeli-Palestinian conflicts, suggesting that during these periods, shocks in the ESG index volatility prompt investors to pay

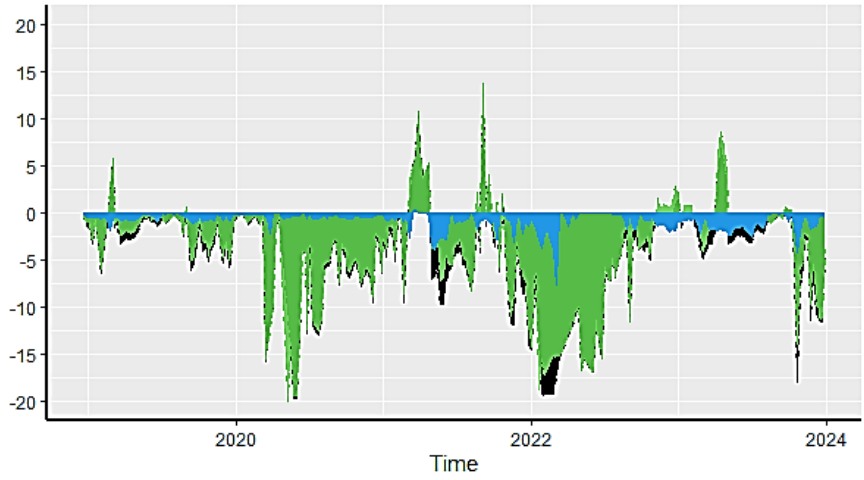

Figure 3. Short-term, long-term, and overall dynamic net pairwise connectedness between sentiment and ESG index volatility

Notes: The results are estimated via the median *QVAR* model with a 52-week rolling window, a lag length of order 1 (BIC) and a generalised forecast error variance decomposition at 100 steps forward. The black area depicts the time dynamic connectedness values, whereas the green and blue areas represent the long-term and short-term connectedness values, respectively.

Source: own elaboration.

more attention to what is being said about sustainable investment in social media. This finding is in line with that of Wan et al. (2024), who found that the level of attention given to ESG has risen sharply since 2020, implying that ESG attention has been strongly influenced by the pandemic. The high attention given to ESG investing can generate shocks in sentiment and therefore encourage more investors to include ESG stocks in their portfolios, leading to significant movements in ESG index returns, with sentiment thus becoming a net sender of shocks to ESG market volatility. This validates the conclusions reached by Li et al. (2023), who emphasised that investor panic caused by the COVID-19 epidemic is a possible trigger for risk spillovers in the stock market. Our findings also validate those of Liu et al. (2022), who found that ESG sentiment is positively related to the volatility risk premium, particularly the impact of environmental and social factors. Nevertheless, these results are not consistent with those of Dhasmana et al. (2023), who found that investor sentiment does not affect the ESG index in the Indian context, nor with those of Boubaker et al. (2022), who showed that responsible investment improved companies' resilience to the negative shocks of the COVID-19 health crisis. Therefore, our results confirm Hypothesis 2.

Like the total connectedness index, the net pairwise spillovers between ESG sentiment and volatility are also concentrated at low frequencies. This suggests that this interconnection is driven mainly by long-term fluctuations, indicating that markets do not react quickly to change. This observation is in line with the findings of El Oubani (2024), who found that the connectivity between ESG sentiment and volatility is due mainly to the long-term component. It also highlights the prevalence of strong risk aversion, an inherently unstable financial market, and a significant level of uncertainty, as confirmed by Baruník and Křehlík (2018). Together, these elements lead to slower shock transmission and more persistent investor reactions to these shocks. Consequently, these findings also validate Hypothesis 4.

To examine the dynamic connectedness between investor sentiment and ESG index volatility under different market conditions, we utilise the quantile connectedness approach of Ando et al. (2022). The empirical results in Figure 4 show that the *TCI* is stronger in the upper quantiles than in the other quantiles. This phenomenon can be attributed to investors' tendency to overreact to extreme shocks in the ESG market, as shown by previous studies (Dhasmana et al., 2023; Guo & Shi, 2024; Yang et al., 2024). Notable episodes include the COVID-19 health crisis in the first part of 2020 and the war between Russia and Ukraine in 2022, which caused disruptions in the supply of oil and other raw commodities. This means that periods of crisis are accompanied by high volatility and therefore high connectivity in the system, indicating high market risk. This contradicts some views that regard ESG stocks as safe havens (Rubbaniy et al., 2022). Importantly, investing in ESG stock indices does not protect against the risks that financial markets confront uniformly,

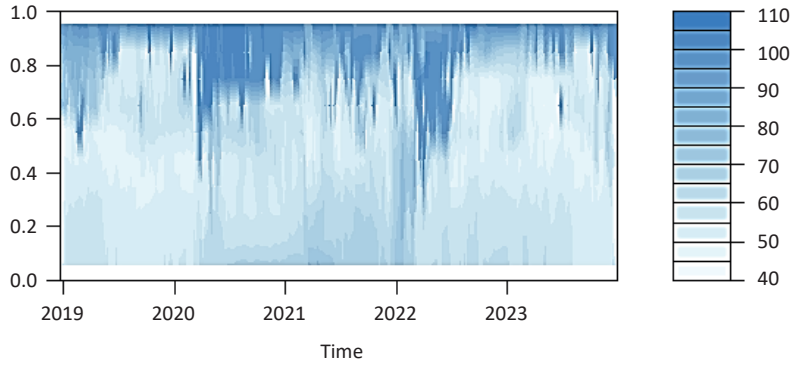

Figure 4. Quantile total connectedness between sentiment and volatility

Notes: The results are estimated via the median *QVAR* model with a 52-week rolling window, a lag length of order 1 (BIC) and a generalised forecast error variance decomposition at 100 steps forward. Warmer shades on the graph reflect greater levels of connectedness.

Source: own elaboration.

as their performance and volatility can be affected by a variety of extreme events (Chen & Lin, 2022). This encourages investors to implement effective risk management measures when investing in ESG markets, and to proactively hedge against potential shocks.

Now, we concentrate the analysis on the pairwise connectivity between sentiment toward sustainability and ESG volatility under different market conditions. On the basis of Figure 5, the estimation results show that investor

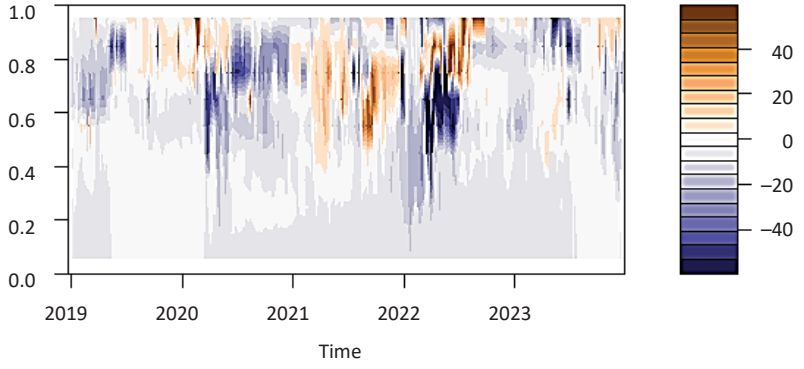

Figure 5. Quantile net pairwise connectedness between ESG sentiment and volatility

Notes: The results are estimated via the median *QVAR* model with a 52-week rolling window, a lag length of order 1 (BIC) and a generalised forecast error variance decomposition at 100 steps forward. Warmer shades indicate net-transmission.

Source: own elaboration.

sentiment transmits shocks to ESG index volatility mainly in the upper quantiles, implying that the impact of investor sentiment on ESG index volatility is more pronounced during positive extreme market conditions. In line with our previous results, the most notable events are the COVID-19 epidemic and the war between Russia and Ukraine, both of which are characterised by uncertainty and therefore high volatility. Indeed, media-generated panic during crisis periods is associated with increased market volatility (Haroon & Rizvi, 2020). These results are consistent with those of Naeem et al. (2020), who reported that investor sentiment plays a leading role in stock market volatility. These findings corroborate Hypothesis 5 and suggest that sentiment could be used to predict ESG volatility in the Moroccan stock market, particularly in the upper quantiles, to achieve abnormal returns. Consequently, investors need to make timely adjustments to their ESG portfolios on the basis of investor sentiment. Policymakers also need to consider extreme positive tails when making regulatory decisions.

4. Robustness tests

We complete our analysis by conducting some robustness tests on our results. First, we focused our analysis on social media sentiment to capture investors' attention to sustainability. However, this could be biased in terms of representing a broader investor population. To diversify the data sources and confirm the robustness of our results, we use online search attention as an alternative to social media sentiment. Second, we consider whether our findings differ if we change certain parameters of the *QVAR* method. The analyses are repeated to check whether the same results are obtained.

4.1. Online search attention and ESG volatility

Following Da et al. (2011) and Duc et al. (2024), we employ the Google Volume Search Index (*GVSI*) using sustainability-related terms obtained via Google Trends, to assess investors' attention to ESG investing. In fact, the *GSVI* for the topic "Environmental, social and governance criteria"[4] in Morocco is used. Next, an abnormal *GSVI* (*AGSVI*) is calculated via the following formula:

[4] To check the robustness of the results, other keywords closely related to sustainable investment were used. However, the results for these keywords were not significant.

$$AGSVI_t = \frac{Weekly\,GSVI_t}{Mean_t^{24}} \tag{17}$$

in which $Mean_t^{24}$ is the 24-week moving average before time t.

We then test the dynamic interplay between investor attention to ESG, captured by online search intensity, and ESG volatility via the *QVAR* approach. The results reported in Figure 6 are consistent with those observed when we consider social media sentiment. This confirms the relevance of using social media sentiment to track people's attitudes toward sustainability.

4.2. Changes in the *QVAR* parameters

To check the robustness of the method used in this study, we re-estimate the connectedness between ESG sentiment and volatility via the *QVAR* with the modification of certain parameters such as the forecast horizon, the rolling window size, and the model selection criterion. The results presented in Figure 7 show consistency between the results when the forecast horizon, the rolling window size, and the model selection criterion are modified in the *QVAR* method, implying that the choice of these parameters does not significantly affect the conclusions of the baseline study.

5. Study implications

The outcomes of the study are beneficial for pro-ESG investors, companies, and policymakers. The results suggest that investors should consider what is posted on social media when investing in the ESG market to strategically manage their portfolios, as social media sentiment influences returns and risks in this market. This can help investors build profitable investment strategies, such as momentum strategies (Lekhal & El Oubani, 2020). Indeed, investors systematically exaggerate ESG information disclosed by companies, leading to ESG momentum effects in financial markets that can translate into substantial short-term profits (Chen & Yang, 2020). Additionally, the results help investors manage their ESG portfolios in times of crisis by considering arbitrage opportunities. In fact, we find that sentiment amplified long-term risk in the ESG market during the COVID-19 pandemic because sentiment transmitted persistent shocks to volatility. This finding is confirmed in the US, Europe and emerging markets, where the panic index induced by the COVID-19 pandemic had a significant effect on ESG volatility (Umar et al., 2021). However, this finding does

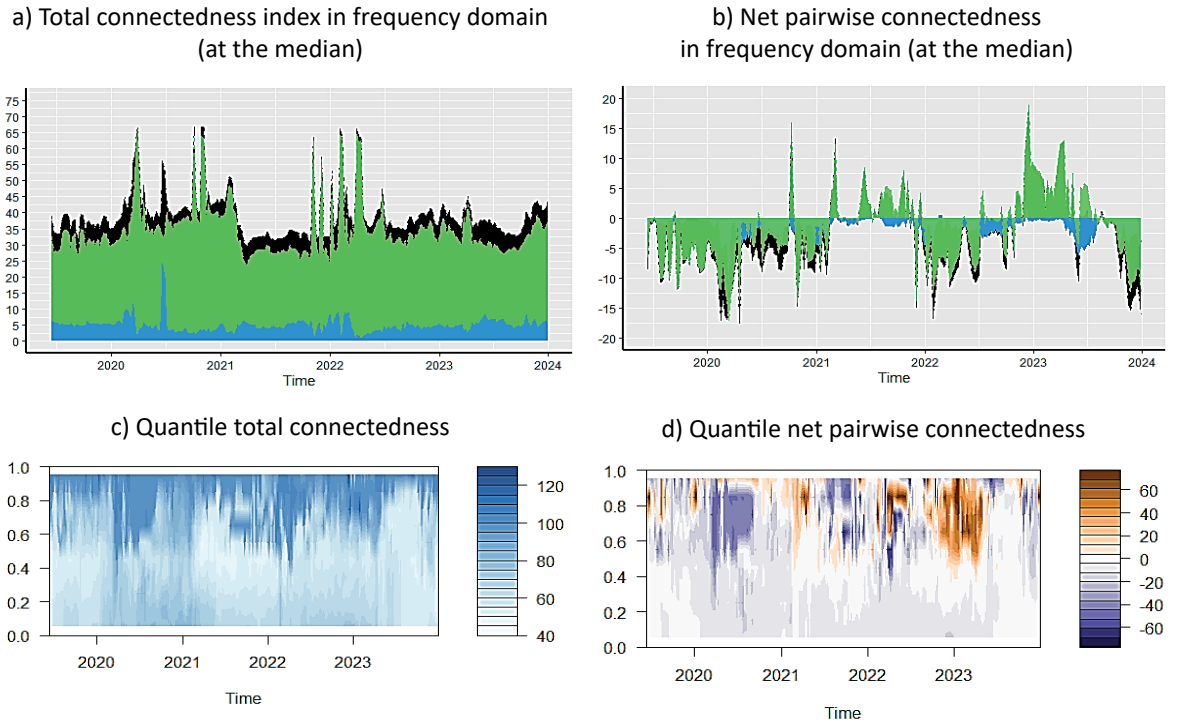

Figure 6. Spillover effects between online search attention and ESG volatility

Notes: The results are estimated via the *QVAR* model with a 52-week rolling window, a lag length of order 1 (BIC) and a generalised forecast error variance decomposition at 100 steps forward. In *a* and *b*, the black area depicts the time dynamic connectedness, whereas the green and blue areas represent the long-term and short-term connectedness, respectively. Warmer shades reflect greater levels of connectedness in *c*. Warmer shades indicate net-transmission in *d*.

Source: own elaboration.

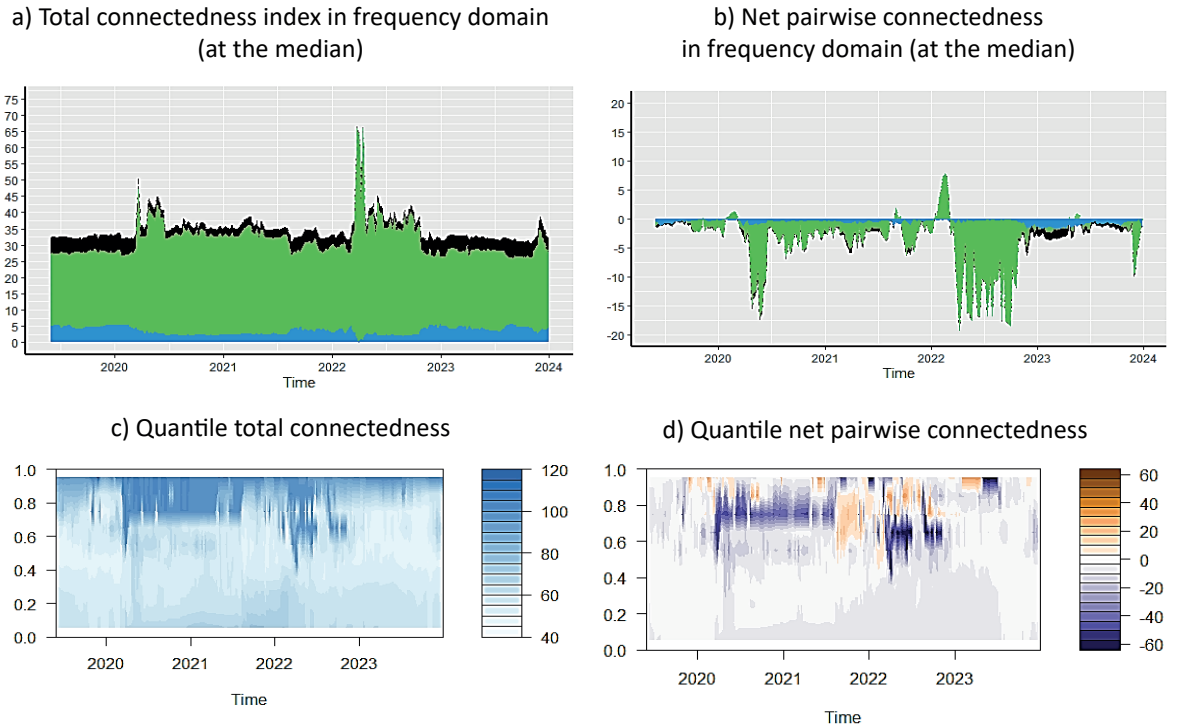

Figure 7. Spillover effects between ESG sentiment and volatility

Notes: The results are estimated via the *QVAR* model with a 100-week rolling-window size, a lag length of order 1 (AIC), and a generalised forecast error variance decomposition at 200 steps forward. In *a* and *b*, the black area depicts the time dynamic connectedness, whereas the green and blue areas represent the long-term and short-term connectedness, respectively. Warmer shades reflect greater levels of connectedness in *c*. Warmer shades indicate net-transmission in *d*.

Source: own elaboration.

not agree with the findings of Liu et al. (2023), according to which strong ESG performance contributed to enhancing stock market stability in Japan during the COVID-19 pandemic. Consequently, the extent to which sentiment influences decision-making and therefore market risk depends on cultural differences. This enables investors to take advantage of cultural differences by using arbitrage strategies. In this context, Naeem et al. (2023) found that the COVID-19 outbreak generated arbitrage opportunities in the ESG markets of the US, Latin America and Asia-Pacific region, but not in Europe. It is therefore important to consider the specific characteristics of each market when investing in ESG indices. Furthermore, our results enable investors to detect under which market conditions sentiment can strongly predict movements in ESG markets. We find that in times of health or geopolitical crisis, the spillover effects between sentiment and volatility are greater in the upper quantiles than in the other quantiles, suggesting that profitable trading strategies can be conceived in such times to exploit the large price movements triggered by sentiment.

Furthermore, our results suggest that companies should consider sentiment when communicating their ESG performance. In fact, financial performance depends not only on a company's ESG score, but also on investor sentiment, particularly during turbulent events. Specifically, the findings show that sentiment influences volatility, notably during the COVID-19 health crisis and geopolitical crises such as the Russian-Ukrainian and Israeli-Palestinian conflicts. This could be explained by the fact that uncertainties prevailing in such periods make investors more sensitive to environmental and social risks, leading to a shift in investor attention from traditional investing to ESG investing and therefore to greater trading activity in the ESG market, which could cause significant fluctuations in stock prices. However, this greater attention might make it easier to raise funds in the market.

As far as regulators are concerned, the results suggest that they should strengthen communication on sustainability guidance, and use social media to draw investors' attention to ESG, particularly during periods of crisis such as the COVID-19 pandemic. This could be a signal to the government to encourage a green recovery in times of crisis, promoting ESG practices and thus fostering sustainable economic growth (Liu et al., 2023). In other words, the government should focus on leveraging the pandemic crisis to advance climate activism, develop a circular economy, and move toward resilient social and economic models capable of resisting disasters and infectious diseases (Taghizadeh-Hesary & Rasoulinezhad, 2023), thereby achieving UN's objectives. However, the strong connectedness observed between sentiment and volatility, particularly during extreme events, increases risk in the ESG market and makes it inefficient and unstable. In this context, policymakers should implement measures and regulations that encourage investors to undertake long-term investment instead of engaging in speculation that causes market instability and inefficiency. In addition, the implementation of standard

frameworks and guidelines for ESG reporting might improve transparency and comparability between companies, providing investors with trustworthy information on companies' environmental and social performance, thereby facilitating better decision-making and lowering market volatility (Liu et al., 2023). In fact, ESG commitments contribute to strengthening public confidence in a company, providing the prospect of significant protection against losses in times of crisis. Lins et al. (2017) asserted that ESG advantages are not constant over time, but are linked to the general level of confidence in companies and financial markets, and that these advantages tend to be greater when confidence is at its lowest. Furthermore, stock exchanges need to strengthen ESG disclosure requirements to enable investors to make informed decisions and reduce the market uncertainty that prevails in times of crisis.

Conclusions

The aim of this study is to examine the dynamic interplay between investor sentiment toward sustainable investment and the volatility of the ESG index in the Moroccan financial market. To this end, we constructed an investor sentiment index from the X platform (Twitter) and used *GARCH*-based ESG index volatility derived from weekly returns, as well as quantile and frequency connectedness approaches. The results show that the spillover effects between investor sentiment and ESG index volatility evolve over time, depending on distress events like the COVID-19 health crisis and geopolitical crises. Moreover, most of the time sentiment acts as a net receiver of shocks from ESG market volatility, mainly in times of crisis, but sometimes becomes a net sender of shocks. Furthermore, the results reveal that long-term spillovers dominate short-term spillovers, particularly during extreme events, implying the persistence of shock transmission due to high uncertainty. Finally, we observe that connectedness is stronger in the upper quantiles than in the middle or lower quantiles, suggesting the impact of extreme positive market conditions on spillover effects between ESG sentiment and volatility.

We investigated the connectedness between investor sentiment and the volatility of the ESG index in Morocco, but it would also be interesting to examine this connectedness across different developed and emerging countries. Additionally, it would be highly representative to use different ESG sentiment proxies, or to construct an aggregate ESG sentiment index combining the most relevant sentiment indicators. Moreover, it would be particularly useful to measure how sentiment expressed in social media improves the predictability of returns and the volatility of the ESG market. These questions could provide important directions for future research.

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