Asian Journal of Economic Modelling
ISSN(e): 2312-3656
ISSN(p): 2313-2884
DOI: 10.55493/5009.v12i1.4986
Vol. 12, No. 1, 53-75.

URL: www.aessweb.com

The impact of investor attention on green bond returns: How do market uncertainties and investment performances of clean energy and oil and gas markets affect the connectedness between investor attention and green bond?

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Article History
Received: 3 November 2023
Revised: 15 January 2024
Accepted: 22 January 2024
Published: 20 February 2024

Keywords
Climate change
Connectedness approach
Green bond returns
Investor attention
Market uncertainties
Investment performances.

JEL Classification:
D91; Q40.

ABSTRACT

This paper empirically investigates the spillover between investor attention and green bond returns by utilizing the connectedness approach. We will examine the impact of uncertainty in the stock, bond, and energy markets, as well as the success of clean energy, oil, and gas investments, on the relationship between green bonds and investor attention. We find that there are positive but small spillovers between investor attention and green bond returns. Besides, the connectedness between investor attention and green bond market performance is stronger in the short run than in the long run. Further, there is a time-varying feedback effect between green bond returns and investor attention. The connectedness approach also implies that the effect of investor attention on green bond returns is greatest in the COVID-19 period. This impact decreased throughout the war era. It is crucial to analyze the behaviour of green bonds in both typical and exceptional market situations. Making a general assessment may lead to insufficient information about how green bonds behave in extreme market conditions. Additionally, in instances of highly volatile market conditions, investor attention can serve as a valuable instrument for predicting the green bond market performance.

Contribution/ Originality: The originality of this study lies in its examination of the impact of investor attention on the performance of the green bond market. Since researching the relationship between green bond market performance and behavioral finance is a relatively new field, there is limited research in related areas.

1. INTRODUCTION

Climate change is an indisputable reality and a significant concern that occupies a prominent position on the global agenda. Furthermore, it is noteworthy that climate risk is increasingly emerging as a significant financial concern. Investors have made efforts to identify innovative solutions across many asset classes that successfully address the difficulties coming from climate change (World Bank Treasury, 2018). The imperative for collaboration between financial professionals and environmental advocates has led to the emergence of green bonds as a prominent instrument within the realm of sustainable finance. Since green bonds are only used for ecologically favorable projects, they are crucial in efforts to combat climate change. The world's first green bond, known as the Climate Awareness Bond, was issued by the European Investment Bank in 2007 and had a value of 600 million euros (European Investment Bank, 2021). In 2008, the World Bank issued its first green bond, which was valued at $300 million

(Organisation for Economic Co-operation and Development (OECD), 2015). Although the green bond market began in 2007, the year 2013 is known as the "green bond boom" (the year when the issuing of green bonds grew significantly). This is mostly because of the entry of corporations and financial institutions into the market in 2013. In addition, the International Capital Market Association (ICMA)'s release of the Green Bond Principles in 2014 International Capital Market Association (ICMA) (2014) marked a turning point, and the entry of Chinese issuers in 2016 significantly boosted the issuance of green bonds.

Investor attention in the green bond market is anticipated to rise in the future for a number of reasons. First, recent studies by Baulkaran (2019), Flammer (2021), Jormalainen (2020), Kuchin, Baranovsky, Dranev, and Chulok (2019), Tang and Zhang (2020), and Zhou and Cui (2019) demonstrate that issuing green bonds boosts a company's ESG[1] score, contributes to the improvement of the environment, raises the company's value as a result of a favorable market response, and increases ownership of the company as stock prices rise in response to the green bond. All of these results indicate that the green bond will provide diversification benefits to investors and garner their attention (Pham & Huynh, 2020). Second, the International Energy Agency (IEA) (2021) states that the number of companies setting a zero-emission target is increasing. Thus, worries about climate change are drawing investors' attention to the financial effects of climate change and motivating them to seek environmentally friendly investments (Pham & Huynh, 2020; Pham & Nguyen, 2022; Piñeiro-Chousa, López-Cabarcos, Caby, & Šević, 2021).

Third, according to the Climate Bond Initiative (CBI) (2018), the growth and success of the green bond market will be contingent upon the attention of retail investors. Retail investors' interest in sustainable investing has been rising significantly in recent years. Retail investors may also play a significant role in encouraging institutional investors to properly handle the risks associated with climate change and allocating cash towards green projects. These factors also serve as the motivation for this study, which looks at how investor attention affects the green bond market. In light of the growing influence of media on financial markets (Da, Engelberg, & Gao, 2011; Gan, Alexeev, Bird, & Yeung, 2020), it is imperative to examine the impact of investor attention on the green bond market. The primary research question of this paper is whether the global Covid-19 pandemic and the ensuing energy security issues brought on by the Russia-Ukraine war have an impact on investor interest in green bonds. By doing this, we will also look into how uncertainties in the stock, bond, and energy markets, as well as the investment performances of the clean energy, oil, and gas markets, affect the connectedness between green bonds and investor attention.

This study makes a valuable contribution to the existing body of research on green bonds by exploring the relationship between green bonds and investor attention. This is a significant area of investigation, as there is a limited amount of literature that examines the interplay between behavioral finance and clean energy finance. To our knowledge, there are only four studies that look at the relationship between investor attention and green bond market performance, but only two of them directly examine the connection between green bonds and investor attention: Pham and Huynh (2020) and Pham and Cepni (2022) while the other two, Piñeiro-Chousa et al. (2021) and Pineiro-Chousa, López-Cabarcos, and Šević (2022) directly examine the connection between green bonds and investor sentiment[2]. Our paper differs from Pham and Huynh (2020) and Pham and Cepni (2022) in several aspects. First, our data includes the impact of Russia's declaration of war on Ukraine. We examine the effects by splitting them into three sub-periods (pre-Covid-19, Covid-19, and the Russian invasion of Ukraine) in addition to the overall effect.

[1]Environmental, Social and Governance: The three main determinants that enable investors to gauge the sustainability and social impact of an investment in a company.

[2] Investment sentiment and investor attention are two distinct behavioral concepts. Investor sentiment is the process by which investors form their beliefs (Barberis, Shleifer, & Vishny, 1998). Besides, investor sentiment is characterized as either a tendency for speculating or as optimism or the pessimism toward stocks in general (Baker & Wurgler, 2006). On the other hand, emphasizing that the concept of attention began to be a central issue in an emergent cognitive psychology in the late 1950s, Kahneman (1973) defines attention as limited cognitive resources and emphasizes that attention is required for the processing of information and decision making. However, despite conceptual differences between investor sentiment and investor attention, both behavioral concepts' predictions are similar (Prapan & Vagenas-Nanos, 2022).

Second, we also examine the effect of uncertainties in the stock, bond, and energy markets and the investment performances of the clean energy, oil, and gas markets on the link between green bonds and investor attention. While Pham and Huynh (2020) examine only general market conditions, including the bond, stock, and energy commodity markets, on the relationship between green bonds and investor attention, Pham and Cepni (2022) examine the volatility of the stock, bond, and energy markets similar to ours. However, they do not concentrate on how the investment performances of the clean energy, oil, and gas markets affect this relationship.

Following is a summary of the main findings. First, the connectedness between investor attention and the success of the green bond market is stronger in the short term compared to the long term. Second, there are positive but small spillovers between investor attention and green bond returns. The impact of investor attention on the returns of green bonds is most pronounced during the Covid-19 period. This effect diminishes during the war period. Third, it can be observed that the influence of investor attention on other series is more pronounced in the short-term as opposed to the long-term. Fourth, there is a feedback channel between green bond returns and investor attention. This feedback channel exists due to the fact that green bond returns that are a net receiver of shocks from investor attention are likely to be followed by green bond returns that are a net transmitter of shocks. Fifth, during periods of Covid-19, all market volatility has a higher impact on investor attention and green bond returns. Finally, VIX (CBOE[3] Volatility), CLEAN (S&P (Standard&Poors) Global ECO Index, which includes stocks of 40 firms operating in ecology-related industries) and OVX (CBOE crude oil volatility index), are the shock transmitters in the network, but OVX affects the system less than other shock transmitters.

This paper's next sections are organized as follows: Section 2 focuses on earlier studies about green bonds and the level of investor interest. The data utilized and summary statistics are provided in Section 3. The methodology is outlined in Section 4. Section 5 discusses the empirical results, while Section 6 presents the final observations.

2. EMPIRICAL LITERATURE

2.1. Empirical Literature on the Green Bond Market

Over the past five years, not only has the literature on the green bond market expanded, but so has the scope of research. Studies on the green bond market generally focus on investigating the difference between the green bond and conventional bond (greenium or green bond premium). A greenium has been proven by Karpf and Mandel (2017); Baker, Bergstresser, Serafeim, and Wurgler (2018); Zerbib (2019); Nanayakkara and Colombage (2019); and Pietsch and Salakhova (2022), among others. In other words, they discover that the yield on a green bond is lower than that of a conventional bond. Larcker and Watts (2020) and Petrova (2016), however, do not discover any proof of a greenium. However, Baulkaran (2019) and Ferrer, Shahzad, and Soriano (2021) find that green bonds have similar features in terms of pricing and yields to conventional fixed-income corporate bonds. The only distinction is that green bonds are only utilized for eco-friendly initiatives (Fatica & Panzica, 2021). However, Jormalainen (2020) demonstrates that with a premium of 0,60 to 0,84%, green bonds are more affordable than conventional bonds.

The second strand of the literature investigates the relationship between oil prices and green bond dynamics. Lee, Lee, and Li (2021) point out that movements in oil prices have explanatory power for green bond price dynamics. Kanamura (2020) uses different green bond indices and looks at the link between green bonds and oil prices and finds that while there is a positive correlation between the Bloomberg Barclays MSCI (Morgan Stanley Capital International), the S&P green bond index, and crude oil price returns, there is a negative correlation between the Solactive green bond index and crude oil prices. Su, Chen, Hu, Chang, and Umar (2023), on the other hand, find that while the effect of oil prices on the green bond return is positive in the short run, this positive effect turns negative in the medium and long run. On the other hand, they also observe that the effect of the green bond return on the oil

[3] Chicago board options exchange.

price is positive, indicating that because of the instability in the Middle East, Covid-19, and the modest scale of green bonds, green bonds are not regarded as effective ways to mitigate the oil crisis.

Dutta, Jana, and Das (2020) examine whether green investments respond significantly to oil price shocks and observe that green assets are more sensitive to oil market volatility than to fluctuations in oil prices. However, Nguyen (2020) finds that there is a negative correlation between OVX and green bond returns, but this negative effect is statistically insignificant. Besides, OVX is statistically less significant when evaluated together with the uncertainty in the energy and stock markets (VXXLE (CBOE energy sector ETF volatility) and VIX, respectively). Pham and Nguyen (2022) find that, especially in low uncertainty periods, there is a small degree of connectedness between green bond returns and uncertainty indices (VIX, OVX, and EPU (economic policy uncertainty)). It means that spillover effects are smaller. Yet, in the case of high uncertainty, spillover effects are greater but less permanent. Azhgaliyeva, Mishra, and Kapsalyamova (2021) investigate the effects of oil price shocks (supply, demand, and risk shocks) on green bond issuance and demonstrate that oil supply shocks affect green bond issuance in a positive way in the private sector.

The third strand of green bond research focuses on the impact of the issuance of green bonds on the financial performance of firms, reflecting the investor perspective. For example, Baulkaran (2019) and Tang and Zhang (2020) observe that stock prices increase after green bond issuance. They also find that green bond issuance contributes to increased corporate ownership and improved stock liquidity. Besides, issuing green bonds can provide greater media visibility and benefit existing shareholders. Tang and Zhang (2020) and Reboredo and Ugolini (2020) find that green bonds can help companies expand their investor base and improve their corporate social responsibility. Unlike Tang and Zhang (2020), they reveal that the green bond market is weakly linked to the stock market. Moreover, consistent with Tang and Zhang (2020) and Flammer (2021), the stock market is positively impacted by the issuance of green bonds. Companies improve their environmental performance and experience an increase in ownership.

The fourth strand investigates the relationship between green bonds, clean energy, and environmental performance. Fatica and Panzica (2021) find a reduction in the carbon intensity of non-financial companies' assets after the green bond issuance. Conversely, Hammoudeh, Ajmi, and Mokni (2020) deduce that the green bond index does not have the power to predict environmental (ECO and CO_2 emission allowances) and financial variables (the US 10-year treasury bond index). Wang, Ma, Bouri, and Zhong (2022) take the issue in terms of signaling theory and provide evidence that the issuance of green bonds supports the signaling theory, that is, that it signals that companies are indeed exhibiting climate-friendly corporate behavior (not doing green washing) by issuing green bonds. They also find that issuing green bonds has an impact on climate risk concerns; in other words, most firms have elevated climate risk concerns after issuing green bonds. In terms of the relationship between clean energy, Yan, Wang, Athari, and Atif (2022) find that there is a bi-directional causal relationship between green bonds, oil prices, gold prices, and clean energy stocks, and an increase in the clean energy stock positively affects the green bond market. On the contrary, Tang, Aruga, and Hu (2023) reveal that the green bond market has not yet had much impact on the clean energy and fossil fuel markets because they find a weak negative correlation between green bond and fossil fuel and clean energy markets.

2.2. Empirical Literature on Investor Attention

The relationship between investor attention and asset pricing is one of the most researched topics in behavioral finance literature. When looking into how investor attention affects asset price dynamics, Peng (2005) discovers that capacity constraints lead to delayed consumption behavior and have an impact on how quickly information is factored into asset pricing. Barber and Odean (2008), Da et al. (2011), and Andrei and Hasler (2015) find that investor attention has a substantial effect on determining asset prices. According to Nafar (2015), the level of investor attention affects security prices. More recently, Halousková, Stašek, and Horváth (2022) developed Google search-based military conflict attention and general stock market attention to examine how the volatility of asset prices in specific countries is affected by investors' attention to the war between Russia and Ukraine. They recover that, whereas the impact of the conflict attention measure was negligible before the invasion, it considerably affected volatility during the period of increasing war risks. Jiang, Liu, Peng, and Wang (2022) investigate how investor attention and asset pricing anomalies interact and discover a positive correlation between investor attention and subsequent anomaly returns.

Some researchers, Liu, Kang, Guo, and Sun (2021); Piñeiro-Chousa, López-Cabarcos, and Ribeiro-Soriano (2020); and Yang, Liu, Yu, and Han (2017), investigate the connection between investor attention and stock markets, while others, Ballinari, Audrino, and Sigrist (2022); Long, Wang, and Cui (2016); and Said and Slim (2022), have widened their research by including stock market volatility into the associated relationship. Yang et al. (2017) employ the IAVS (increments of the attention volume for each stock) and discover that the impact of the IAVS on stock market movement is more consistent and significant when compared to the Baidu index. Additionally, they discover that the IAVS may have a forecasting effect on stock market movement on the same trading day. Piñeiro-Chousa et al. (2020) investigate the effect of investor attention on the water companies' stock returns and find that the stock returns of water companies are negatively correlated with investor attention because investors' increased sensitivity to environmental issues has encouraged them to conserve water, which has resulted in a decline in the stock returns of water companies. Focusing on China's A-share listed new energy companies and polluting companies, Liu et al. (2021) examine the relationship between air pollution, investor attention, and stock prices and discover that while the market is in a bullish period, investors are optimistic, and air pollution as bad information negatively affects investors' expectations, prompting investors to show less attention in the stock market. However, when the stock market is performing poorly, investors will be more cautious, and air pollution will cause investors to start focusing more and more on the stocks of new energy and polluting industries. To gauge investor attention in a specific industry, Long et al. (2016) create two distinct indices, a positive and a negative one, and reveal that the positive index has a substantial adverse effect on stock index volatility but no discernible impact on stock index return. The return and volatility of the stock index are both significantly influenced by the negative index, though. More recently, in their study of the impact of institutional and retail investor attention on stock market volatility, Ballinari et al. (2022) discovered that both have the opposite effect on stock return volatility: While institutional investor attention lowers volatility, retail investor attention increases it on days after news releases. Said and Slim (2022) document that investor attention in the short run has a beneficial effect on future volatility. However, the impact of investor attention is projected to reverse in the long run.

Numerous studies have examined the connection between investor attention/investor sentiment and environmentally friendly investments in light of current climate change concerns. For example, Reboredo and Ugolini (2018) conclude that Twitter sentiment has no significant impact on returns, volatility, or trading volumes, whereas Song, Ji, Du, and Geng (2019) indicate that investor sentiment, measured by the GSVI (Google search volume index), towards renewable energy can partially explain the return and volatility of renewable energy stock. According to López-Cabarcos, Pérez-Pico, and López-Pérez (2019), social network sentiment affects the returns of sustainable companies but has no bearing on those of unsustainable ones. Wang, Yu, and Shen (2021) discover a significant negative link between media environmental attention and the stock returns of green industry companies. Wan, Xue, Linnenluecke, Tian, and Shan (2021) look at the effect of investor attention on investments in clean energy and fossil fuels during the Covid-19 period in China and discover that the performance of clean energy companies rises during the pandemic (the period of attention shift in investor behavior during the unexpected crisis), but that of fossil fuel companies does not. Similar to Wan et al. (2021), Deng, Zhou, Peng, and Zhu (2022) find in their study for China that the occurrence of environmental events will dramatically alter investor attention and ultimately boost pro-environmental investment.

The effects of investor attention have also been studied in different fields. For instance, Amin and Ahmad (2013) investigate the impact of investor attention on the firm's financial performance and discover that profitability, liquidity, and volatility are all partially influenced by investor attention. Besides, they find that investor attention has a greater impact on a company's liquidity than on its profitability or volatility. Xiao and Wang (2021) investigate whether the adjustment of EPU in G7 and BRIC (Brazil, Russia, India, and China) countries alters the link between investor attention and oil market volatility. The initial finding of this study reveals that shifts in investor attention can exert a favorable influence on total oil market volatility. Then, when the total volatility is divided into good volatility and bad volatility, it is discovered that the bad volatility is more affected by changes in investor attention than the good volatility. Additionally, they point out that EPU strengthens the positive relationship between investor attention and low volatility; however, EPU only has an impact on this relationship in the US and Canada. Andrei, Friedman, and Ozel (2023) investigate the connection between economic uncertainty and investor attention to earnings announcements at the firm level and find that investor attention to firm-level data is increasing as economic uncertainty rises.

2.3. Empirical Literature on the Relationship between Investor Attention and the Green Bond Market

Investor attention, a well-recognized predictor of financial market performance in the field of behavioral finance, has not been thoroughly investigated in previous research on green bonds. There are just two scholarly articles, namely Pham and Huynh (2020) and Pham and Cepni (2022), that specifically investigate the correlation between green bonds and investor attention. By using the Diebold and Yilmaz (2012) connectedness model, Pham and Huynh (2020) evaluate how investor attention, as measured by GSVI, affects the performance of the green bond market. Additionally, they assess the importance of the bond, stock, and energy commodity markets in the relationship between green bonds and investor attention. They come to the conclusion that investor attention can affect green bond returns and volatility, but the relationship varies over time. More specifically, the relationship between investor attention and green bond market performance exhibits significant short-term interdependence; however, the relationship fades in the long run. By constructing a quantile connectedness network and using two alternative measures of investor attention which are retail investor attention, as measured by GSVI and institutional investor attention as measured by Bloomberg Terminal news, Pham and Cepni (2022) investigate the impact of investor attention on the performance of green bonds. Furthermore, the researchers examine the impact of several macroeconomic variables on the relationship between investor attention and the financial performance of green bonds. According to their findings, a reciprocal relationship (feedback effect) exists between investor attention and green bond returns. This relationship is particularly obvious in the context of the Covid-19 pandemic, which has exacerbated instability in financial markets. Additionally, according to the VIX, OVX, EPU, and MOVE (Merrill Lynch option volatility estimate) indices, market volatility has a significant impact on the correlation between green bonds and investor attention.

However, only two papers, Piñeiro-Chousa et al. (2021) and Pineiro-Chousa et al. (2022), directly examine the relationship between green bonds and investor sentiment. Piñeiro-Chousa et al. (2021) use the GMM (generalized method of moments) to analyze the impact of investor sentiment on green bond performance. Additionally, they look into how investor sentiment and green bond returns are related to the S&P 500 index, VIX, and the S&P GSCI (Goldman Sachs Commodity Index) Natural Gas Index (GAS), which are each proxy for the stock market, stock market volatility, and investment performance of the natural gas market, respectively. They derive investor sentiment from the messages posted on Twitter and find a significant influence of investor sentiment on green bond performance. They also discover that the returns on green bonds are found to be unaffected by VIX, but to have a negative relationship with returns on the S&P 500 and GAS indices. Using the Wang (2015) panel smooth transition regression model, Pineiro-Chousa et al. (2022) investigate whether the S&P 500, VIX and MSCI World index would affect investor sentiment and consequently on the return of green bonds. Their findings demonstrate that variations in the S&P 500 and VIX indices do not affect the relationship between investor sentiment and returns on green bond indices, but that the MSCI World index, to some extent, leads this relationship to deviate from the linear one.

Numerous studies indirectly examine the relationship between green bonds and investor attention. For example, Broadstock and Cheng (2019) calculate the green bond market sentiment by employing 5300 news articles relating to green bonds and provide evidence that the relationship between green and black bonds is sensitive to a variety of factors, including positive and negative news-based sentiment towards green bonds. Tang and Zhang (2020) investigate whether green bond issuance benefits shareholders by concentrating on investor attention as well. They demonstrate that with the issuance of green bonds, stock turnover and Google search volume both considerably increase around the event days. This shows that investors pay attention to the firm's environmentally friendly initiatives. Gao, Li, and Wang (2023) investigate the influence of investor attention on green security markets, including green bonds and green stocks in China, and show that green stocks and investor attention are more interdependent than green bonds. Chen, Weber, and Saravade (2022) investigate the general investor reaction to green bond announcements in the stock markets of Mainland China and Hong Kong and discover that both stock markets react positively to green bond announcements, indicating that investor reaction is favorable.

3. DATA AND SUMMARY STATISTICS

This study employs the S&P green bond index (SPGB) to monitor the performance of the green bond market. This index tracks the performance of green-labelled bonds that are issued globally, weighted by market value (S&P Global, 2023a). Next, the study adopts the Google Search Volume Index (GSVI) as a proxy for investor attention since it is widely used in the body of behavioral finance literature. The Search Volume Index quantifies the level of interest for particular keywords. Put simply, it offers data on the frequency of searches for a specific keyword during a specific timeframe. In addition, search engines gather information on search queries and classify them according to their frequency of occurrence. This data enables marketers to discern high-performing keywords and comprehend market patterns. Hence, the attention of retail investors may be quantified using GSVI, which in turn can forecast stock returns and trading volumes (AlContentfy, 2023; Lai, Chang, Hu, & Chou, 2022).

Using GSVI, we incorporate the keyword "Green bond" to provide an attention index for the green bond market. Our attention measures are retrieved from Google Trends. Since the launch date of the SPGB is July 31, 2014, our data set ranges from July 31, 2014, to April 28, 2023, with a total of 2275 daily observations. Figure 1 and Figure 2 depict the daily values of GSVI[4] and SPGB indices. There has been an upward trend in the GSVI over time. Investor attention and green bond returns have grown, particularly since 2016. One possible explanation could be the entry of Chinese issuers into the green bond market. It has been noted that once Covid-19 has been designated as a pandemic by the WHO (World Health Organization) (i.e., after March 11, 2020), investor attention as well as green bond returns surge. Both indices continue their upward trend but begin to fall after February 24, 2022 (when Russia started its invasion of Ukraine). One possible explanation is that when the war was first declared, nations, particularly those in the EU (European Union), began to explore alternatives to Russian gas and focused on guaranteeing energy security; as a result, the use of coal-fired power plants was prioritized during this time, followed by a truly doubled transition to clean energy (Tollefson, 2022).

[4] Google calculates the relative search volume for a keyword with an indexed value between 0 and 100. For a given keyword, 0 denotes the lowest relative search interest and 100, the highest relative search interest. For extended periods of time, Google provides monthly statistics rather than daily data. Due to this, daily data for each month is multiplied by the corresponding month's search interest weight in order to properly compare periods in long-run data. This ensures that the processed daily data and monthly data follow roughly the same paths. In accordance with Pham and Cepni (2022) we add 1 to this index before log-transforming because the GSVI index has a minimum value of 0.

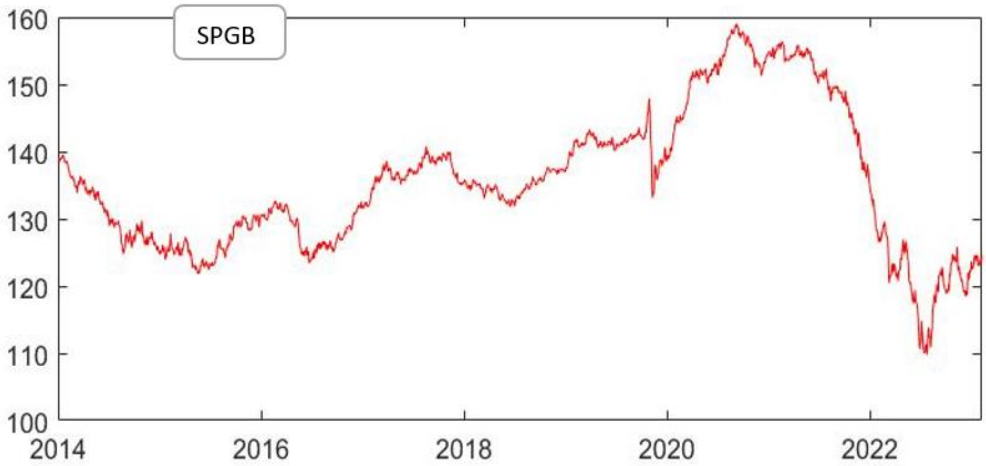

Figure 1. Daily values of SPGB.

Source: S&P Global (2023b).

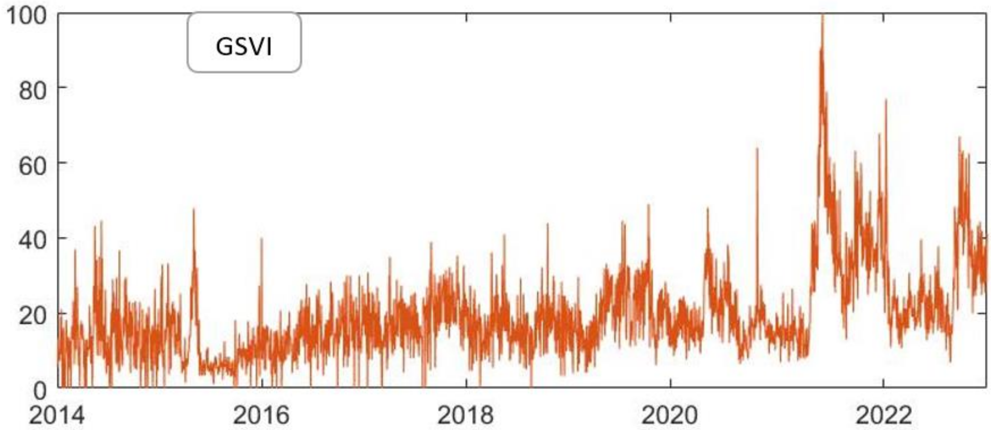

Figure 2. Daily values of GSVI.

Source: Google Trends (2023).

In addition to these variables, we also use control variables to look at how volatile the stock, bond, and energy markets are (VIX, MOVE, and OVX, respectively). These variables also show how well investments have done in the oil, gas, and clean energy markets (OIL, GAS, and CLEAN, respectively). All series are non-stationary at levels but stationary in their first difference. Therefore, all series are used in log-differenced analyses in the subsequent analyses, depending on the outcomes of the unit root tests. The reasons for selecting these control variables are as follows:

- The VIX index can serve as a valuable instrument for investors in evaluating the level of risk, fear, or market stress before making investment decisions since it provides insights into the overall movement of the stock market (Kuepper, 2023; Kumar, 2023). An increase in the VIX index frequently indicates an escalation in market volatility, potentially impacting the green bond market. The VIX serves as a representative measure for stock market volatility within the model.
- The fixed-income markets that include treasury, corporate debt, and high-yield corporate debt are intricately linked to the green bond market, and developments in those markets have an impact on the green bond market (Reboredo & Ugolini, 2020). The MOVE index, also referred to as the bond market volatility index, is used to gauge the volatility of the fixed-income market.
- Dutta et al. (2020) reveal that green assets exhibit a higher degree of sensitivity to oil market volatility compared to swings in oil prices. They also discover that crude oil volatility has a major impact on the returns on environmental investments, which in turn influences investor attention in these markets (Pham & Cepni, 2022). OVX is used as a proxy for energy market volatility in the model.

- Based on the fact that green bonds are exclusively employed for investments that promote environmental sustainability and taking into account that approximately 32% of green bond issuance is allocated towards clean energy investments (CBI, 2023), it is expected that there will be a significant correlation between the returns of green bonds and the performance of the clean energy market. The S&P Global ECO index (CLEAN) is employed as a proxy for assessing the investment performance of the clean energy market.
- Naeem, Nguyen, Nepal, Ngo, and Taghizadeh–Hesary (2021) and Piñeiro-Chousa et al. (2021) discover a substantial negative correlation between natural gas returns and green bond returns. It implies that green bond returns rise following a fall in the natural gas market, and vice versa. It demonstrates the hedging feature of green bonds in decreasing portfolio risk for investors in the gas market, therefore influencing investors' attention to green investments. Therefore, the S&P GSCI natural gas index (GAS) is used as a proxy for the investment performance of the natural gas market.
- The decline in oil prices has a negative impact on the attractiveness of green assets for investors while simultaneously increasing the attraction of oil investments. Consequently, this shift in preference towards oil investments significantly influences the level of attention that investors allocate to green investments. Besides, Khamis and Aassouli (2023) observe green bonds as an effective diversifier in a portfolio of natural gas and crude oil, indicating that investors in the oil and gas market are turning to green bonds to reduce portfolio risk, suggesting that green bonds can provide effective diversification benefits to fluctuations in oil and gas returns. S&P GSCI crude oil index (OIL) is used as a proxy for the investment performance of the oil market.

Table 1 demonstrates the descriptive statistics of the log-differenced series. Unconditional variance of SPGB and CLEAN is the lowest, followed by that of OIL, GAS, MOVE, OVX, VIX, and GSVI. This suggests that SPGB and CLEAN have the lowest volatility, while GSVI has the highest. Moreover, GSVI, OVX, VIX, and MOVE are positively skewed, whereas SPGB, CLEAN, OIL and GAS are negatively skewed. In addition, Jarque-Bera (JB) test statistics show that all series are not normally distributed. According to ERS (Elliott, Rothenberg, and Stock) unit root test, all series are stationary[5].

Table 1. Descriptive statistics of the log-differenced series.

Variables	GSVI	SPGB	OVX	VIX	MOVE	CLEAN	OIL	GAS
Mean	0.001	0	0	0	0	0	0	0
Variance	0.399	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Skewness	0.07 (0.148)	-0.2*** (0.000)	1.5*** (0.000)	1.2*** (0.000)	0.5*** (0.000)	-0.6*** (0.000)	-2.6*** (0.000)	-0.2*** (0.000)
Excess kurtosis	7.04*** (0.000)	4.6*** (0.000)	29.6*** (0.000)	7.3*** (0.000)	8.3*** (0.000)	11.6*** (0.000)	64.0*** (0.000)	3.2*** (0.000)
JB	4709.8*** (0.000)	2056.4*** (0.000)	83999.2*** (0.000)	5769.9*** (0.000)	6674.0*** (0.000)	13086.9*** (0.000)	391612.6*** (0.000)	998.2*** (0.000)
ERS	-4.2*** (0.000)	-7.9*** (0.000)	-13.5*** (0.000)	-22.8*** (0.000)	-4.8*** (0.000)	-9.1*** (0.000)	-20.1*** (0.000)	-16.2*** (0.000)

Note: ***p<0.01. ( ) denotes standard errors.

Figure 3 demonstrates that the SPGB, OVX, VIX, MOVE, CLEAN, OIL, and GAS indices displayed dramatic responses during the global pandemic period. GAS has experienced the most volatility since Russia's invasion of Ukraine, followed by SPGB, CLEAN, and MOVE.

[5] The stationarity of all series is also supported by the KPSS (Kwiatkowski, Phillips, Schmidt, Shin) unit root test. The results of KPSS unit root tests are available from the author on request.

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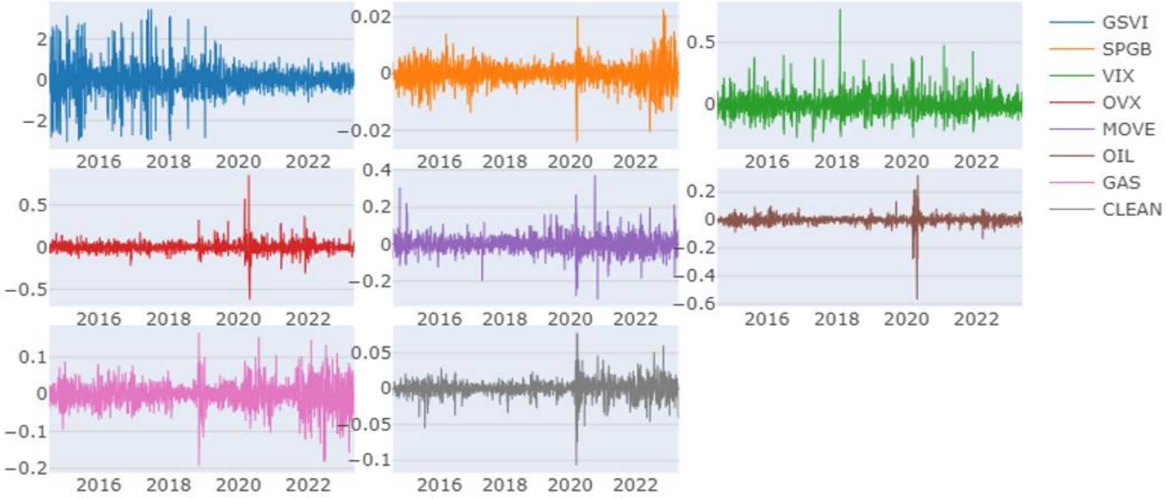


Figure 3. Historical evolution of the series.

Source: OVX, VIX, and MOVE indices are retrieved from investing.com. CLEAN, OIL, GAS and SPGB indices are retrieved from S&P Global. GSVI is retrieved from google trends.

4. METHODOLOGY

We investigate the relationship between green bonds and investor attention using the Diebold and Yilmaz (2012) connectedness framework. This approach offers a framework for examining the impact of an individual variable as well as the influence of the entire network. Considering a covariance stationary N-variable VAR(p) is:

$$x_t = \sum_{i=1}^{p} \Theta_i x_{t-i} + \varepsilon_t \qquad (1)$$

Where x_t is a vector of n endogenous variables, including the green bond index, the GSVI and other control variables? Put simply, $x_t = (x_{SPGB,t}, x_{GSVI,t}, x_{OIL,t}, x_{GAS,t}, x_{CLEAN,t}, x_{VIX,t}, x_{OVX,t}, x_{MOVE,t})'$ is a N-vector of variables (with N=8 variables in our case in point). The time index, t, has a range of 1 to T. Individual abbreviations are represented, respectively: Green bond returns (SPGB), investor attention (GSVI), investment performance of the crude oil market (OIL), investment performance of the natural gas market (GAS), investment performance of the clean energy market (CLEAN), volatility index (VIX), oil volatility index (OVX), and bond market option volatility estimate (MOVE). p represents the lag order. Θ_i are parameter matrices and $\varepsilon_t \sim (0, \Sigma)$ is the residual vector. We employ the moving average form to get the dynamic structure in our VAR system as $x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}$, where the NxN coefficient matrices A_i obey the recursion $A_i = \sum \Theta_j A_{i-j},\ j = 1, \ldots, p$, with A_0 being an NxN identity matrix and with $A_i = 0$ for i < 0.

In order to assess the extent to which each variable contributes to the explanation of other variables, we employ H-step-ahead GFEVD (generalized forecast error variance decomposition), which is the variance decomposition that is independent of the order of the variables. Due to the non-orthogonalization of the shocks to each variable, the sum of the contributions to the variance of the forecast error does not equal one (Diebold & Yilmaz, 2012). H-step-ahead GFEVD is:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_j)} \qquad (2)$$

Where σ_{jj} is the standard deviation of the error term for the j-th equation, Σ is the variance matrix for the error vectorε, and e_i is a vector with values 1 for the i-th element and 0 otherwise. Therefore, θ_{ij}^{g} (H) represents the effect of variable j on i in terms of the margin of error variance estimation, which is characterized as bidirectional connectedness from j to i. In this case, each predictive error variance decomposition can be normalized as follows:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} \qquad (3)$$

The following is the empirical process: Initially, we calculate the VAR (vector autoregression) model, selecting the lag order according to the Akaike Information Criteria. Then, the forecast error variance decompositions that result from a VAR model are estimated, and this forms the basis for the subsequent measures. The ability to distinguish between net transmitter and net receiver of a shock further aids in understanding the underlying dynamics and makes it easier to formulate policy implications when results for total, directional, and net interdependence are obtained. Finally, an investigation of interdependence is conducted using a rolling window strategy. We follow Diebold and Yilmaz (2012) in using a 200-day rolling window and a 10-step forecast horizon.

5. EMPIRICAL RESULTS

Following the static connectedness between variables is the dynamic connectedness. The static model encompasses the entire sample data, enabling it to capture the long-term dynamics between the variables. In contrast, the dynamic model focuses on the short-term dynamics between the variables (Pham & Huynh, 2020). Connectedness table gives the average values of the series over time. We can see in Table 2 demonstrates that investments in the gas market come in second with a 95.48% impact on investor attention, with shocks within its own system having the biggest impact at 98.91%. Besides, TO indicate the total directional spillovers to others from each of the series, and FROM indicates the total directional spillovers from others to each series. We can see that total directional spillovers from others to CLEAN and VIX are relatively large, with the spillovers from others explaining 38, 60% and 38, 58%, respectively, followed by OVX and OIL. Likewise, the total directional spillovers from CLEAN and VIX to the others are at most 43, 73% and 43, 48%, respectively. Specifically, VIX and CLEAN are both those that have the greatest impact on other series and those that are most affected by other series. Other series have an impact on green bond returns, at 13, 12%. The spillover between the series is also observed in Table 2. For instance, when the GSVI row is analyzed, it is seen that 0,24% of the external shock to GSVI is due to VIX, 0,23% to SPGB, 0,18% to CLEAN, 0,12% to GAS, 0,11% to OIL, 0,11% to OVX, and 0,10% to MOVE. Similarly, when the SPGB row is analyzed, the largest share of external shocks to SPGB stems from CLEAN (8.07%) after the shocks that occur within their own system (86, 88%). Additionally, it is clear that the largest share of external shocks to VIX stems from CLEAN, with a rate of 18, 99%. As for the net directional spillovers, the largest are from CLEAN to others, with 5.12%. Additionally, the total spillover index is 23%, which means that 23% of the forecast error variation in all series is, on average, a result of spillovers throughout the entire sample. Finally, we can reach the conclusion that while the SPGB, MOVE, OIL, and GAS are net receivers of the shocks, the GSVI, VIX, OVX, and CLEAN are net transmitters of the shocks according to the static model.

Table 2. Static connectedness among variables.

Particulars	GSVI	SPGB	VIX	OVX	MOVE	OIL	GAS	CLEAN	FROM
GSVI	98.91	0.23	0.24	0.11	0.10	0.11	0.12	0.18	1.09
SPGB	0.26	86.88	1.05	0.89	1.70	0.50	0.65	8.07	13.12
VIX	0.24	0.12	61.42	7.88	7.91	3.19	0.25	18.99	38.58
OVX	0.07	0.17	8.37	66.29	3.55	15.73	0.23	5.59	33.71
MOVE	0.15	1.05	10.40	4.52	75.71	2.15	0.50	5.52	24.29
OIL	0.15	0.18	4.23	17.83	2.26	69.96	1.01	4.37	30.04
GAS	0.23	0.14	0.43	0.67	0.51	1.53	95.48	1.01	4.52
CLEAN	0.14	4.04	18.75	6.39	4.40	4.31	0.57	61.40	38.60
TO	1.25	5.92	43.48	38.29	20.42	27.53	3.34	43.73	183.96
Inc. own	100.1	92.80	104.91	104.58	96.13	97.49	98.82	105.12	Total spillover index: 183.96/800 =23%
NET	0.15	-7.20	4.91	4.58	-3.87	-2.51	-1.18	5.12	

According to the dynamic model results presented in Table 3, while the total spillover index is 23% in the long run, it increases to 41.14% in the short run. This shows that the variables affect each other more in the short run. While investor attention accounts for only 0.26% of the external shock to green bond returns in the long run, it accounts for 3.59% in the short run. Similarly, while green bond returns account for only 0.23% of the shocks to investor attention in the long run, they account for 3.83% in the short run. These findings reveal that the association between investor attention and green bond returns exhibits a significant influence on one another in the short term; however, this association diminishes over time. This observation is consistent with the prior investigations conducted by Pham and Huynh (2020) and Pham and Cepni (2022). This is an indication that investors adjust their decisions quickly by monitoring price fluctuations in financial markets and analyzing market conditions. This is the ideal way for an investor to maximize their profits while minimizing their losses. Furthermore, the biggest shock spillovers from investor attention to other series in the short run are found to be towards MOVE with 3.63%, SPGB with 3.59%, and GAS with 3,52%. Additionally, it is evident that VIX and CLEAN are the ones that affect the other series' most strongly in the short run as well as in the long run. One of the most important differences is that while the effect of investor attention on other series is 1.25% in the long run, it jumps to 22.55% in the short run. Finally, although their coefficients have various sizes, their status as shock transmitters and receivers remains the same, except for investor attention. Investor attention shifts from being a net transmitter of shocks in the static model to a net receivers in the dynamic model. This could be because green bonds have become attractive to investors seeking to make investments that align with sustainability objectives. As a result, investor attention will continue to rise in the long run. However, in the short run, investors may become net receiver of shocks due to fluctuations in market conditions.

Table 3. Dynamic connectedness among variables.

Particulars	GSVI	SPGB	VIX	OVX	MOVE	OIL	GAS	CLEAN	FROM
GSVI	72.64	3.83	4.42	4.14	3.71	3.73	4.14	3.38	27.36
SPGB	3.59	62.98	5.26	4.30	6.93	4.67	3.83	8.44	37.02
VIX	2.85	3.74	48.50	8.87	9.44	5.15	2.44	19.00	51.50
OVX	2.96	3.46	9.27	53.35	5.34	14.81	3.78	7.04	46.65
MOVE	3.63	5.67	11.22	5.79	57.81	4.75	2.90	8.24	42.19
OIL	3.40	3.26	5.94	16.36	4.76	56.13	4.00	6.14	43.87
GAS	3.52	4.54	4.40	4.68	4.02	5.16	69.16	4.53	30.84
CLEAN	2.60	6.06	20.11	7.00	6.48	5.12	2.36	50.27	49.73
TO	22.55	30.57	60.61	51.13	40.68	43.39	23.45	56.77	329.16
Inc. own	95.19	93.55	109.1	104.48	98.50	99.51	92.61	107.05	Total spillover index: 329.16/800= 41.14%
NET	-4.81	-6.45	9.11	4.48	-1.50	-0.49	-7.39	7.05	

The dynamic total connectedness index (Figure 4) gives us the data we need to look at how structural changes and times of crisis have affected the series' connectedness levels over time. Our sampling period encompasses significant developments such as the Fed's decision to raise interest rates and the slowdown of the Chinese economy in 2016, Donald Trump being elected as US President in November 2016, the British government's formal start of the process of exiting from the EU (Brexit) in 2017, declaring Covid-19 a pandemic by WHO on March 11, 2020, Brexit officially taking place on 31 January 2020, and Russia starting to invade Ukraine on 24 February 2022. In line with these developments, it is understood that the system's shock spillover is heightened during particular periods. The dynamic total connectedness index mostly fluctuates between thirty-five and forty-five percent. However, there is one very important exception, which is the declaration of a global pandemic in 2020. The index has dramatically increased over the fifty percent. The Covid-19 pandemic's rapid global spread has had a significant impact on financial markets all around the world. Investors suffered substantial losses in a short period of time as a result of the unprecedented level of risk it produced. Four consecutive meltdowns in the US stock market and the ensuing decline in the oil market coincided with the rapid spread of market turmoil in global financial markets (Huang, Chen, Xu, & Xia, 2023; Zhang, Hu, & Ji, 2020). The armed conflict between Russia and Ukraine, which produced market uncertainty around the world, does not result in a major spike in the index, as it did with Covid-19. The primary reason for this is that the market reaction to this conflict did not last as long as it did for Covid-19.

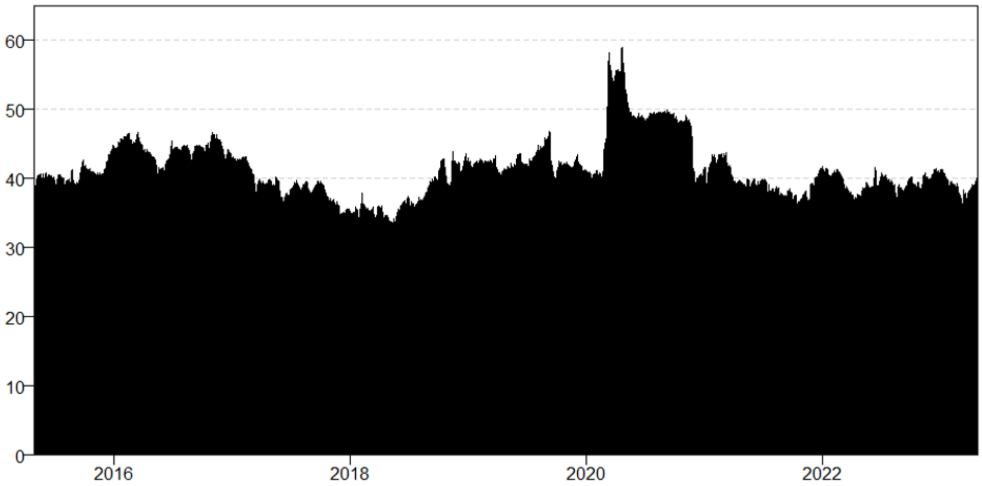


Figure 4. Dynamic total connectedness index.

TO_i denotes how series i affects all series, whereas $FROM_i$ demonstrates how all series influence series i. The net total directional connectivity (NET) shows their difference. The last row (NET) in Table 3 gives the average value of the total NET variable over time, but there may also be periods when the net variable changes from positive (net shock transmitter) to negative (net shock receiver) or from negative to positive over time. Dynamic net total directional connectedness (Figure 5) allows us to observe these behaviors. If the series has a value above the x-axis, it indicates the periods when the relevant series is a net shock transmitter, and a value below the x-axis indicates the periods when the relevant series is a net shock receiver. Figure 5 demonstrates that while GSVI, SPGB, and GAS have generally maintained the status of shock receivers in all periods, OVX, VIX, and CLEAN have continued to be shock transmitters in general. The NET row in Table 3 indicates that MOVE and OIL are net shock receivers; nevertheless, throughout time, because of both internal and external dynamics, their status has changed. After the declaration of the global pandemic by WHO, OVX, VIX, MOVE, and CLEAN are net shock transmitters, while SPGB, along with GAS, is becoming a major shock receiver.

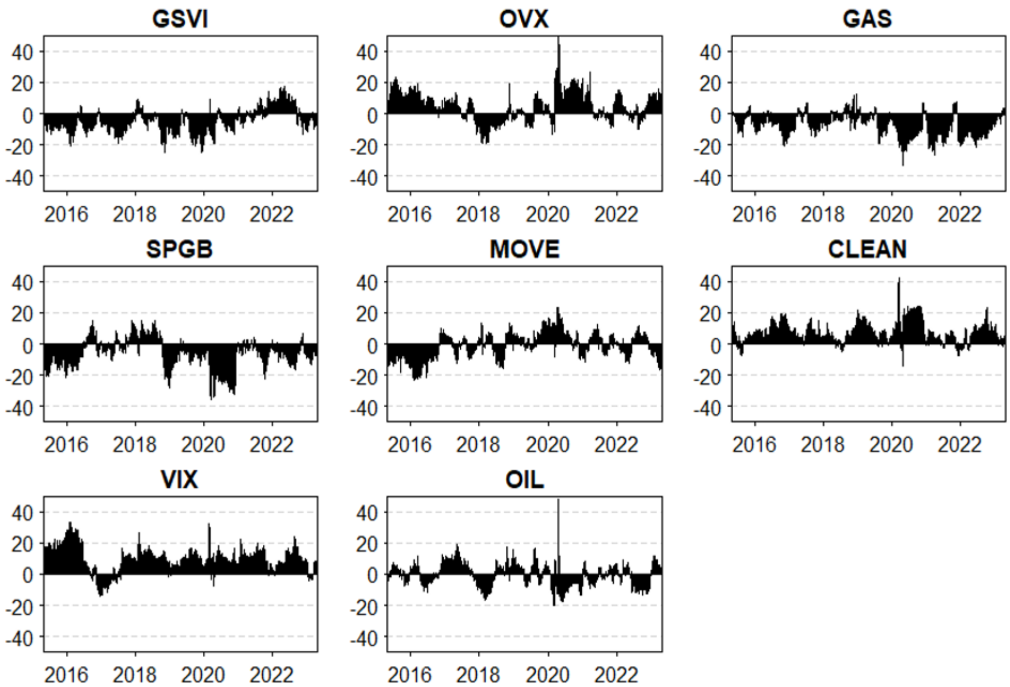


Figure 5. Dynamic NET total directional connectedness.

Figure 6 demonstrates the net pairwise spillovers between the series. If $NPSO_{ij} > 0$ ($NPSO_{ij} < 0$), then series i affects series j more (less) than series j affects series i. Accordingly, based on the observed net pairwise spillover between GSVI and SPGB, it can be inferred that green bond returns that receive net shocks from investor attention are more likely to be succeeded by green bond returns that transmit net shocks. This demonstrates the existence of a feedback effect between the returns of green bonds and the attention of investors. As investor attention towards green bonds grows, so may the returns of these bonds. This may attract the attention of investors. During the time period under examination, SPGB had a net reception role in their pairwise relations with all other series (with the exception of their relationship to GAS). On the other hand, spillover from green bond returns increased at the end of 2017 and early 2019 (see Figure 5), due to the fact that the green bond market grew by 82% to $158,5 billion in 2017 compared to 2016, and by $269,1 in 2019 (CBI, 2023) due to the high level of liquidity in the system and the growing awareness of these assets among businesses and investors, these shocks are transmitted to OVX, VIX, MOVE, and CLEAN. Furthermore, after the declaration of Covid-19 as a global pandemic, CLEAN is more effective on GSVI than GSVI on it, while GSVI is more effective on GAS and OIL in the same period. After Russia declared war on Ukraine, GSVI has more influence on clean energy, oil, and gas. However, the influence of GAS and CLEAN on GSVI increases in subsequent periods. On the other hand, SPGB is more impacted by CLEAN, VIX, and MOVE throughout both the war and the COVID-19 periods than SPGB impacts on them. In terms of investment performances, during the first declaration of COVID-19 and the war, CLEAN had a greater impact on SPGB, while SPGB had a greater impact on GAS than GAS had on SPGB.

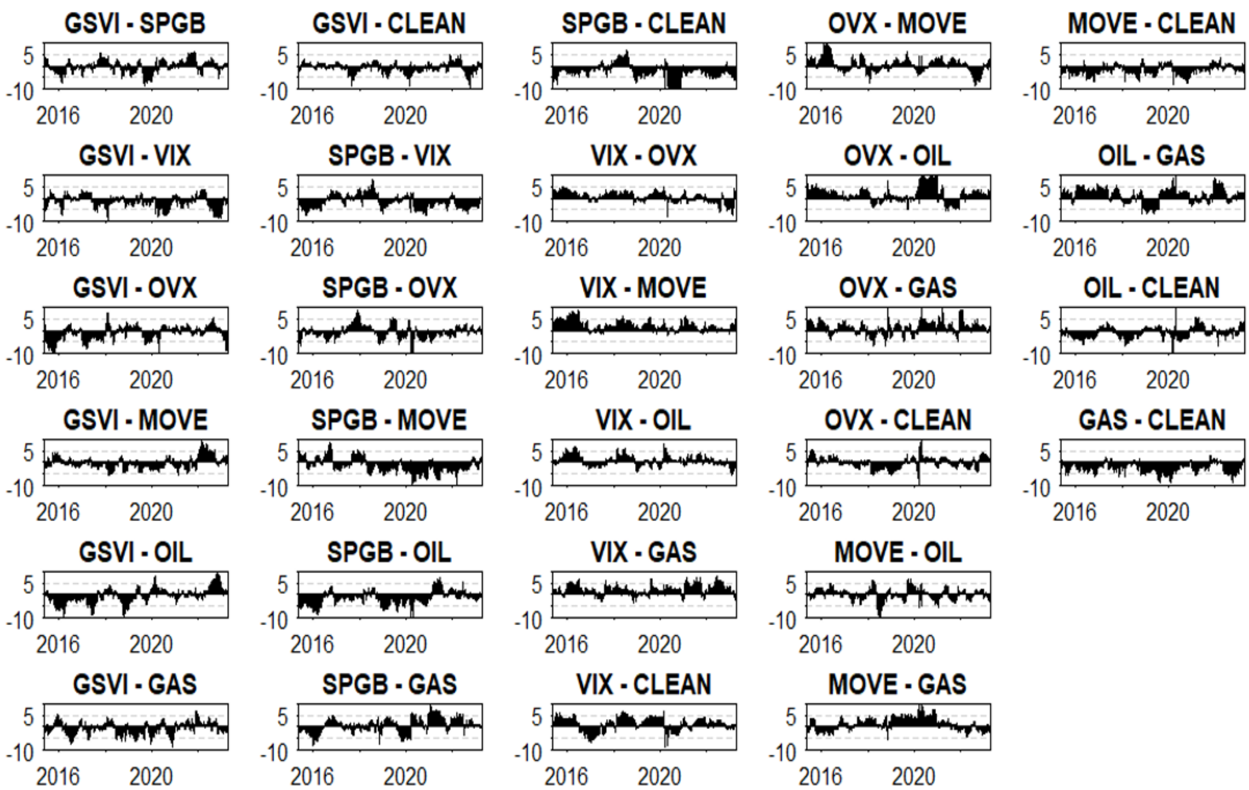


Figure 6. Net pairwise directional connectedness ($NPSO_{ij}$).

With the aid of network analysis, Figure 7 depicts the shock distribution between the series in order to make it easier to see how the average net relationships between the series have changed over time. The arrow's direction indicates which series, on average over time, delivered shocks to which series. For example, the investment performances of clean energy market are, on average, a net shock transmitter to green bond returns, as shown by the arrow from CLEAN to SPGB. The thickness of the edge between the two series determines how connected they are;

therefore, thicker edges indicate a stronger relationship. Accordingly, the connectedness between SPGB and CLEAN is the one that is most strongly connected, followed by the connectedness between VIX and GAS. Being the strongest connectedness between green bond returns and investment performance of the clean energy market, as well as being a net shock transmitter of investment performance of the clean energy market to green bond returns, is reasonable. Because green bonds are solely utilized for environmentally friendly investments and the majority of green bond issuance, roughly 32%, is used for clean energy investments (CBI, 2023). This is corroborated by Yan et al. (2022), who show that a rise in clean energy stocks has a favorable impact on green bond markets, and by Tang et al. (2023) who find that the impact of the green bond market on the clean energy and fossil fuel industries is minimal (explains why the direction of the arrow is CLEAN to SPGB and not SPGB to CLEAN). The magnitude of each circle represents the aggregate extent of the net total directional connectedness for each series. We can see that the greater the circle, the more it impacts the system as a transmitter of shocks between series and the more it is influenced by the system as a receiver of shocks. Besides, the color of each circle helps determine whether a series is a net transmitter or a net receiver. In the network plot below, a series is depicted in blue if it is the net shock transmitter within the network and in yellow if it is the net shock receiver. Accordingly, VIX and CLEAN are the largest shock transmitters on average across time, whereas SPGB and GAS, followed by GSVI, are the largest shock receivers. It is understandable that the VIX index, also known as the fear index, is in the position of the variable that spreads shocks the most to the other series because it is used to determine the general expectation about the near future of the market and because a high VIX index makes investments riskier and forces the investor to act more cautiously.

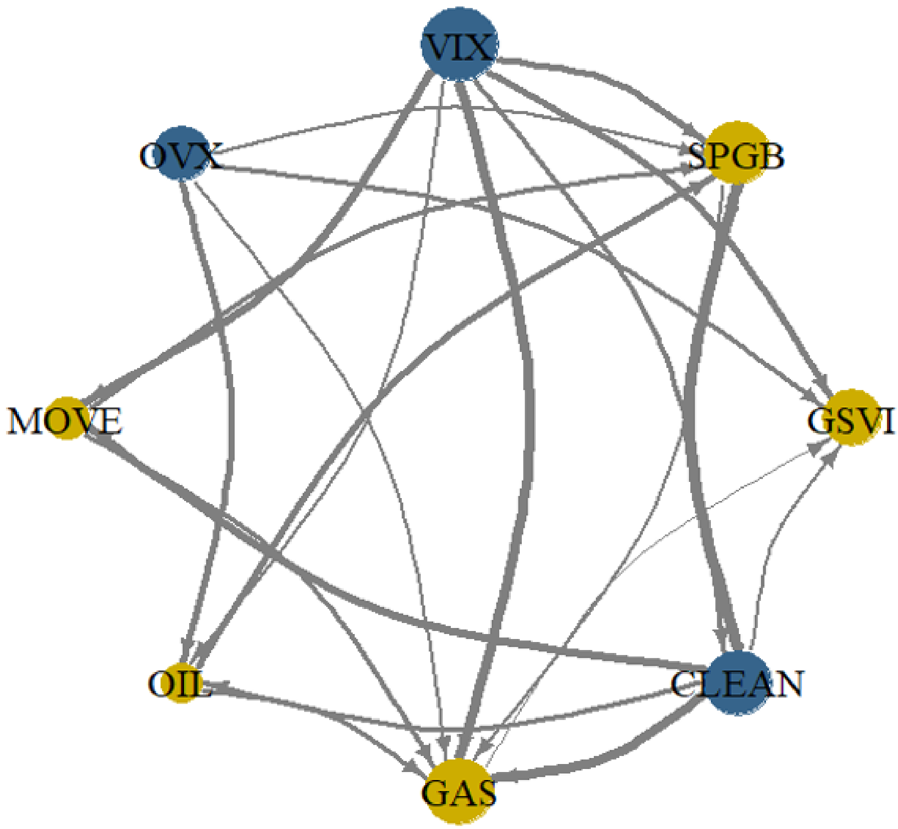


Figure 7. Network analysis.

5.1. Net-Pairwise Directional Connectedness in Sub-Periods

The connection can be individually investigated in sub-periods to better comprehend the effects of Covid-19 and the Russian invasion of Ukraine in related dynamic relationships. There are three sub-periods: Pre-Covid-19 (March

31, 2014–March 10, 2020), Covid-19 (March 11, 2020–February 23, 2022), and the Russian invasion of Ukraine[6] (February 24, 2022–April 28, 2023). According to Table 4, SPGB remains constant and maintains its status as a net shock receiver during all sub-periods. VIX is the largest shock transmitter in all sub-periods. The largest shock recipient during pre-Covid-19 was GSVI, but during COVID-19 and the war, the biggest shock recipient was SPGB. Additionally, GSVI was the largest shock receiver prior to COVID-19, but during COVID-19 and the war, it transitioned from being a net receiver to a net transmitter.

Table 4. Net Directional connectedness in three sub-periods.

Variables	Pre-COVID-19	COVID-19	Russian invasion of Ukraine
GSVI	-7.22	1.13	1.54
SPGB	-4.13	-8.20	-6.76
VIX	10.09	12.09	8.24
OVX	2.77	1.47	-5.42
MOVE	-3.32	0.69	-0.57
OIL	1.08	-0.10	-5.33
GAS	-5.81	-8.14	-2.51
CLEAN	6.55	1.07	10.81

Note: (+) Net-transmitter, (-) Net-recipient.

Table 5 depicts the dynamic connectedness between SPGB and GSVI in three sub-periods. Investor attention had the biggest impact on green bond returns during the COVID-19 period, with a 5.69%. This is corroborated by Pham and Cepni (2022) who find that investor attention has a significant impact on green bond returns under extreme conditions. On the other hand, green bond returns significantly affected investor attention in the pre-Covid-19 period, at 3.25%. There was a significant decrease in their connectedness during the war period. Compared to the other two periods, the trend towards green energy is stronger during the COVID-19 period. The implementation of green recovery plans by governments in reaction to the epidemic attracts investors' attention to clean energy investments and raises stock values (Ghabri, Ayadi, & Guesmi, 2021; Wan et al., 2021). However, Russia's invasion of Ukraine brought the problem of energy security to the highest level, but as a result of the impossibility of a rapid transition to clean energy in a short time, countries dependent on Russian oil and gas preferred to procure oil and natural gas from other countries. Countries planning to accelerate the transition to clean energy by closing their coal and nuclear power plants have decided to postpone their plans for now (Besson, 2022).

Table 5. Dynamic connectedness between green bond returns and investor attention in three sub-periods.

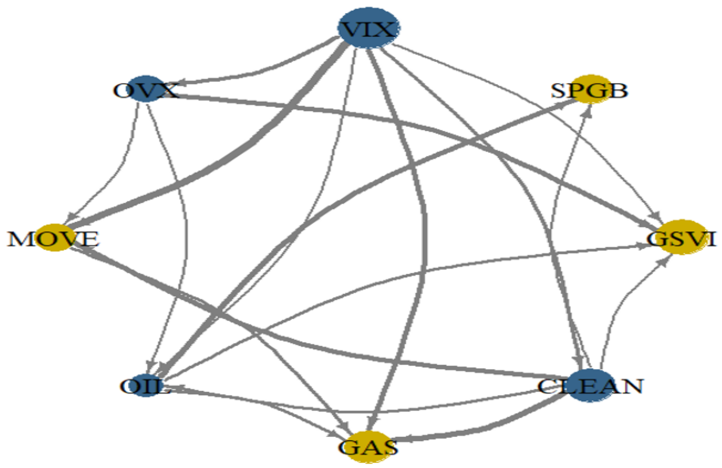
Pre-COVID-19			COVID-19			Russian invasion of Ukraine		
Variable	GSVI	SPGB	Variable	GSVI	SPGB	Variable	GSVI	SPGB
GSVI	75.36	3.25	GSVI	80.60	3.05	GSVI	95.33	0.13
SPGB	2.75	70.79	SPGB	5.69	65.83	SPGB	0.10	63.04

Figure 8 that the total connectedness index is particularly weakening from the pre-Covid-19 period to the war period (from 38.82% in the period before Covid-19 to 33.05% in the period of Covid-19 and to 27,82% in the period of war). VIX and CLEAN are net shock transmitters in all sub-periods, while SPGB and GAS are net shock receivers. This is in line with the results obtained by Tiwari, Abakah, Gabauer, and Dwumfour (2022), who find that green bonds are the primary net recipients of shocks, whereas clean energy is the primary net transmitter of shocks. OIL was a net shock transmitter before COVID-19, but during COVID-19 and the Russian invasion of Ukraine, it became a net shock receiver. It may be inferred that negative NET effects during COVID-19 and the war are more pronounced for the oil and gas markets, in line with the findings of Karkowska and Urjasz (2023).

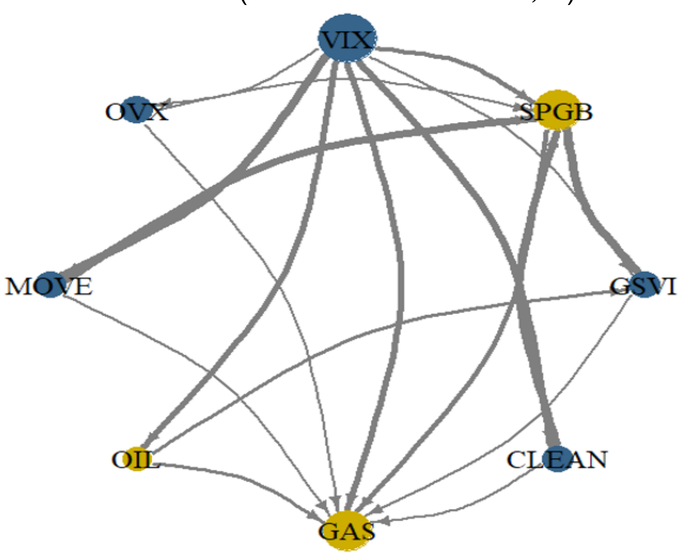
[6] It will henceforth be referred to as the war period.

Furthermore, the net shock transmitters of CLEAN to SPGB and VIX to MOVE are the same in all sub-periods. GSVI is a net shock receiver from VIX, OVX, and OIL and CLEAN in pre-Covid-19. However, in Covid-19 period, GSVI is a net shock receiver from OIL and VIX, whereas GSVI is a net transmitter to SPGB and GAS. In the war period, GSVI was a net shock transmitter only to OIL. It can be concluded that GSVI has become a net shock transmitter during the periods of Covid-19 and war. Moreover, the frequency of shocks increases during the Covid-19 period, that is, when volatility is high. In times of crisis, a strong correlation can arise between market volatility and oil, gas, and energy investments. These investments may be more exposed to the effects of market fluctuations. For example, volatility in the stock market and energy markets increases the risk perception of investors and affects their investment decisions. High volatility may cause investors to be more cautious (Balash, Faizliev, Sidorov, & Chistopolskaya, 2021). However, the frequency of shocks decreases during the period of war. One possible explanation is that both Covid-19 and the war have created financial market volatility and shifts in investors' risk appetite. However, the Covid-19 epidemic has caused a higher volatility shock due to its global economic impact. In addition, the Russian-Ukrainian conflict has not been as severe as the Covid-19. This is explained by market assumptions that the war wouldn't last very long (Izzeldin, Muradoğlu, Pappas, Petropoulou, & Sivaprasad, 2023).

Pre-COVID-19 (Total connectedness: 38,82).



COVID-19 (Total connectedness: 33,05)



Russian invasion of Ukraine (Total connectedness: 27,82)

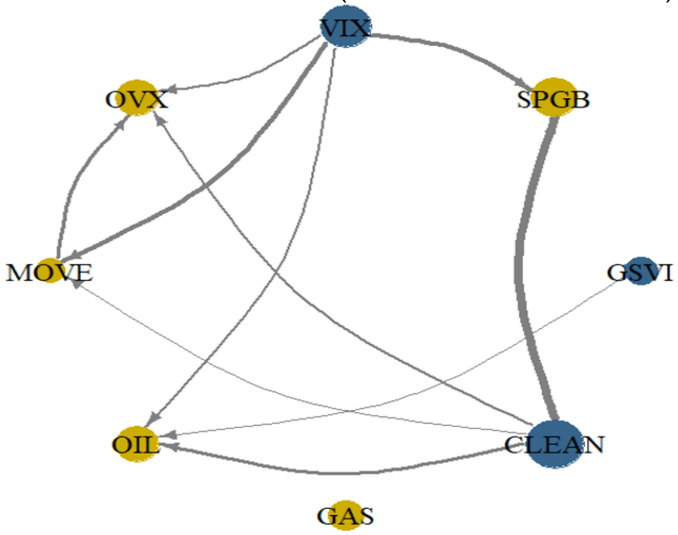


Figure 8. Network analysis in three sub-periods.

6. CONCLUSIONS AND POLICY IMPLICATIONS

This study attempts to examine the interdependence between investor attention and green bond returns. Specifically, we investigate how volatility in stock, bond, and energy markets and the investment performances of clean energy, oil, and gas markets affect investors' attention to green bonds and consequently green bond returns. We employ Diebold and Yilmaz (2012) connectedness approach, and the dataset included in this study comprises daily data spanning from July 31, 2014 to April 28, 2023.

Our main findings are as follows: First, while investor attention only contributes 0.26% of external shocks to green bond returns in the long run, it contributes 3.59% in the short run. This finding suggests that the dynamic model, as opposed to the static model, better represents the relationship between investor attention and green bond returns. Furthermore, it implies that there is a larger correlation between investor attention and returns on green bonds over the short term than over the long term. This finding is in line with earlier studies by Pham and Huynh (2020) and Pham and Cepni (2022). To put it more precisely, the Covid-19 period has the most pronounced impact of investor attention on green bond returns. The aforementioned effect experienced a reduction during the war period. Second, while green bond returns account for only 0.23% of the shocks to the investor's attention in the long run, they account for 3.83% in the short run. This finding indicates the positive but small spillover effects between investor attention and green bonds, which aligns with the findings of Pham and Huynh (2020) and Piñeiro-Chousa et al. (2021).

Third, in contrast to the long run, where the impact of investor attention on other series is 1.25%, the short-run impact is 22.55%. This is an indication of the swift adjustments made by investors in the financial markets. Fourth, when examining the net pairwise spillover effects between the returns of green bonds and investor attention, it can be observed that green bond returns that are a net receiver of shocks from investor attention are likely to be followed by green bond returns that are a net transmitter of shocks. This demonstrates the existence of a feedback channel between green bond returns and investor attention. This result is consistent with Pham and Huynh (2020). Fifth, during the Covid-19 pandemic, market volatility exerts a greater influence on investor attention and green bond returns compared to the impact that investor attention and green bond returns have on market volatility. Pham and Nguyen (2022) find significant correlations between green bond returns and the uncertainty indices (VIX, OVX, and EPU) during periods of high uncertainty, which lends support to this conclusion. Finally, VIX, CLEAN, and OVX are the shock transmitters in the network, but OVX affects the system less than other shock transmitters. This finding seems to be consistent with the previous study from Nguyen (2020), where OVX has a statistically less significant impact on the returns on green bonds when compared to the volatility in the energy and stock markets (VXXLE and

VIX, respectively). In addition, VIX has a greater effect on the green bond returns than other types of market volatility (MOVE and OVX), which is consistent with Nguyen (2020) findings, who discover that VIX has a greater effect on the performance of the green bond market than VXXLE and OVX.

There are several implications. First, the presence of a feedback effect between investor attention and green bond returns indicates that investor attention significantly influences the performance of green bonds. In other words, as investors' attention on green bonds grows, so does demand for these bonds, driving prices to climb and yields to decline. This could result in better returns for investors who hold these bonds. As a result, green bonds can serve as an alternative funding mechanism for the transition to a low-carbon economy. Second, green bond returns are often affected in a similar way to conventional bonds during extreme market conditions. However, since green bonds are issued specifically considering environmental, social, and governance factors, the returns of green bonds may be less affected than other bonds in some cases. For instance, investor attention is higher in the Covid-19 period than in the pre-Covid period. This highlights the importance of examining how green bonds behave under normal and extreme market conditions. Making a general assessment may lead to insufficient information about how green bonds behave in extreme market conditions.

Besides, in instances of highly volatile market conditions, the attention of investors can serve as a valuable instrument for predicting the performance of green bonds. However, it is important for investors to exercise caution, as the correlation between green bonds and investor attention is subject to fluctuations over time. The following suggestions are proposed for conducting further analysis in future studies. First, TVP-VAR (time-varying parameter VAR) could be a useful alternative methodology for future research. This model has the ability to detect and analyze significant changes in the structure of the data set, such as financial crises or economic recessions, and forecast the consequences of these changes. Therefore, both the date of Covid-19 being officially designated a pandemic and the date of war being officially proclaimed may be classified as shocks in the model, and their impacts can be examined in more detail. Second, the impact of investor attention on green bonds in the USA and China, the two main green bond issuers, can be investigated in addition to the relationship between green bonds and investor attention on the global level. An examination can be conducted to determine the degree to which market uncertainties impact investor attention in two countries.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The author states that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: Upon a reasonable request, the supporting data of this study can be provided by Aysegul Uckun-Ozkan.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

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