Dynamic Connectedness and Investment Strategies between Commodities and ESG Stocks: Evidence from India

Ishwar Sharma[1], Meera Bamba[2], Bhawana Verma*[3] and Bharti Verma[4]

Abstract

The study investigates the connectedness between commodities and ESG stocks of India using the extended joint connectedness approach. The study found a time-varying relationship between commodities and ESG stocks. It also discovered that there is a low spillover between the two. However, the total connectedness increased during the Russia-Ukraine war but remained low. The study found that crude oil and natural gas act as net transmitters, while ESG stocks and gold act as net receivers. ESG stocks are negatively connected with gold and have a low degree of positive correlation with crude oil and natural gas. Therefore, portfolio diversification opportunities exist between commodities and ESG stocks. The study exhibits that investors may derive significant benefits by adjusting their portfolios based on the optimum weights provided by the portfolio construction technique. The study provides valuable insights for portfolio managers, investors, and policymakers.

JEL: Q56; G11; O16; Q02

Keywords: ESG; Commodities; connectedness approach; Portfolio diversification

[1]Assistant Professor, Indira Gandhi University, Meerpur, Rewari, Haryana, India, ishwarsharmaigu@gmail.com.
[2]Associate Professor, Chaudhary Bansi Lal University, Bhiwani, Haryana, India, meerabamba@gmail.com.
[3] * Corresponding author. Research Scholar, Indira Gandhi University, Meerpur, Rewari, Haryana, India, vermabhawana436@gmail.com. ORCID ID: https://orcid.org/0000-0002-2766-5155
[4] Research Scholar, Indira Gandhi University, Meerpur, Rewari, Haryana, India, bv918947@gmail.com

INTRODUCTION

Sustainable investments have become crucial in portfolio construction in contemporary scenarios (Branch et al., 2019; Henriksson et al., 2019). Currently, investors are giving importance to non-financial aspects of a company along with financial aspects, as a company's success depends on these non-financial factors as well. ESG (Environmental, Social and Governance) elements are non-financial elements that measure the sustainability performance of firms (Santamaria et al., 2021). ESG investments have recently caught the attention of investors; therefore, it is crucial to understand the relationships between ESG stocks and other financial assets to make an optimal sustainable portfolio. Commodity price variations heavily impact their stock value as they are inputs in many industries (Cagli et al., 2022). Commodities are considered safe-haven assets, and as such, they have become a vital financial asset in portfolio management (Enilov et al., 2023; Junttila et al., 2018; Lahiani et al., 2021; Naeem et al., 2022; Rubbaniy, Khalid, Syriopoulos, et al., 2022). It is critical to examine the interconnectedness between commodities and ESG stocks, given the importance of commodities and ESG investment.

ESG stocks outperform conventional stocks in times of financial crisis (Deshmukh & Sharma, 2022; Nofsinger & Varma, 2014; Omura et al., 2021) as ESG stocks differ from traditional stocks; therefore, their relationship with commodities may exhibit diverse connectivity features (Cagli et al., 2022). Extensive research has been conducted to explore the interconnectedness between commodities and conventional stocks (Aziz et al., 2020; Bouri et al., 2017; Chatziantoniou et al., 2022; Drake, 2022; Guru et al., 2023; Kirithiga et al., 2018; Kumar et al., 2023; R. Lu et al., 2023; Mensi et al., 2022; Perumandla & Kurisetti, 2018; Rehman et al., 2023; Younis et al., 2023), however, the literature lacks insights on the relationship between commodities and sustainable stocks. It is crucial to examine this relationship as investors pay more attention to sustainable investment. The current study examines the connectedness between commodities and ESG stocks in the Indian context. Besides this, it also examines such connectedness during the Russia-Ukraine war. Moreover, it determines the optimum portfolio weight for a commodity-ESG stock portfolio. The study has broader ethical and sustainable portfolio management implications.

This work's contributions to the body of literature can be summed up as (i) This study examines the connectedness between commodities and ESG stocks. (ii) It addresses a research gap by focusing on a period that includes significant events such as the Russia-Ukraine War. The paper highlights the connectedness between commodities and ESG stocks during this turbulent period. (iii) An extended joint connectedness method based on time-varying parameter vector autoregression is employed in this study. Compared to the traditional connectivity approach, this new approach offers various advantages. (iii) It provides the portfolio weight to create the optimum portfolio. Following these best practices, this study investigates the relationship and explores investment strategies between ESG stocks and commodities.

This research holds practical significance for investors seeking to optimize their financial returns and to uphold their commitment to socially responsible investment. It will help them optimize their risk-return profiles and maintain their commitment to sustainability. It will help investors and portfolio managers make an optimal portfolio that balances financial and sustainability goals. It will assist policymakers in creating policies regarding sustainable and ethical business practices.

The remainder of this paper is structured as follows: Section II outlines the literature review, followed by an in-depth description of the study's methodology in Section III. Section IV presents the empirical results, while Section V covers the conclusion.

LITERATURE REVIEW

Currently, investors and portfolio managers are paying greater attention to sustainable investment. Numerous research has been conducted in the field of sustainable investments (Arif et al., 2021; Balcilar et al., 2017; Broadstock & Cheng, 2019; Cagli et al., 2022; Dutta et al., 2020; Elsayed et al., 2022; Ferrer et al., 2018; Jain et al., 2019; Kaiser & Welters, 2019; X. Lu et al., 2023; Naeem et al., 2022; Rubbaniy, Khalid, Rizwan, et al., 2022; Shaik & Rehman, 2023; Umar et al., 2020). Dutta et al. (2020) discovered that the effect of crude oil prices on environmental investments is statistically insignificant. Additionally, some previous studies examined how sustainable investments can help reduce risk and act as safe havens. Rubbaniy et al. (2022) discovered the safe-haven qualities of ESG equities during the coronavirus pandemic. Similarly, Kaiser & Welters (2019) found that while ESG portfolios provide lower returns during large momentum rallies, they also significantly reduce total portfolio risk during momentum falls, indicating the safe-haven nature of ESG investing. Likewise, Verheyden et al. (2016) found that ESG screening can have long-term risk-reduction effects. Besides this, Elsayed et al. (2022) investigated how financial markets and green bonds are related. The results indicate that the relationship between green bonds and financial markets is unstable over time, and diversification options are more evident in the short run.

Financial market interconnectedness is an important factor in portfolio diversification and risk management. Shaik & Rehman (2023) found that ESG stock market indices are interconnected, with the Africa, Latin America and Middle East ESG stock indices serving as net shock transmitters and the United States and Asia Pacific's ESG stock indices serving as net volatility receivers. Meanwhile, Cagli et al. (2022) found a mediocre level of linkage between the commodities and ESG stocks and concluded that diversification opportunities exist between them. Besides this, studies on the linkage between conventional stocks and sustainable investments, such as Balcilar et al. (2017), found a significant linkage between conventional and sustainable equities. However, Arif et al. (2021) found that traditional investments had a low intergroup connectedness while green investments had a high intergroup connectedness. Jain et al. (2019) further discovered no difference in the performance of conventional and sustainable indices, indicating that the former is a suitable replacement. Meanwhile, (Lundgren et al., 2018) investigated the relationship and found a substantial correlation between stock indices of renewable energy sources and conventional assets.

Some studies highlight the influence of global events on ESG investments, such as Akhtaruzzaman et al. (2022) looked at the relationship between the media coverage index (MCI) and the ESG leader indices in terms of dynamic connectedness and discovered that the connection between the two was more robust during the pandemic's peak. Similarly, Jiang et al. (2023) found that ESG had higher post-war spillover effects on the oil market. After the war, the oil market's impact on the new energy market grew. Likewise, Lu et al. (2023) discovered that the dynamic total connectedness of the indices' returns shows a significant spike after the COVID-19 pandemic. Similarly, Naeem et al. (2020) examined the relationships between electricity, the clean and carbon energy markets, and oil shocks. The study discovered higher interconnectedness during the shale oil boom and the global financial crisis. Total connectivity is higher in the short term than in the long run. Besides this, Cagli et al. (2022) discovered connectedness between ESG stocks and commodities rises during turmoil periods like COVID-19 and the European debt crisis. The studies concluded that the interconnectedness between financial markets increases during times of turmoil.

Moreover, Commodities act as a hedge against inflation as commodity and stock returns show a low degree of correlation during an inflationary period (Purankar & Singh, 2017; Charfeddine & Benlagha, 2016; Jaiswal & Uchil, 2016). Therefore, it is crucial to understand the stock and commodity relationship for risk management and portfolio diversification. Many previous studies have explored the relationship of commodities with conventional stocks (Aziz et al., 2020; Chatziantoniou et al., 2022; Guru et al., 2023; Kirithiga et al., 2018; Mensi et al., 2022; Rehman et al., 2023; Younis et al., 2023)**.** An equity-commodity portfolio provides diversification benefits as they have a low relationship (Jena & Goyari, 2016; Perumandla & Kurisetti, 2018; Purankar & Singh, 2020). Numerous studies have investigated the correlation between commodities and traditional stocks; however, green stocks differ from traditional stocks, so their relationship with commodities may show distinct connectivity features (Cagli et al., 2022). Currently, there is a growing focus on socially responsible investing, and as a result, it is important to examine the relationship between commodities and ESG stocks. The current study aims to explore this relationship in the Indian context.

DATA AND METHODOLOGY

1. Data

We have collected daily closing price data of commodities and ESG (Environmental, Social, Governance) stocks from April 2019 to December 2023. This time covers a diverse range of market conditions, including periods of major global events and geopolitical tension. In light of Russia's declaration of war on February 24th, 2022 (Saini & Sharma, 2023), the present study takes into consideration the data from February 24th, 2022, to December 31st, 2022, in the context of the ongoing conflict between Russia and Ukraine. The analysis focuses on this specific time frame to gain insights into the impact of the war. The NIFTY 100 ESG Enhanced index is used for ESG stocks as it comprises companies with strong ESG performance. It measures companies' sustainable practices. Gold is classified as a precious metal, while natural gas and crude oil belong to the energy sector. In India, there are two major stock exchanges, BSE and NSE. Since NSE has a higher number of shares traded, the proposed study only considers it. MCX and NCDEX are the two leading commodity exchanges in India. Still, data for commodity indices has been collected from MCX, India's largest commodity exchange, with a market share of 96.7% in the financial year 2022-23. We used the index series because it represents the overall market performance. The data was collected from MCX and NSE websites, and the variables are shown in Table 1.

Table 1: Description of Variables

Variable	Index Name
Natural	MCX iCOMDEX Natural Gas
Gas Crude	MCX iCOMDEX Crude Oil
Oil Gold	MCX iCOMDEX Gold
ESG Stocks	Nifty100 ESG Enhanced

The closing price data of all the variables are non-stationary. We have converted all series into returns by applying a natural log returns transformation formula to all raw data to make them stationary. The formula is: Rt = ln (Pt /Pt-1)

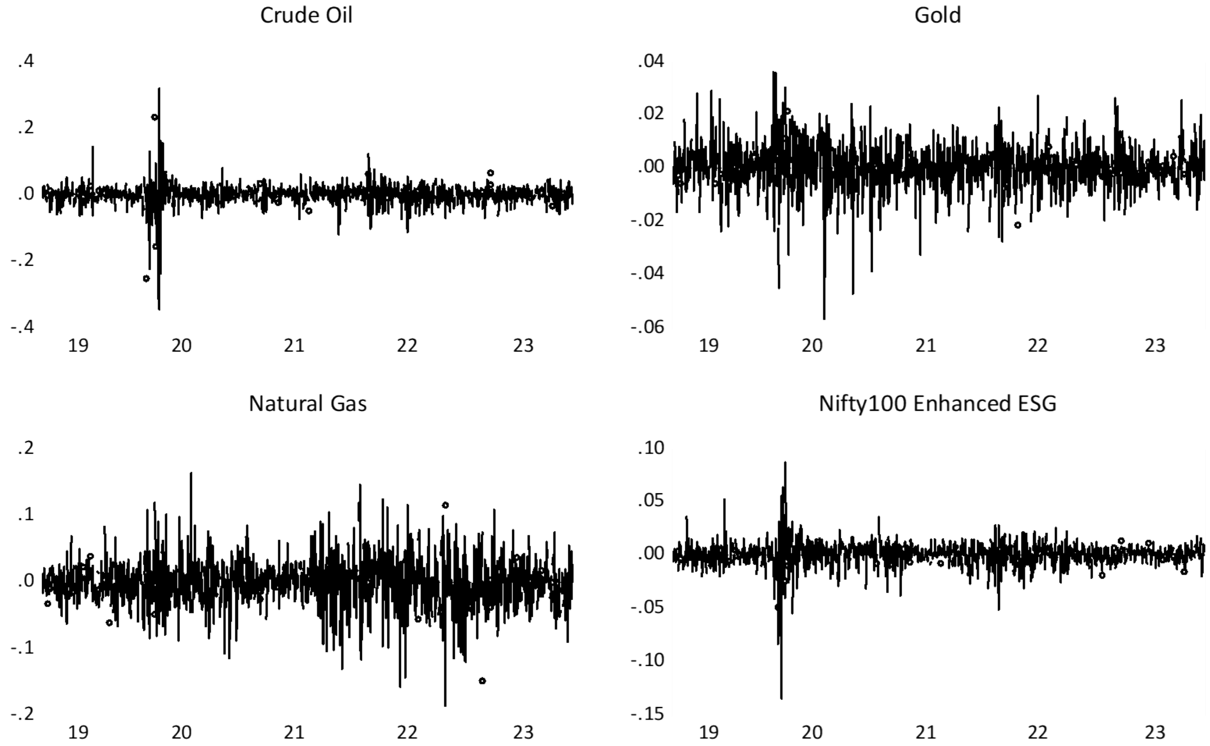


Figure 1: Log returns

2. Methodology

The extended joint connectedness method TVP-VAR (Balcilar et al., 2021) is the combination of the joint spillover approach (Lastrapes & Wiesen, 2021) and the TVP VAR connectedness approach (Antonakakis et al.,2020).

TVP VAR Connectedness Technique (Antonakakis et al., 2020) can be mathematically shown as:

$$a_t = A_t a_{t-1} + c_t \qquad c_t \sim N(0, Q_t) \tag{1}$$

$$\mathrm{Vec}(A_t) = Vec(A_{t-1}) + z_t \qquad z_t \sim N(0, X_t) \tag{2}$$

$$\lambda_t(H) = a_{t+H} - E(a_{t+H}|a_t, a_{t-1,\dots}) \tag{3}$$

$$= \sum_{g=0}^{H-1} F_{g,t} c_{t+H-g}, \tag{4}$$

$$E(\lambda_t(H)\lambda_t'(H)) = F_{g,t} Q_t F_{g,t}'. \tag{5}$$

This connectedness approach models how a shock in the variable j affects variable i:

$$\lambda_{i\,j,t}^{gen}(H) = \frac{E(\lambda_{i,t}^2(H)) - E[\lambda_{i.t}(H) - E(\lambda_{i.t}(H))|\boldsymbol{c}_{\boldsymbol{j,t+1,\dots,}}\, \boldsymbol{c}_{\boldsymbol{j,t+H}}]^2}{E(\lambda_{i,t}^2(H))} \tag{6}$$

$$= \frac{\sum_{g=0}^{H-1}(d_i' F_{gt} Q_t d_j)^2}{(d_j' Q_t d_j)\sum_{g=0}^{H-1}(d_i' F_{gt} Q_t F_{gt}' d_t)} \tag{7}$$

$$gSOT_{i\,j,t} = \frac{\lambda t_{i\,j,t}^{gen}(H)}{\sum_{j=1}^{R} \lambda t_{i\,j,t}^{gen}(H)} \tag{8}$$

The computation of the total directional connectivity from variable i to other variables and the total directional connectivity from other variables to variable i is shown as:

$$S_{i\rightarrow\cdot,t}^{gen,to} = \sum_{j=1,i\neq j}^{R} gSOT_{j\,i,t} \tag{9}$$

$$S_{i\leftarrow\cdot,t}^{gen,from} = \sum_{j=1,i\neq j}^{R} gSOT_{i\,j,t} \tag{10}$$

$$S_{i,t}^{gen,net} = S_{i\rightarrow\cdot,t}^{gen,to} - S_{i\leftarrow\cdot,t}^{gen,from} \tag{11}$$

If $S_{i,t}^{gen,net} > 0$; it indicates that variable i is a net transmitter or $S_{i,t}^{gen,net} < 0$; variable i is a net receiver.

Total Connectedness Index (TCI) is a crucial indicator for portfolio managers since it shows how interconnected a network is or how much market risk there is. The following equations are used to calculate the TCI:

$$gSOI_t = \frac{1}{R}\sum_{i=1}^{R} S_{i\leftarrow\cdot,t}^{gen,from} = \frac{1}{R}\sum_{i=1}^{R} S_{i\rightarrow\cdot,t}^{gen,to} \tag{12}$$

If the TCI value is high, it indicates a high network spillover and market risk. While a low value denotes low market risk, it also shows that shocks to one variable primarily affect that variable's values without affecting those of other variables, which is vital from the portfolio diversification standpoint. The connectedness approach offers information regarding the pairwise relationships through the net-pairwise spillovers, which can be shown by:

$$S_{i\,j,t}^{gen,net} = gSOT_{j\,i,t}^{gen,to} - gSOT_{i\,j,t}^{gen,from} \tag{13}$$

$S_{i\,j,t}^{gen,net} > 0$, it is implied that variable i dominates variable j because variable i has a more significant effect on variable j and vice versa.

The normalisation method is the primary benefit of the joint connectedness approach over the original connectedness approach. Mathematically, it can be expressed by:

$$S_{\cdot\to i,t}^{gen,from} = \frac{E(\lambda_{i,t}^2(H)) - E[\lambda_{i.t}(H) - \lambda_{i.t}(H))|c_{\forall\neq i,,t+1,\dots,}\ c_{\forall\neq i,t+H}]^2}{E(\lambda_{i,t}^2(H))} \tag{14}$$

$$= \frac{\sum_{g=0}^{H-1}(d_i' F_{gt} Q_t M_i (M_i' Q_t M_i')^{-1} M_i' Q_t G_{gt}' d_i}{\sum_{g=0}^{H-1}(d_i' G_{gt} Q_t G_{gt}' d_i)} \tag{15}$$

where, M_i is a matrix of order R × R − 1 such that M_i is equal to unit matrix with the ith column removed. Also, at time $t + 1$, $c_{\forall\neq i,}$ $t + 1$ indicates R − 1 dimension vector shocks for every variable except i.

The following formula is used to calculate the joint total connectedness index:

$$jSOI_t = \frac{1}{R}\sum_{i=1}^{R} S_{i\leftarrow\cdot,t}^{jnt,from} \tag{16}$$

The $gSOT_{ij,t}$ and $jSOT_{ij,t}$ are assumed:

$$S_{i\leftarrow\cdot,t}^{jnt,from} = \sum_{j=1,i\neq j}^{R} jSOT_{i\,j,t} \tag{17}$$

$$S_{\cdot\leftarrow i,t}^{jnt,to} = \sum_{j=1,i\neq j}^{R} jSOT_{j\,i,t} \tag{18}$$

The use of multiple scaling factors to relate $gSOT$ and $jSOT$ is a significant extension of Balcilar et al. (2021). For every row, the scaling factor gets changed, which gives the expressions:

$$\lambda_i = \frac{S_{i\leftarrow\cdot,t}^{jnt,from}}{S_{i\leftarrow\cdot,t}^{gen,from}} \tag{19}$$

$$\lambda = \frac{1}{R}\sum_{j=1}^{R} \gamma_j \tag{20}$$

This technique offers more flexibility due to multiple scaling factors. The final stage is to programme the following steps:

$$jSOT_{i\,j,t} = \lambda_i gSOT_{i\,j,t} \tag{21}$$

$$jSOT_{i\,i,t} = 1 - S_{i\leftarrow\cdot,t}^{jnt,from} \tag{22}$$

Total directional connectivity from variable i to all other variables can be formulated as follows:

$$S_{i\to\cdot,t}^{jnt,to} = \sum_{j=1,i\neq j}^{R} jSOT_{i\,j,t} \tag{23}$$

Mathematically, the net total and pairwise directional connectedness can be expressed as:

$$S_{ij,t}^{jnt,net} = S_{i\to.,t}^{jnt,to} - S_{i\leftarrow.,t}^{jnt,from} \tag{24}$$

$$S_{ij,t}^{jnt,net} = gSOT_{ji,t} - gSOT_{ij,t} \quad (25)$$

Additionally, Multivariate portfolio construction techniques have been utilised in this study to build a diverse portfolio of assets and reduce overall portfolio risk and volatility. Minimum Variance Portfolio technique (Markowitz, 1959) is used to determine the portfolio weight by reducing the risk and volatility of portfolio. Portfolio weight is calculated as follows:

$$\omega_{\Sigma_T} = \frac{\Sigma_T^{-1} I}{I \Sigma_T^{-1} I} \quad (26)$$

Where ω_{Σ_T} is portfolio weight matrix having M-row and one column. I is used to denote M-dimensional unit matrix. $\sum_T$ is a conditional covariance-variance matrix with order M × M in time T.

Minimum Correlation Portfolio (Christoffersen et al., 2014) is used to determine the portfolio weight by minimising conditional correlations. Portfolio weight can be calculated by the formula:

$$\mathbb{R}_T = diag(\Sigma_T)^{-0.5} \Sigma_T diag(\Sigma_T) \quad (27)$$

$$\mathbb{w}_{\mathbb{R}_T} = \frac{\mathbb{R}_T^{-1} I}{I \mathbb{R}_T^{-1} I} \quad (28)$$

Where $\mathbb{R}_T$ is the conditional correlation matrix of order M × M.

Minimum Connectedness Portfolio (Broadstock et al., 2022) is used to determine the portfolio weight by minimising the pairwise connectedness indices rather than variances or correlations. This can be expressed mathematically as:

$$w_{C_T} = \frac{PI_T^{-1} I}{I PI_T^{-1} I} \quad (29)$$

Where PI_T denotes the matrix of the pairwise-connectedness index.

RESULTS AND DISCUSSION

As depicted in Table 2, the correlation between ESG stocks and gold is negative, while ESG stock has a low and positive correlation with natural gas and crude oil. Furthermore, Table 3 provides an average dynamic connectivity between the two market groups, which gives a general idea of their interdependence. The diagonal parts of the table represent idiosyncratic shocks, while the off-diagonal elements demonstrate the interaction between various financial assets. It is worth noting that the TCI value during the whole period is 6.48%, indicating a low interdependence between ESG stocks and commodities. However, during the Russia-Ukraine war, this value increased to 10.56%, which is still relatively low. The average TCI value during the whole period indicates that cross-sector innovations account for 6.48% of the variation in forecast errors within the network, while idiosyncratic risk accounts for the remaining 93.52% of the system's forecast error variation. Similarly, the average TCI value during the Russia-Ukraine war is 10.56%, indicating that cross-sector innovations account for 10.56% of the variation in forecast errors within this network of sectors, and idiosyncratic risk accounts for the remaining 89.44% of the system's forecast error variation. Notably, ESG stocks and gold act as net receivers, while crude oil and natural gas act as net transmitters.

Understanding the connectedness between financial assets in case of significant events is crucial. The average result does not provide a dynamic analysis framework. It provides a broad overview only. Depending on the situation, a specific market may act as a net receiver or net transmitter. The role of financial markets may change over time (Hanif et al., 2023; Mishra et al., 2023), as the historical development of the TCI demonstrates. High TCI values typically indicate substantial spillovers or otherwise. When the Total Connectedness Index is high, it indicates a presence of high market risk. In such a scenario, diversification cannot reduce market risk, and avoiding investing in those markets is better. A dynamic analysis framework indicates that the total connectedness of commodities and ESG stocks increased during the Coronavirus pandemic and the Russia-Ukraine war, as shown in Figure 2. These events had more significant spillover effects than the total period.

Table 2: Unconditional Correlation

	Gold	Natural Gas	Crude Oil	Nifty100 ESG Enhanced
Gold	1.0000	-0.0002	0.0750	-0.0039
Natural Gas	-0.0002	1.0000	0.1311	0.0020
Crude Oil	0.0750	0.1311	1.0000	0.1420
Nifty100 Enhanced ESG	-0.0039	0.0020	0.1420	1.0000

Source: Calculated by authors

Table 3: Average joint connectedness

	Gold	Natural Gas	Crude Oil	Nifty100 Enhanced ESG	From
Panel A: Whole period (April 1st, 2022 to December 31st, 2023)					
Gold	93.54	1.26	4.01	1.19	6.46
Natural Gas	0.82	95.26	2.94	0.98	4.74
Crude Oil	3.46	2.79	90.98	2.76	9.02
Nifty100 Enhanced ESG	1.17	0.79	3.74	94.3	5.7
To	5.44	4.84	10.69	4.94	25.92
Inc.Own	98.98	100.1	101.68	99.25	TCI
NET	-1.02	0.1	1.68	-0.75	6.48
Panel B: During Russia-Ukraine war (February 24th, 2022 to December 31st, 2023)					
Gold	86.71	1.48	9.93	1.88	13.29
Natural Gas	0.73	93.18	5	1.09	6.82
Crude Oil	9.76	5.5	83.39	1.35	16.61
Nifty100 Enhanced ESG	0.97	2.34	2.21	94.48	5.52
TO	11.46	9.32	17.14	4.33	42.25
Inc.Own	98.17	102.5	100.53	98.8	TCI
NET	-1.83	2.5	0.53	-1.2	10.56

Source: Calculated by authors

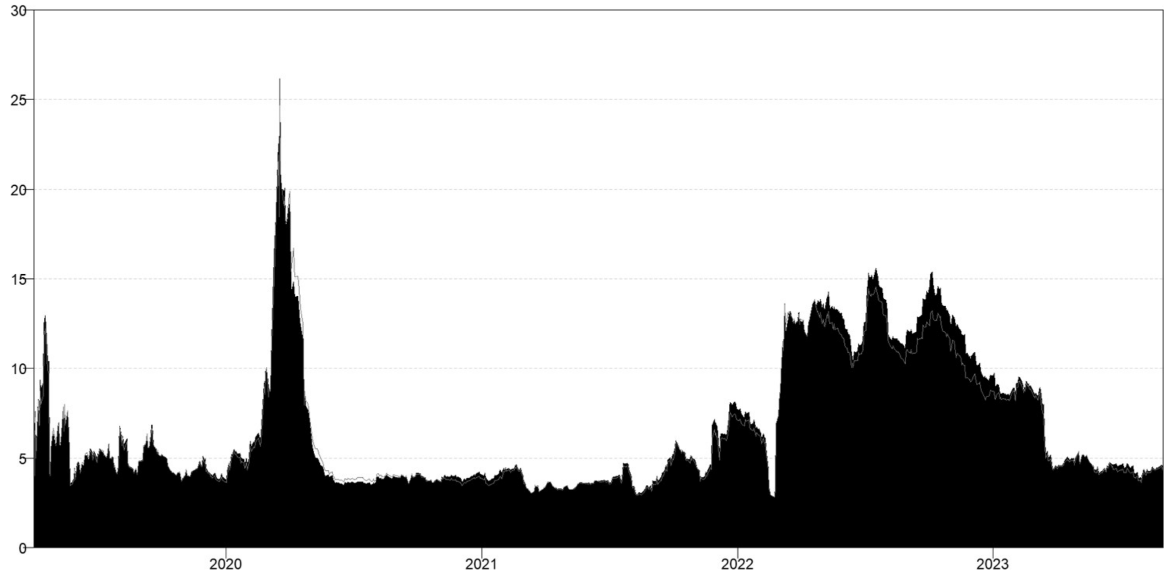


Figure 2: Dynamic Total Connectedness

Notes: The shaded area represents the measurements based on Balcilar et al. (2021), and the grey line shows the outcomes of Antonakakis et al. (2020).

Figure 3 demonstrates the overall dynamic net connectivity between ESG stocks and commodities over the sample period. The total net connection illustrates the variation in shocks transmitted to and received from each market. A market that has a net transmitting effect displays positive values in the shaded area. Conversely, negative values indicate instances where the market acts as a net recipient. However, crude oil and natural gas have primarily been identified as net transmitters, while ESG stocks and gold have been found to act as net receivers, as depicted in Figure 3. Figure 4 displays the pairwise connections among various financial assets. During COVID-19, ESG stocks have a high degree of negative relationship with gold and a low degree of negative connection with gold during the Russia-Ukraine war. During the early stages of the Russia-Ukraine war, ESG stocks exhibited a low level of negative correlation with crude oil, which later turned into a positive correlation. ESG stocks exhibited a negative correlation with natural gas, which later turned positive and then negative again. This indicates that diversification opportunities are present between ESG stocks and commodities. Figure 5 depicts the net pairwise directional connectivity between commodity and ESG stocks. The yellow and blue colours of the circles represent the net volatility spillover and net transmitters, respectively. The thickness of the arrows represents the size of the net spillover, and their direction shows the direction of the spillover.

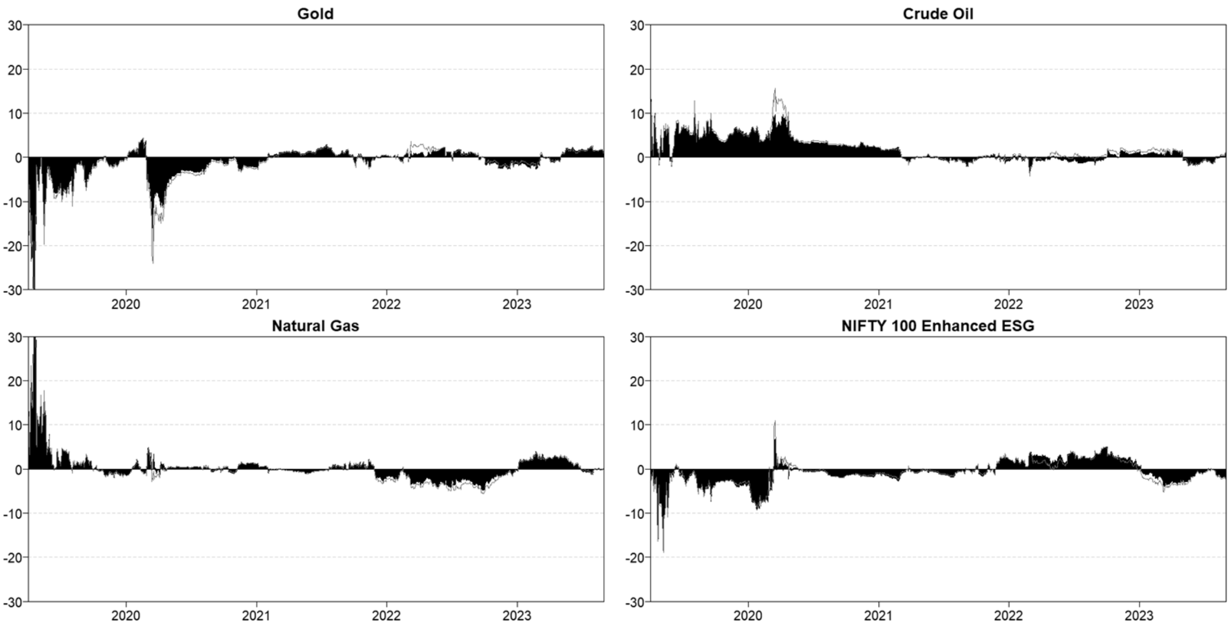


Figure 3: Dynamic Net Total Connectedness

Notes: The shaded area represents the measurements based on Balcilar et al. (2021), and the grey line shows the outcomes of Antonakakis et al. (2020).

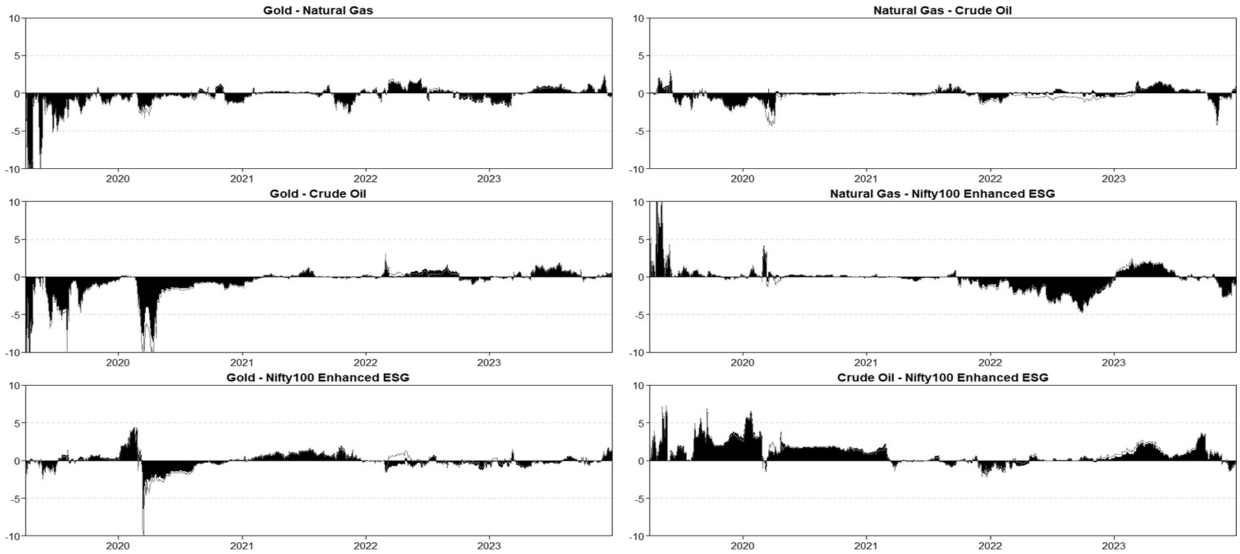
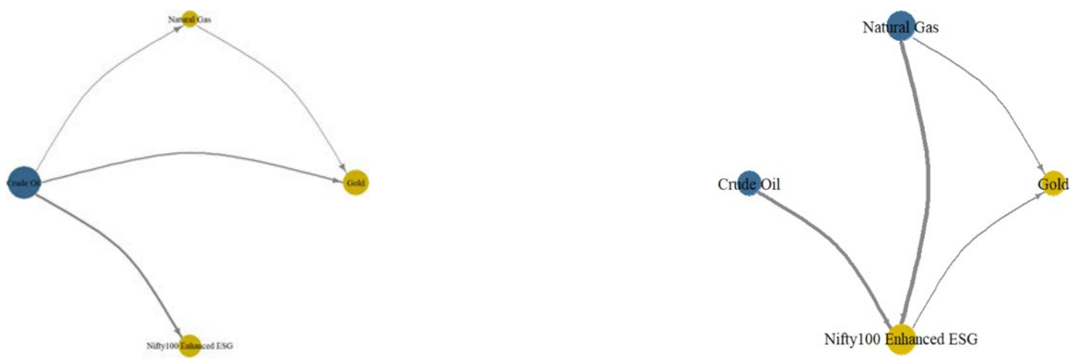


Figure 4: Dynamic net pairwise connectedness

Notes: The shaded area represents the measurements based on Balcilar et al. (2021), and the grey line shows the outcomes of Antonakakis et al. (2020).



(a) During the Whole Period **(b) During the Russia-Ukraine war**

Figure 5: Net pairwise directional connectivity between pairs of commodities and ESG stocks

Table 4 presents the ideal weight allocation for each financial asset through the application of the Minimum Variance Portfolio (MVP), Minimum Correlation Portfolio (MCP), and Minimum Connectedness Portfolio (MCoP) techniques. It is graphically presented in Figure 5. Panel A of Table 4 highlights the recommended investment percentages for a diversified portfolio comprising different commodities and ESG stocks that minimize overall variance. By allocating 58% to gold, 4% to natural gas, 1% to crude oil, and 36% to ESG stocks, the volatility of each financial asset would be reduced by 44% for gold, 97% for natural gas, 96% for crude oil, and 7% for ESG stocks. The highest allocation is assigned to gold, while the lowest allocation is assigned to crude oil, based on the optimization provided by the Minimum Variance Portfolio technique.

Panel B of Table 4, on the other hand, illustrates the recommended investment percentages for a diversified portfolio composed of different commodities and ESG stocks that minimize overall correlation. By allocating 28% to gold, 26% to natural gas, 19% to crude oil, and 27% to ESG stocks, the volatility of each financial asset would be reduced by -13.2% for gold, 87% for natural gas, 85% for crude oil, and -26% for ESG stocks. Similar to Panel A, the highest allocation of the portfolio's value is in gold, while the lowest allocation is in crude oil, based on the optimization provided by the Minimum Correlation Portfolio technique.

Panel C of Table 4 presents the recommended investment percentages for a diversified portfolio, composed of different commodities and ESG stocks, that overall connectedness between financial assets. By allocating on average 25% to gold, 26% to natural gas, 23% to crude oil, and 26% to ESG stocks, the volatility of each financial asset would be reduced by - 15.3% for gold, 86% for natural gas, 84% for crude oil, and 37% for ESG stocks. As per the Minimum Connectedness Portfolio technique, the portfolio weight recommendations do not exhibit significant differences.

A well-structured portfolio allocation positively impacts reducing the contribution of volatility from different financial assets. These findings demonstrate the significant impact of a specific portfolio allocation on the reduction of asset volatility. Significant reductions in the contribution to volatility are observed by distributing investments across different assets with a well-calculated weight. Figure 6 displays the dynamic portfolio weights using the Minimum Variance Portfolio, Minimum Correlation Portfolio, and Minimum Connectedness Portfolio technique for all financial assets considered in this study. Figure 7 depicts the cumulative return of the multivariate portfolio, with the black line representing the cumulative return of the portfolio suggested by the MVP technique, the red line representing the cumulative return of the portfolio suggested by the MCP technique, and the sky-blue line representing the cumulative return of the portfolio suggested by the MCoP technique. Figure 7 shows that the cumulative return of the portfolio suggested by the MVP technique is higher compared to the other techniques. Investors and portfolio managers may take substantial benefits by adjusting their portfolios based on the optimum weights provided by these techniques.

Table 4: Multivariate Portfolio Weight

	Mean	Std. Dev.	5%	95%	HE	p-value	SR
Panel (A): MVP Weight							
Gold	0.58	0.07	0.48	0.73	0.44	0.00	1.05
Natural Gas	0.04	0.02	0.01	0.08	0.97	0.00	1.05
Crude Oil	0.01	0.01	0.00	0.03	0.96	0.00	1.05
Nifty100 Enhanced ESG	0.36	0.08	0.19	0.48	0.70	0.00	1.05
Panel (B): MCP Weight							
Gold	0.28	0.02	0.26	0.3	-1.32	0.00	-0.26
Natural Gas	0.26	0.02	0.23	0.28	0.87	0.00	-0.26
Crude Oil	0.19	0.03	0.14	0.23	0.85	0.00	-0.26
Nifty100 Enhanced ESG	0.27	0.04	0.22	0.35	-0.26	0.00	-0.26
Panel (C): MCoP Weight							
Gold	0.25	0.02	0.22	0.27	-1.53	0.00	-0.2
Natural Gas	0.26	0.01	0.24	0.28	0.86	0.00	-0.2
Crude Oil	0.23	0.02	0.21	0.25	0.84	0.00	-0.2
Nifty100 Enhanced ESG	0.26	0.02	0.23	0.29	-0.37	0.00	-0.2

Source: Calculated by authors

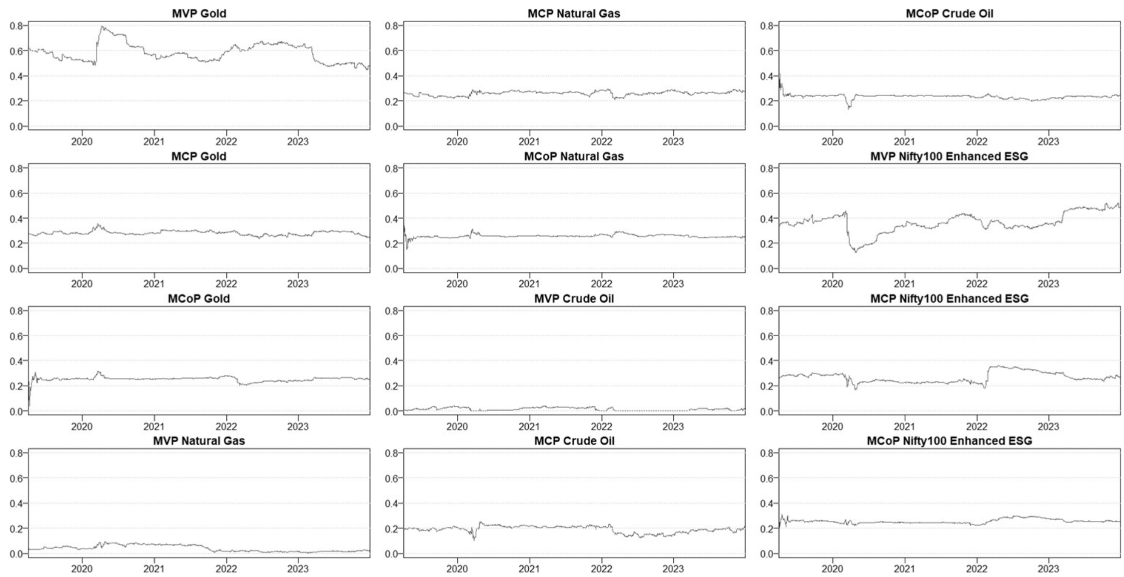


Figure 6: Dynamic multivariate portfolio weight

Figure 7: Multivariate portfolio cumulative return

CONCLUSION

This study uses the extended joint connectedness method to examine the dynamic connectedness between commodities and ESG stocks. Besides this, different portfolio weight techniques are used to construct an optimum portfolio. The study shows that there is a low correlation between ESG stocks and commodities. However, there was a slight increase in their correlation during the Russia-Ukraine war, although it remained low. The study also discovered that crude oil and natural gas act as net transmitters, whereas ESG stocks and gold act as net receivers. ESG stocks exhibit an inverse correlation with gold and a low degree of positive correlation with natural gas and crude oil. Therefore, diversification in the commodities and ESG stocks portfolio is possible. The study found that there is a significant time-varying connection between ESG stocks and commodities, which requires a review of the diversification strategy. A well-structured portfolio allocation helps reduce volatility. The study recommends allocating the highest percentage to gold and the least to crude oil, leading to a statistically significant reduction in volatility and an increase in cumulative returns. Volatility would be statistically significantly reduced, and cumulative returns would be increased by allocating the highest amount in the gold and ESG stocks. This study has practical implications for investors, portfolio managers, regulators, and policymakers. It helps investors and portfolio managers to decide on asset allocation and risk management. Regulators and policymakers can identify which financial assets are highly interrelated and develop the required regulations to minimize any potential systemic risks based on the study's findings.

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