

## **Environmental, Social, and Governance (ESG)-Based Stocks and Bitcoin: A Sustainable Investment Perspective – Evidence from Indonesia**



Maria Naftalie Iswanto, Siti Saadah\*<sup>ID</sup>

School of Business and Social Innovation, Atma Jaya Catholic University of Indonesia, Jakarta 12930, Indonesia

Corresponding Author Email: [siti.saadah@atmajaya.ac.id](mailto:siti.saadah@atmajaya.ac.id)

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### **ABSTRACT**

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This study examines the role of Environmental, Social, and Governance (ESG)-based equities in diversifying Bitcoin investment portfolios from a sustainable investment perspective in Indonesia during the post-COVID-19 market normalization period. Using daily data from January 2023 to December 2024, the analysis employs a Generalized Vector Autoregression (G-VAR) framework and Diebold-Yilmaz spillover methodology to capture dynamic return connectedness between Bitcoin and the FTSE Indonesia ESG Index. VAR estimation and Granger Causality tests reveal no significant bi-directional causality between the two assets, indicating independence in their return dynamics. Spillover analysis confirms an exceptionally low level of connectedness, with total spillover index averaging below 1% over the sample period. Time-varying spillover analysis using a rolling-window approach further demonstrates the stability of this weak relationship under normal market condition. These findings provide robust evidence that combining Bitcoin with ESG-based equities can enhance portfolio diversification while maintaining sustainability-oriented investment objectives. This study contributes post-pandemic empirical evidence from a major emerging market and offers practical implications for investors and policymakers promoting risk-efficient and sustainability-aligned investment strategies. For capital market development, this study shows that sustainable capital markets and crypto assets can co-exist to support the development of diversified green investment product.

## **1. INTRODUCTION**

In this rapidly evolving digital era, crypto investment has become an unstoppable global phenomenon. In recent days, investors have increasingly viewed cryptocurrency as an alternative digital safe haven. Its supporters, mostly the younger generations who are equipped with strong financial literacy, often refer to crypto as digital gold, believing that this asset function similarly to precious metals during periods of economic uncertainty. Global crypto transactions have reached USD 6.34 billion in 2025 and are projected to grow to USD 18.26 billion by 2033, growing of 14.5% from 2026 to 2033. Bitcoin, the largest cryptocurrency asset, has increasingly appeared in the portfolios of both retail and institutional investors [1]. Moreover, Bitcoin is often considered a diversification alternative due to its relatively low correlation with conventional capital markets [2].

On the other hand, Bitcoin exhibits extremely high annual price volatility, reaching 75.8% during the 2014–2024 period, which reflects its high-risk nature. Such volatility indicates the potential for sharp price fluctuations over a short period, making Bitcoin more suitable for investors with high risk tolerance. Bitcoin's high price volatility not only affects investors' financially and behaviorally but also raises environmental concerns due to the substantial energy

consumption associated with the proof-of-work mechanism used in the Bitcoin network. Data from the Cambridge Centre for Alternative Finance [3] indicate a significant energy consumption, highlighting its environmental implications. It is estimated that global Bitcoin mining consumes between 110 and 173 terawatt-hours of electricity annually, comparable to the electricity consumption of mid-sized countries such as Malaysia, Sweden, and Pakistan. A significant portion of this electricity is generated from fossil energy sources, including coal and natural gas, which emit large amounts of carbon dioxide and contribute to global warming and air pollution [4]. Additionally, Bitcoin mining has resulted in substantial amounts of electronic waste (e-waste) due to the short lifespan of mining hardware, particularly application-specific integrated circuit (ASIC) miners, which require frequent replacement. Consequently, e-waste is estimated to reach tens of thousands of tons annually, comparable to the total electronic waste produced by a small European country.

When Bitcoin prices surge, creating strong economic incentives, mining activities increase significantly, leading to higher energy consumption. Conversely, when prices decline sharply, many miners suspend their operations, resulting in unstable and inefficient energy consumption patterns. In other words, Bitcoin's volatile prices are significant contributing factor to understand fluctuations in energy consumption and

carbon emissions from mining activities [5], suggesting that environmental concerns should not be overlooked in sustainable investment discussions.

However, despite the controversy surrounding Bitcoin for its perceived conflict with green economy principles, the blockchain technology underlying it demonstrates potential to enhance transparency and efficiency in ESG-related practices, particularly in areas such as supply chain tracking or environmental data verification. The tension between the environmental costs of Bitcoin mining and the potential benefits of blockchain technology highlights the importance of examining the Bitcoin-ESG relationship in the context of sustainable investment. Moreover, with rising awareness of sustainability and corporate social responsibility, along with growing concerns about corporate social responsibility and climate change, ESG investment has gained prominence and become a central consideration in global investment decisions. Corporations have increasingly incorporated ESG-related practices into their business strategies. Furthermore, studies suggest that the disclosure of ESG attributes can enhance corporate financial performance while also promoting a low-carbon economy [6, 7].

Despite these ongoing dynamics, there is growing potential to integrate Bitcoin and ESG principles within an investment strategy. Analyses of such strategies are essential for supporting global net-zero emission targets. Sustainable investment strategies may indirectly function as carbon offset in crypto investment while simultaneously providing diversification benefits that reduce portfolio risks. Incorporating crypto assets and ESG equities into investment portfolios has emerged as an attractive approach, particularly for investors concerned with promoting green economy.

Research on sustainable investment strategies, particularly those examining the relationship between Bitcoin investment and ESG equities, remains limited in developing markets, especially in Asia. Less than 5% of literature on ESG investment focuses on this region [8] despite Asia accounting for one of the largest shares of cryptocurrency transaction volumes [9]. Indonesia, for instance, was among the top ten countries worldwide in terms of cryptocurrency investment in 2025. Nevertheless, studies examining Bitcoin-ESG investment strategies remain scarce. A study conducted by Kakinuma [10] in Japan, Hong Kong, South Korea, Thailand, and Indonesia—suggests that a combination of ESG equities and Bitcoin reduces risks. However, Arif et al. [11] found that portfolios combining both green and conventional assets exhibited higher return connectedness during the Covid-19 crisis, thereby offering limited diversification benefits in reducing portfolio risk during the same period. This difference may arise because Kakinuma [10] did not distinguish between the normal economic conditions (2014-2019) and the pandemic crisis period (2020-2022), which could influence the relationship between ESG equities and Bitcoin. Indonesian ESG equities were among the assets examined in Kakinuma's [10] study. A recent study conducted by Asih et al. [12] indicated that pairing ESG-based assets with Bitcoin may provide diversification benefits.

The limited literature examining Bitcoin-ESG equities integration in Indonesia highlights the importance of this study. While Asih et al. [12] used data covering up to one year of the post-Covid-19 recovery period, no subsequent study has examined sustainable investment strategies in Indonesia when markets returned to normal after the pandemic. Indonesia is a developing market with high cryptocurrency growth, but there

is minimal research related to this. This study aims to investigate the role of ESG-based assets in providing diversification benefits for Bitcoin investments. In contrast to Asih et al. [12], this study adopts a dynamic approach that captures return spillovers between the two asset markets and identifies which market serves as the net transmitter of shocks. Capital markets play a critical role in developing sustainable and responsible investment products, which further underscores the relevance of this study. In supporting the net-zero emission program, sustainable investment strategies demand further investigation, as they may offset carbon footprint associated with cryptocurrency investments while also reducing investment risk through diversification.

## 2. LITERATURE REVIEW

At present, ESG has emerged as one of key frameworks in sustainable investment. Its components enable investors to assess corporate performance not only from the financial perspective but also in terms of long-term sustainability impacts. Consequently, ESG has been increasingly important in investment practices as global awareness of corporate social responsibility and climate change continues to grow, IMD [13].

The environmental dimension of ESG focuses on how companies manage the environmental impacts of their operations, including measuring their carbon emissions, using renewable energy, or managing waste. Companies adopting such practices often demonstrate higher operational efficiency and lower reputational risk. Jiang et al. [14] found that businesses switching to renewable energy can reduce long-term operational costs and attract investors concerned with climate change.

The social dimension of ESG concerns the relationship between companies and their employees, customers, and the wider community. Employee welfare, social inclusivity, and contribution to the community are essential for creating a harmonious and productive work environment. Strong social practices can enhance employee retention and strengthen relationships with local communities, thereby improving corporate reputation and creating values for stakeholders.

The governance dimension, on the other hand, relates to leadership structure, transparency, and business ethics. Firms with good corporate governance ensure responsible management practices and compliance with rules and regulations. Strong corporate governance allows companies to better navigate economic challenges and maintain investor trust. Piserà and Chiappini [15] found that businesses with good governance often demonstrate more stable financial performance and lower levels of risk. As awareness of sustainability continues to grow, ESG considerations are expected to remain a key factor shaping future investment strategies.

Bitcoin, as a type of asset, exhibits several distinctive characteristics that differentiate it from conventional investment instruments. Baur et al. [16] highlighted key characteristics such as high volatility, scarcity (a maximum supply of 21 million units), and relatively low connectedness with traditional assets. Having been used as a store of value, Bitcoin is often referred to as “digital gold” in the contemporary portfolio analysis, particularly during periods of global economic uncertainties [17].

Investment in Bitcoin differs from investment in traditional

assets. Bitcoin is characterized by high liquidity, a borderless market operating 24 hours a day, significant price volatility influenced by speculations and sensitivity to global news, and varying regulatory frameworks across countries. Despite these characteristics, Bitcoin remains a potential diversification instrument. However, investment in this asset requires careful risk management. The environmental impacts of Bitcoin mining are a key factor, Baur and Dimpfl [2]. Transaction validation alone demands substantial computational power. Köhler and Pizzol [18] estimated that Bitcoin mining consumed 296 TWh of electricity in 2024. This level, which is comparable to the total energy consumption of a small country, contributes significantly to carbon emissions.

The Modern Portfolio Theory has expanded beyond conventional assets such as stocks and bonds to include alternative assets such as cryptocurrencies and ESG investments. Trimborn et al. [19] found that allocating 5% of Bitcoin to a conventional portfolio can increase the portfolio's risk-adjusted return by up to 20%, suggesting Bitcoin's potential as an effective diversification asset. In addition, Pedersen et al. [20], Dai [21], and Díaz et al. [22] found that ESG-based investments improve portfolio efficiency and serve as diversification assets for conventional stock portfolios. These findings demonstrate the continued relevance of Modern Portfolio Theory even when non-financial factors are considered in investment decisions.

A further investigation into the relationship between Bitcoin and ESG stocks is warranted. Despite their distinctive characteristics, these assets may complement each other. Evidence from Chamanara et al. [23], Kakinuma [10], Robiyanto et al. [24] and Asih et al. [12] suggests that the low correlation between Bitcoin/Ripple and ESG stocks provides significant diversification opportunities. These findings are consistent with the principles of Modern Portfolio Theory, which emphasize the importance of diversification in mitigating risk while maintaining returns. Overall, these studies indicate that ESG stocks and Bitcoin have substantial potential to be incorporated into investment strategies aimed at reducing risk and optimizing portfolio diversification. However, most of these studies used data from the pandemic period. Therefore, consistency of diversification strategies during and after recovery period warrants further investigation.

### 3. RESEARCH METHOD

This study investigates the potential of ESG-based assets in diversifying Bitcoin portfolios using the Generalized Vector Autoregression (G-VAR) framework to capture the dynamic relationships between Bitcoin returns and ESG index returns. The analysis focuses on estimating return spillovers across the

assets simultaneously. High spillovers between Bitcoin and ESG indicate strong connectedness, which may limit potential for portfolio diversification. In contrast, low spillovers indicate assets' independence, thereby increasing chances for diversification and risk reduction. Analyzing spillovers using the G-VAR framework is therefore essential for evaluating the effectiveness of incorporating Bitcoin and ESG equities into portfolios for risk management.

The G-VAR model is selected for its ability to capture temporal interdependence among financial variables as well as its flexibility in analyzing bidirectional relationships without exogeneity assumptions. Unlike the Standard-VAR model, the G-VAR framework is insensitive to variable ordering.

This study employs daily closing data for Bitcoin and the FTSE Indonesia ESG Index covering a period from January 6, 2023, to December 30, 2024, yielding 515 daily return observations after computing log returns. Bitcoin price data (BTC/USD) was obtained from capitalmarket.com, a platform providing comprehensive and accurate financial data. ESG performance was measured using the FTSE Indonesia ESG Index compiled by FTSE Russell. This index was selected because it is the most established sustainability-screened benchmark for the Indonesian equity market, providing a direct, investable proxy for ESG-based equities in a major emerging market.

Because the claim that 2023–2024 represents a normal post-COVID regime should not be merely asserted, we verify it with an objective, data-driven regime test rather than a narrative judgment. For each asset we test for a structural break in volatility (squared returns) using the Bai-Perron supF test, and we require that the most recent estimated break precede the sample start (6 January 2023). We further compare the pre-window and in-window periods using the Fligner-Killeen test of equal variances and the Wilcoxon rank-sum test of distributional equality to confirm that volatility shifts to a lower regime. The results of these tests are reported in Table 1; because the analysis window begins after the last estimated volatility break for both assets, the sample lies entirely within a single, lower-volatility post-break regime.

Connectedness between the two returns series is measured using the Diebold-Yilmaz [25, 26] framework built on a generalized forecast error variance decomposition (G-FEVD) of the estimated VAR. The object of analysis is return connectedness, all variables and tables are based on daily returns. The total connectedness index (TCI) and the directional FROM/TO and net measures are computed from the G-FEVD at a forecast horizon of  $H = 10$  days, the conventional choice in this literature. Because GFEVD-based connectedness can be sensitive to the choice of horizon, we assess robustness by tracing the connectedness measures dynamically through a 100-day rolling window rather than relying on a single static horizon.

**Table 1.** Volatility regime/structural break tests (squared returns)

Test	Bitcoin	FTSE Indonesia ESG
Fligner-Killeen (variance equality)	$\chi^2 = 11.65, p = 0.0006$	$\chi^2 = 9.37, p = 0.0022$
Wilcoxon (distribution)	$W = 192,808, p = 0.0104$	$W = 193,737, p = 0.0065$
supF structural break (Bai-Perron)	$17.42, p = 0.0009$	$17.11, p = 0.0011$
Estimated break date	11 Nov 2022	30 Nov 2021
Window starts after break? (start 6 Jan 2023)	Yes	Yes

Note: The most recent volatility break for each asset precedes the sample start (6 Jan 2023), so the analysis window lies entirely within the post-break, normalized regime.

Generalized Forecast Error Variance Decomposition (G-

FEVD) is employed to measure the contribution shock from

each asset to the other assets within the VAR system. FEVD provides insights into the extent to which exogeneous shocks originating from one asset influence others, thereby revealing the dynamic interdependence between assets over time. In this study, the variance decomposition was computed using the G-FEVD method proposed by Lanne and Nyberg [27], which ensures decomposition results sum to one without requiring orthogonalization of shocks. The resulting G-FEVD estimates are then used to conduct spillover analysis within the Generalized VAR (G-VAR) framework developed by Diebold and Yilmaz [25]. G-FEVD forms the basis for constructing spillover matrix, which captures the degree to which shocks from one asset affects other assets in the system. The use of generalized approach allows decomposition to be independent of variable ordering, making the results more robust. The total return spillover index is then used to quantify the contribution of one asset's return spillover to the total forecast error variance, as measured by the following equation:

$$S^g(H) = \frac{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)} \cdot 100 = \frac{\sum_{i \neq j} \tilde{\theta}_{ij}^g(H)}{N} \cdot 100$$

$\tilde{\theta}_{ij}^g(H)$  denotes the H-step-ahead forecast error variance decomposition, where  $H = 1, 2, \dots$

In the subsequent stage, the rolling-window sample technique is employed over the observation period. This method allows the identification of the periods in which the total return spillovers become extreme. A higher level of total return spillovers suggests lower diversification potential between assets. Moreover, the total return spillover index provides insights into the extent of spillover across assets. The generalized VAR method can further identify the direction of spillovers, known as directional return spillovers. Directional return spillovers received by asset  $i$  and originating from all other assets  $j$  are defined as follows:

$$S^g_{.i}(H) = \frac{\sum_{j \neq i} \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)} \cdot 100 = \frac{\sum_{j \neq i} \tilde{\theta}_{ij}^g(H)}{N} \cdot 100$$

Meanwhile, directional return spillovers transmitted from asset  $i$  to all other assets  $j$  are formulated as follows:

$$S^g_{i.}(H) = \frac{\sum_{j \neq i} \tilde{\theta}_{ji}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ji}^g(H)} \cdot 100 = \frac{\sum_{j \neq i} \tilde{\theta}_{ji}^g(H)}{N} \cdot 100$$

Based on the directional spillovers above, net spillover transmitted from asset  $i$  to all other assets  $j$  can be calculated using the following equation:

$$S^g_i(H) = S^g_{i.}(H) - S^g_{.i}(H)$$

Net spillover measures the difference between volatility transmitted to other assets and volatility received from them.

#### 4. RESULT AND DISCUSSION

Dynamic interaction between ESG-based stocks and Bitcoin in this study was examined using daily return data from the FTSE Index ESG Indonesia and Bitcoin, comprising

a total of 515 daily observations. Similar to the standard VAR framework, diagnostic tests were conducted to ensure stationarity of the return series for both assets. The results are presented in Table 2.

**Table 2.** Results of data stationarity test

Variable	p-Value	Result
<b>btc_return</b>	0.01	Stationary
<b>Esg_id Return</b>	0.01	Stationary

As shown in Table 2, the Augmented Dickey-Fuller test results indicate that the return series for Bitcoin and Indonesian ESG-based stocks are stationary. This stationarity provides a reliable basis for examining of the dynamic relationship between the two variables. Descriptive statistics of return series for both assets are presented in Table 3.

**Table 3.** Descriptive statistic of Bitcoin and Indonesia Environmental, Social, and Governance (ESG) stocks

Variable	Min	Mean	Max
<b>btc_return</b>	-13.9536	0.32784	18.72395
<b>esg_id return</b>	-5.62947	-0.02037	3.88551

As shown in Table 3, Bitcoin returns exhibit substantially higher volatility than returns on the Indonesian ESG index. While Bitcoin returns range from -13.95% to 18.72%, Indonesian ESG returns range between -5.63% and 3.89%. This result is consistent with the existing literature that characterizes cryptocurrency as highly volatile assets. Bitcoin's average return of 0.33% indicates a positive performance over the observation period, whereas the Indonesian ESG index exhibits an average return close to zero (-0.02%), suggesting relatively stagnant movements.

Optimal lag selection is a crucial stage in estimating the Vector Autoregression (VAR) model. The results of the optimal lag selection test based on several criteria are reported in Table 4.

**Table 4.** Optimal lag selection

	1	2	3	4	5
<b>AIC(n)</b>	2.37048*	2.37841	2.38607	2.39274	2.40793
<b>HQ(n)</b>	2.39660*	2.41759	2.43832	2.45805	2.48630
<b>SC(n)</b>	2.43710*	2.47834	2.51932	2.55992	2.6078
<b>FPE(n)</b>	10.7025*	10.7877	10.8708	10.9435	11.1111

Note: \* denotes optimal lag according to each criterion

The results indicate that lag 1 is the optimal lag length across all criteria. This consistency suggests that only values from the previous period ( $t-1$ ) are relevant in predicting dynamics of both variables. The model specification for the endogenous variables, namely Bitcoin returns and ESG index returns, is expressed as follows:

$$BTC\_Return_t = \alpha_1 + \beta_{11} \cdot BTC\_Return_{t-1} + \beta_{12} \cdot ESG\_Return_{t-1} + \varepsilon_{1t}$$

$$ESG\_Return_t = \alpha_2 + \beta_{21} \cdot BTC\_Return_{t-1} + \beta_{22} \cdot ESG\_Return_{t-1} + \varepsilon_{2t}$$

The estimation results are presented in Tables 5 and 6.

The estimation results reveal a distinctive characteristic in the relationship between the two assets. Neither the  $\beta_{12}$  (Table

5) nor the  $\beta_{21}$  (Table 6) parameters are positive and statistically significant. This indicates potential diversification benefits from incorporating both assets into investment portfolios.

**Table 5.** Estimation results for the bitcoin return equation

Variable	Estimate	Std. Error	T Value	Pr(> t )
<b>btc_return.l1</b> ( $\beta_{11}$ )	-0.02366	0.04441	-0.533	0.5944
<b>esg_id_return.l1</b> ( $\beta_{12}$ )	0.07048	0.13651	-0.516	0.6059
<b>const</b>	0.33208	0.14096	2.356	0.0189*

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

**Table 6.** Estimation results for the Indonesian Environmental, Social, and Governance (ESG) return

Variable	Estimate	Std. Error	T Value	Pr(> t )
<b>btc_return.l1</b> ( $\beta_{21}$ )	0.008646	0.01442	0.599	0.549
<b>esg_id_return.l1</b> ( $\beta_{22}$ )	0.021824	0.04434	0.492	0.623
<b>const</b>	-0.02467	0.04578	-0.539	0.59

Results of the Granger causality test presented in Table 7 support this finding.

**Table 7.** Granger causality test results

Causality	F-Statistic	p-Value
<b>btc_return</b> → <b>esg_id_return</b>	0.35927	0.549
<b>esg_id_return</b> → <b>btc_return</b>	0.26653	0.6058

The results of the Granger causality test demonstrate no causal relationships between Bitcoin return and Indonesian ESG return in either direction at the 5% significance level. This implies that past movements of one of the assets do not help predict the returns of the other.

To further assess the potential diversification benefits of combining Bitcoin and ESG-based stocks, spillover effects were analyzed using the Generalized VAR framework developed by Diebold and Yilmaz [25] to estimate connectedness and shock transmission between assets. The results of the spillover analysis are reported in Table 8.

**Table 8.** Generalized vector autoregression (G-VAR) spillover matrix (%)

	btc_return	esg_id_return	C. from others
<b>btc_return</b>	99.02	0.98	0.98
<b>esg_id_return</b>	0.98	99.01	1
<b>C. to others</b>	1	0.98	0.99

The connectedness matrix reported in Table 8 summarizes return connectedness between the two assets, computed from the generalized FEVD at a 10-day horizon. The first row under the “from others” column indicates that only 0.98% (less than 1%) of the variance in Bitcoin returns is explained by shocks originating from ESG-based stocks. Conversely, only 1% of the forecast error variance in Indonesian ESG index returns is attributable to shocks from the Bitcoin market. The total

spillover index of 0.99% demonstrates extremely low return connectedness between the two assets. In other words, the vast majority (approximately 99%) of volatility in each market is driven by its own shocks, while less than 1% is transmitted from the other market.

Despite the extremely low level of shock transmission between the two assets, Table 9 indicates that Bitcoin acts as a net transmitter although with a really small magnitude of 0.02%. This indicates that shocks transmitted from the ESG-based stock market to Bitcoin are weaker than those transmitted from Bitcoin to the ESG market. This can be attributed to Bitcoin’s higher liquidity and trading volume in the global markets. Nevertheless, the weak spillover effects demonstrate that the Indonesian ESG-based stock market remains relatively resilient to shocks originating from the global cryptocurrency market. This finding suggests that the expansion of the cryptocurrency market does not necessarily undermine the stability of sustainable capital markets, allowing financial innovations and sustainability-oriented agendas to coexist.

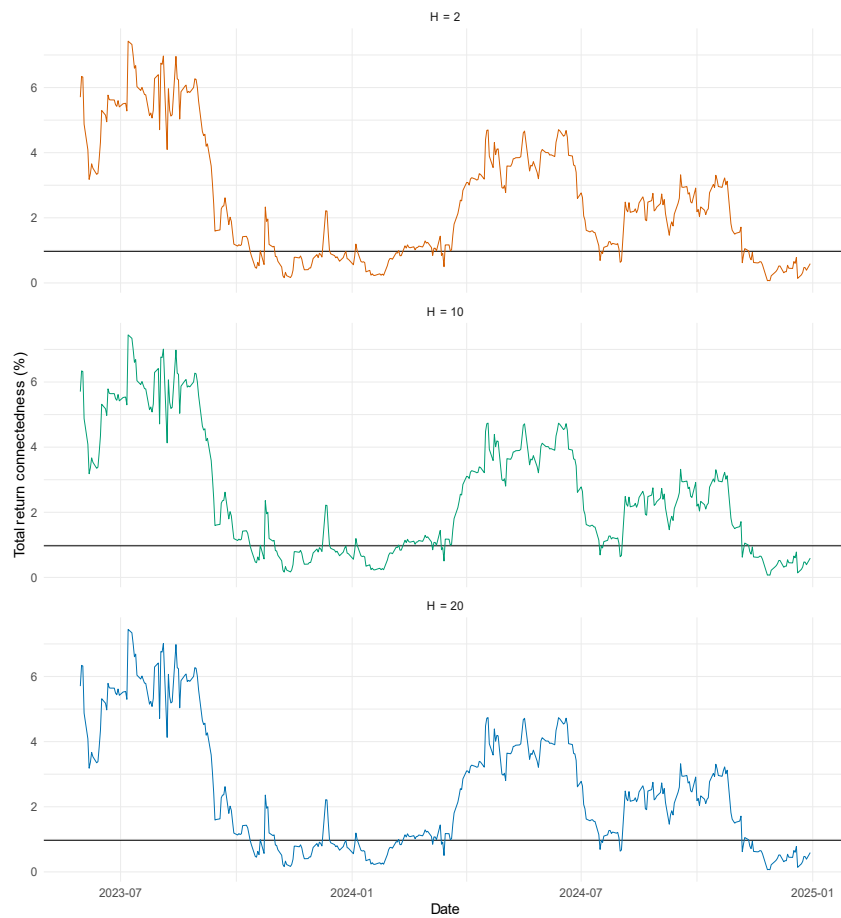
**Table 9.** Net spillover effects

	Net Spillover Effects			Transmitter
	To	From	Net	
<b>btc_return</b>	1	0.98	0.02	TRUE
<b>esg_id_return</b>	0.98	1	-0.02	FALSE

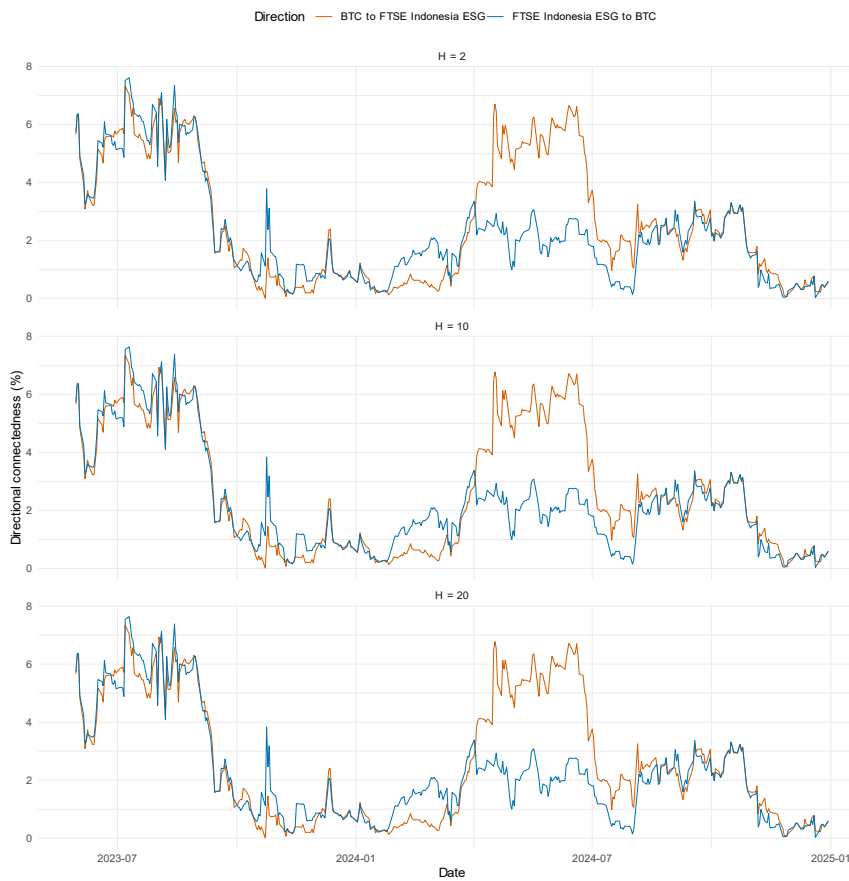
The connectedness measures discussed so far are static averages over the full sample. To analyze the robustness of the connectedness result and to confirm that the finding of negligible return connectedness is not an artifact of a single forecast horizon or a particular sub-period, a dynamic analysis was conducted using a 100-day rolling window, and the resulting time-varying total and directional connectedness are presented in Figures 1 and 2. Figure 1 plots the time-varying total connectedness index, while Figure 2 reports the directional connectedness between Bitcoin and the Indonesian ESG index, providing temporal insight into how the relationship evolves within the observation period.

As shown in Figure 1, the total return connectedness index fluctuates within a narrow, consistently low range and remains well below 5% throughout the analysis period, confirming the weak connectedness between the two assets across the entire sample rather than only at the baseline 10-day horizon. Figure 2 also shows that directional connectedness between Bitcoin and ESG index is similarly small in both directions with neither asset emerging as a persistent transmitter.

Despite the overall low level of connectedness, some temporal variation is observed, reflecting the time-varying nature of connectedness that evolves with changing market conditions. Nevertheless, there is no specific period in which the connectedness level surges, suggesting a stable relationship between the two assets over the observation period. The consistently low level of spillovers during the post-pandemic period suggests that Bitcoin’s diversification benefits for ESG-based portfolios are not temporary and extend beyond crisis periods, as commonly reported in studies conducted during the Covid-19 pandemic [10, 12, 24]. In contrast, this study confirms that both assets remain independent in relatively normal market conditions, suggesting that the idiosyncratic risks of each asset in the portfolio do not transmit to the other. This study contributes to the literature and confirms the validity of ESG-Bitcoin investment strategies for medium- to long-term investment.



**Figure 1. Dynamic total return spillover**



**Figure 2. Directional return connectedness**

Results of this study carry important implications for sustainable investment. Although Bitcoin mining is associated with negative environmental impacts, the asset demonstrates significant diversification potential. Therefore, incorporating it into ESG-based portfolios may be justified. Diversification can reduce investment risk while promoting sustainability-oriented investment. In this way, sustainable portfolio strategies may help offset the negative environmental impacts associated with Bitcoin mining.

For policy makers, the findings of this study suggest that ESG-based investment products may serve as strategic instruments to channel capital toward more sustainable activities without constraining digital asset innovation. Capital markets, through asset allocation mechanisms, can act as catalysts in supporting the net-zero emission targets by offering alternative investment strategies that promote both risk diversification and socially and environmentally responsible investment.

## 5. CONCLUSION

Using G-VAR and the Diabold and Yilmaz spillover approach, this study found that the connectedness between Bitcoin and Indonesian ESG stocks is very low. The total spillover is only around 0.99%, indicating the independence of the movements of the two assets. There is no Granger causality between Bitcoin and ESG stocks. Bitcoin acts as a net transmitter, but with a very small magnitude (0.02%).

The G-VAR framework employed in this study provides empirical evidence that combining Bitcoin with ESG-based stocks in an investment portfolio can offer potential diversification benefits, not only during crisis and recovery periods, but also during the post-pandemic period. The key indicator is the consistently low spillover index between the two assets. This low level of connectedness suggests that the two assets move independently, implying that risk in one market does not necessarily transmit to the other.

The findings of this study contribute to the existing literature by showing that integrating Bitcoin into Indonesian ESG-based investment portfolios can be financially beneficial while also supporting market-driven sustainability. Markets naturally provide investors with opportunities to diversify risk without undermining sustainability preferences. Furthermore, markets play a key role in facilitating the transition to a low-carbon economy, particularly when regulatory frameworks fail to internalize the environmental externalities associated with cryptocurrency activities. By combining Bitcoin and ESG-based stocks, investors implicitly implement risk-offsetting mechanism that balances the high risk and negative environmental concerns associated with cryptocurrency assets with sustainability-oriented assets characterized by strong governance. Such portfolios may represent a market-based carbon mitigation strategy that emerges endogenously from investor preferences.

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