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# The Dynamic Connectedness Between Environmental Attention and Green Cryptocurrency:
## Evidence From the COVID-19 Pandemic

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## ABSTRACT

The results indicate a dynamic pattern of interconnectedness throughout history. Based on the findings, the transmission of volatility exhibited a higher magnitude during the period of COVID-19. The issue of high transmission volatility due to limited diversification options concerns investors, green stakeholders, and policymakers alike. This article proposes various potential areas for future research. The ICEA index can potentially assist businesses operating in environmentally sensitive sectors make well-informed policy decisions. It includes sectors such as environmental green bonds, and commodities. Consideration should be given to implementing blockchain technology, as it can consume less power in this particular scenario. By employing a time-frequency paradigm, this study is able to incorporate the investment horizon, a crucial factor to be taken into account when making financial judgments. The advancement of this research could be facilitated by directing our attention toward the implications of our findings on portfolios and developing appropriate measures for their evaluation.

## KEYWORDS

COVID-19, Cryptocurrency, Dynamic Connectedness, Environmental Attentions

## INTRODUCTION

How frequently do discussions about the energy consumption of cryptocurrency mining and its environmental implications arise in online and offline forums? What is the rationale behind engaging in these debates? Remarkably, these questions lack straightforward answers. The perspective that cryptocurrency is an environmental problem is widely believed to be prevalent and increasing. The

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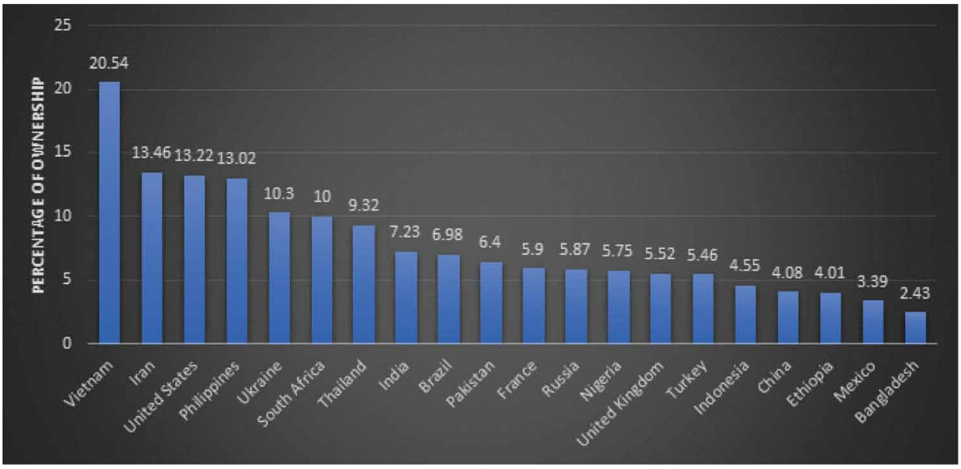
chief executive officer of Tesla, Elon Musk, has garnered attention in the media for announcing that the company will cease accepting Bitcoin as a form of payment due to its adverse environmental impact (Sriram, 2023). Legislative discussions have failed to adequately address the implications of cryptocurrency expansion and the corresponding increase in energy demand for its networks. Likewise, despite global efforts to promote environmental sustainability, the cryptocurrency industry remains unregulated. The recent decision to recognize Bitcoin as an official medium of exchange in El Salvador (Alazzam et al., 2023b; Arslanian et al., 2021) is a significant turning point in the broader acceptance of cryptocurrencies. The United Nations Economic and Social Council, as well as academics worldwide, must prioritize the assessment of the environmental implications connected with this developing category of currency and assets. Please refer to figure 1 to figure 3 related cryptocurrency ownership.

The scholarly debate surrounding cryptocurrencies has lasted a long time, owing to the awareness of their potential long-term benefits in fields of economics, the environment, and society (Li et al., 2022a; Vranken, 2017). Recent studies (Alshebami, 2021; Karim et al., 2022; Kołodziejczyk, 2023) indicate an increasing trend in the volatility transmission of cryptocurrency-based financial assets to green financial assets. Studies have shown a correlation between the Economic Policy Uncertainty

**Figure 1. Map depicting ownership percentage of cryptocurrencies (Source: Present research)**

**Figure 2. Map depicting the top-20 countries for cryptocurrency ownership (Source: Present research)**

**Figure 3. Ownership percentage of cryptocurrency with respect to population (Source: Present research)**




index and the Volatility Index, which is an example of volatility spillover (Kamal & Hassan, 2022; Karim et al., 2021). It is imperative to consider the transmission of environmental uncertainty from Bitcoin mining, as explored in previous research (Blahušiaková, 2022; Naeem et al., 2021a), and the measurement of uncertainty in the cryptocurrency domain (Yilmaz et al., 2020) regarding the impact on green financial assets. The measurement of environmental awareness in the realm of cryptocurrency can be accomplished through the utilization of the Index of Cryptocurrency Environmental Attention (Krochmal & Staniewski, 2011; Wang et al., 2022b).

The COVID-19 pandemic has been found to be associated with health concerns that are also connected to an elevated likelihood of transmitting the virus (Moslehpour et al., 2022; Özdemir, 2022; Sadiq et al., 2022; Zhang et al., 2023). Consequently, the presence of COVID-19 may pose challenges to the practice of hedging within financial markets (Sarkodie et al., 2022; Ul-Durar et al., 2023). Please refer figure 4 trend in value of digital assets around the globe.

**Figure 4. Trend in value of digital assets around the globe (Source: Present research) (Note: The dotted line in red depicts the estimated growth in digital assets in the future)**

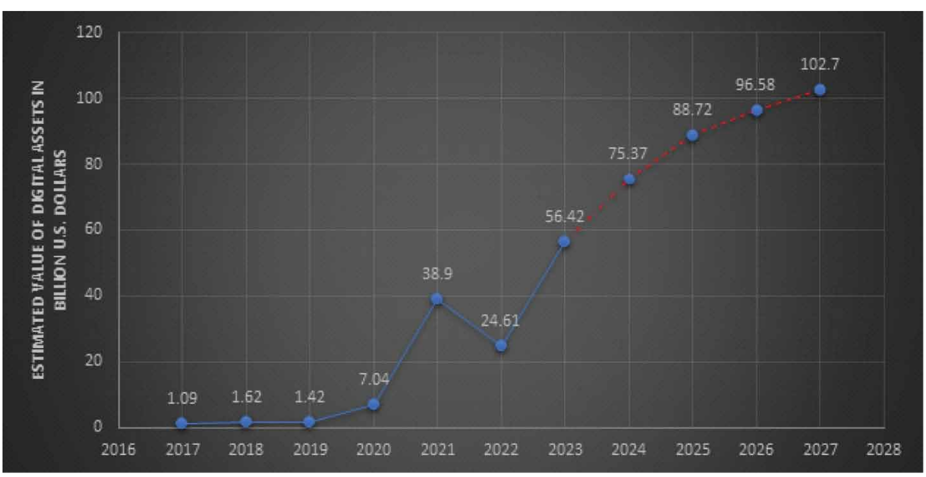


Fig. 4 depicts the estimated growth in digital assets. The trends in the growth of digital assets indicate stable growth, indicating a bright future for them. The graph indicates rapid growth from almost 7 billion to 38 billion from 2020 to 2021, while there was a considerable decline in 2022 owing to the rapid increase in prices of digital assets along with skepticism of market participants. It is indisputable that the Bitcoin market has evolved into a valuable instrument for hedging and diversification.

According to Symitsi and Chalvatzis (2019) and Tiwari et al. (2023), the correlation between the mining of cryptocurrencies and climate change is weak. However, the financial industry's growth has raised concerns regarding the environmental impact of blockchain and cryptocurrency mining. Wang et al. (2019) have identified issues such as carbon dioxide emissions, high energy consumption, and air pollution and their contribution to climate change. Hence, the subsequent justifications underlie the necessity of undertaking this research endeavor. Initially, it can be argued that cryptocurrencies are considered currencies with negative environmental implications, making them unappealing to individuals who prioritize sustainable energy and environmental preservation as viable investment opportunities (Alazzam et al., 2020; Fang et al., 2023; Symitsi & Chalvatzis, 2019).

Furthermore, the process of cryptocurrency mining, specifically Bitcoin mining, exerts a significant strain on the power grid. According to Blandin et al. (2020) and Novitasari et al. (2021), the current annual electricity consumption of Bitcoin amounts to approximately 0.55 percent, equivalent to 110 TWh, of global energy usage. Therefore, examining the propagation of Bitcoin's environmental impact within the context of sustainable financial markets is imperative. Prior studies have indicated limited empirical support for the environmental concerns associated with cryptocurrency (Wang et al., 2019).

Hence, this endeavor serves to address a knowledge deficit. This study contributes to the existing body of knowledge in three main areas: the lower and higher (Akhtaruzzaman et al., 2021) time-varying parameter vector autoregression (TVP-VU) models can benefit from incorporating the findings of the expanding body of research on the long-term viability of cryptocurrencies. Studies conducted by Adams et al. (2022) and Al-Shboul et al. (2023) examine the impact of volatility spillover from Bitcoin's environmental concentration on both Asia/Pacific and global certainty periods, particularly during the COVID-19 period. Scholars have widely acknowledged and recognized the utilization of the cryptocurrency market as a means of diversification and hedging (Alazzam & Alshunnaq, 2023; Alazzam et al., 2020; Huynh et al., 2021). Li et al. (2022b) assert that the practice of cryptocurrency mining has emerged as an untrustworthy metric for assessing the phenomenon of climate change. The proliferation of the financial sector has raised concerns regarding the environmental impact of blockchain technology and cryptocurrency mining. These activities have been found to contribute to carbon-dioxide emission, excessive energy consumption, air pollution, and, ultimately, climate change (Wang et al., 2020). Hence, the subsequent justifications underlie the necessity of undertaking this research endeavor.

First, it is important to note that cryptocurrency has the potential to negatively impact investors in green and renewable energy sectors (Alazzam et al., 2023a; Naeem et al., 2021b). Furthermore, cryptocurrency mining, specifically Bitcoin mining, significantly strains the power grid. According to Blandin et al. (2020), Bitcoin accounts for approximately 0.55 percent (110 TWh) of global annual electricity consumption. Hence, examining the impact of Bitcoin's ecological principles on sustainable financial systems is imperative. The existing body of research indicates that the environmental concerns associated with cryptocurrency lack empirical evidence to substantiate their claims (Almeida & Gonçalves, 2023).

Academics have taken an intensely curious interest in the long-term viability of cryptocurrency. This information void is addressed by our research. Because of this work, our knowledge has increased. The results of our study have substantial consequences for policymaking and green investors, particularly in the context of the lower and higher TVP-AR models proposed by Akhtaruzzaman et al. (2021) and Alazzam et al. (2023a). Three main topics (cryptocurrency, covid-19 and environmental attentions) emerge from the studies conducted by Antonakakis et al. (2020), Staniewski et al. (2023), and Wang et al. (2022b). Using the work of Ribeiro-Navarrete et al. (2021) and Wang et al. (2019), we can analyze the COVID-19 period's effect on the volatility spillover to green financial assets and the effect of cryptocurrency's environmental focus on global certainty periods (Wang et al., 2022a). Hence, examining the impact of Bitcoin's ecological principles on alternative monetary frameworks is imperative.

## LITERATURE REVIEW

### Energy Demand and Cryptocurrency

The energy demands associated with cryptocurrency mining greatly exceed those of gold mining (Symitsi & Chalvatzis, 2019). Although the initial impression of the crypto may evoke a sense of melancholy, it effectively encapsulates the situation. Is it possible to develop environmentally friendly cryptocurrency solutions? Extensive research has been conducted on the energy consumption and carbon footprint attributed to the process of Bitcoin mining (Kamal & Hassan, 2022). The current market encompasses over 4,000 distinct cryptocurrencies, requiring a substantial commitment of time and effort. According to Weinhardt et al. (2019), the power consumption associated with Bitcoin mining has experienced a significant increase over the last two years. Consumption experienced a significant rise, escalating from 4.82 TWh to 73.12 TWh. According to Badea and Mungiu-Pupăzan (2021), the emission of carbon dioxide resulting from a solitary Bitcoin transaction is projected to be on par with the emissions produced by 350,000 credit-card purchases or the energy consumption of a typical American household over 20,920 days.

According to Ji et al. (2019), in the absence of governmental intervention, it is projected that the annual energy consumption of Bitcoin in China will reach its highest point at 296.59 TWh by the year 2024. China is home to a significant proportion of the Bitcoin market. The aggregate amount of carbon-dioxide emissions was recorded at 130.50 million metric tons. The cumulative annual carbon emissions from Bitcoin exceed the combined emissions of Qatar and the Czech Republic. According to the findings of Corbet et al. (2020), in June 2017, the energy consumption of the Ethereum network was equivalent to that of Cyprus (Ante et al., 2021).

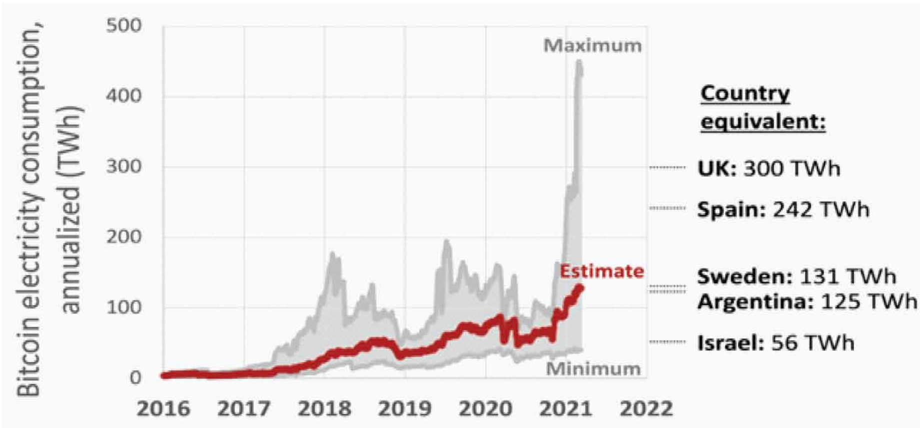
### Environmental Attention and Green Cryptocurrency

According to Chenguel (2022) and Zimmer (2017), the ecological impact of cryptocurrency mining is significantly negative, rendering it unsustainable. Several concerns have arisen as a direct consequence of this circumstance. Currently, it remains challenging to establish definitive scientific conclusions regarding the impact of Bitcoin technology on global warming due to a limited number of studies that assess the magnitude and fundamental factors driving the increasing energy consumption associated with cryptocurrencies (Miśkiewicz et al., 2022). Please refer to figure 5 for electricity consumption of mining bitcoin.

There is a scarcity of research on negative interactions, as evidenced by the limited attention given to this topic by scholars. Determining the relative volatility of financial or economic factors in response to media coverage of cryptocurrencies poses a challenge, thereby adding complexity to comprehending the influence of media on cryptocurrency markets (Brady et al., 2005; Czaja & Röder, 2021). Moreover, the existing norms and protocols fail to adequately consider the environmental consequences associated with cryptocurrency, as evidenced by several scholarly publications (Burggraf et al., 2020; Cardon et al., 2017; Cheah & Fry, 2015; Chen et al., 2020).

A substantial body of scholarly literature exists regarding the classification of cryptocurrencies as either commodities or currencies (Adams et al., 2022; Ishaque et al., 2022; Li et al., 2022b; Tiwari et al., 2018). The complexity associated with cryptocurrencies has prompted speculation regarding their viability as a practical mode of payment. Based on the data provided in Ullah and

Figure 5. The electricity consumption for mining bitcoin (Source: Cho, 2021)




Nasim (2021), the predominant use of Bitcoin is observed to be as a store of value rather than as a medium of exchange. Studies by Baur and Dimpfl (2021), Hiaeshutter-Rice et al. (2023), and Huynh et al. (2021) conclude that cryptocurrencies, similar to commodities, possess the ability to manage risks and exhibit symmetrical responses to news events. Recent scholarly research has undertaken a comparative analysis of the cryptocurrency sector concerning other industries. These studies examine the advantages of bubble behavior (Cheah & Fry, 2015), efficiency, and diversity (Özdemir, 2022; Sarkodie et al., 2022; Silva & Mira da Silva, 2022). Brugni et al. (2021) and Özdemir (2022) also present arguments for significant interdependencies and volatility spillovers.

The decision made by Tesla to exclude cryptocurrencies from its procurement strategy has prompted legislators and market participants to raise concerns regarding the enduring sustainability of cryptocurrencies. In 2021, 204,501 TWh of electricity were produced to be consumed to facilitate the mining operations of Bitcoin. This energy consumption is equivalent to that of Thailand. Ethereum was projected to consume 103,420 TWh, equivalent to the energy consumption of Kazakhstan. A single transaction involving Bitcoin or Ethereum emits carbon dioxide comparable to the annual emissions of Kuwait or Hungary. Based on the calculations conducted by Huong et al. (2021), Krause and Tolaymat (2018), and Ma et al. (2021), it has been determined that a Google search consumes approximately 0.80 mg of energy. In contrast, a VISA transaction utilizes a comparatively lower amount of 0.40 mg (Kohli et al., 2023).

Green and environmental investors often experience anxiety due to prevalent issues such as cybercrime, market crashes, and price bubbles (Cheah & Fry, 2015). There is a discernible trend among investors to redirect their attention toward investments that prioritize environmental sustainability, driven primarily by mounting apprehensions regarding the environmental ramifications associated with the Bitcoin industry (Miyazaki et al., 2005; Mohapatra et al., 2019; Naeem et al., 2023).

Contemporary society is confronted with the substantial and daunting task of effectively curbing environmental degradation and mitigating the impacts of climate change. The adverse impact of increasing temperatures on ecosystems worldwide has been attributed by scientists primarily to the escalation of carbon-dioxide emissions (Sang et al., 2022). Governments and businesses have endeavored to address this issue by implementing strategies to diminish carbon emissions and curb reliance on fossil fuels (Drei et al., 2019). Investing in green markets, such as green bonds, renewable energy, sustainable indices, and ESG indices, is considered a critical step (Karim et al., 2022; Karim et al., 2021; Khullar et al., 2020; Kołodziejczyk, 2023).

The European Investment Bank (EIB) introduced the notion of green bonds in 2007 to finance environmentally sustainable initiatives globally. In 2014, the adoption of the Green Bond Principles by the International Capital Markets Association enhanced market trust and credibility, heightened transparency, and bestowed official recognition. Based on the forecasts conducted by the Climate Bond Initiative (Wang et al., 2022b), the market is anticipated to witness a substantial growth trajectory, escalating from a modest value of slightly above US$11 billion in 2014 to a significant sum exceeding US$260 billion by 2020. Three countries have transitioned toward renewable energy sources within the clean-energy sector due to increasing environmental consciousness and adherence to the Paris Climate Agreement of 2015 (Kohli et al., 2023; Sial et al., 2022; WEIR, 2022). Based on the existing statistical data, it can be observed that the renewable energy sector has exhibited the most substantial growth rate over the last twenty years. According to Almeida & Gonçalves (2023) and Sial (2022), renewable sources accounted for 20.1% of global power generation and 19.9% of total energy consumption in the year 2021.

### Global Perspective

Global investors currently perceive investments in renewable energy as an attractive and potentially lucrative asset category. The equity markets related to renewable energy have experienced substantial growth in recent years, primarily due to the backing of investors (Kamal & Hassan, 2022). According to Miśkiewicz et al. (2022) and Sial & Panasenko (2022), companies involved in the production of renewable and sustainable energy have recently outperformed equities market indices and companies engaged in fossil-fuel generation.

The empirical findings presented here align with the previous studies conducted by Özdemir (2022), Sarkodie et al. (2022), and Silva and Mira da Silva (2022). These studies indicate that the performance of this particular asset class is superior to that of a compromised asset class. The sustainable investing market encompasses investment operations that prioritize corporate, social, and environmental responsibility across various asset classes (Corbet et al., 2018; Sial, 2022). In recent years, there has been significant growth in the sustainable investment market, which has garnered praise for its capacity to address climate change and other environmental concerns (Mohapatra et al., 2019; Naeem et al., 2023). The demand for environmentally sustainable products experienced a significant surge as a consequence.

According to the Global Sustainable Investment Alliance, the total value of managed assets is to reach US$35.301 trillion by the conclusion of 2020. This figure signifies a substantial growth rate of 55% when compared to the data recorded in 2016. In the initial quarter of 2020, a total investment exceeding $45.6 billion was allocated to sustainable funds by seven global institutional investors, with a specific focus on environmental preservation, social equity, and effective governance. Nonetheless, a substantial financial deficit of $384.7 billion was accrued as a result of the departure of international capital. Investors have exhibited increased awareness regarding the potential financial and environmental advantages linked to endorsing this particular sector. Its heightened awareness can be attributed to the repercussions of climate change on businesses and the diversification benefits that arise from allocating funds toward assets related to green investments. Consequently, there is a heightened focus on the eco-friendly business sector (Naeem et al., 2023; Sial et al., 2021).

## DATA AND METHODS

### Data Source

Several indices were considered in this study. These included the Dow Jones World Sustainability Index (DJWSI), the Dow Jones Sustainability Asia/Pacific Index (DJSAPI), the S&P Green Bond Index (S&P-GRBN), the S&P Global Clean Energy Index (S&P-GLCEI), and the Index of Cryptocurrency Environmental Attention (ICEA). Created by Wang et al. (2022), the news based ICEA was chosen as it attempts to reflect the proportional volume of media conversations about cryptocurrency's environmental effects. There has been little research into the long-term effects of

Bitcoin environmental attention on macro-financial markets and economic development. The sample period for green financial assets begins on January 3, 2014, and ends on December 31, 2022, with dates sourced from ICEA's weekly reports. The data for the subsample analysis spans from January 1, 2019, to December 31, 2022. Financial-asset data is from DataStream, while cryptocurrency-market coverage is from brianmlucey.wordpress.com.

## Research Model

This study examined the comparative performance of cryptocurrency in relation to environmentally sustainable investments. The time-varying parameter vector autoregressive (TVP-AR) model was developed by Antonakakis et al. (2020) and was employed for this analysis. The empirical model was originally introduced by Primiceri (2005) and subsequently revised by Antonakakis et al. (2020). There exist numerous advantages associated with the utilization of this strategy in comparison to alternative approaches. Three key criteria emerge as particularly significant. First, it is crucial to establish the capacity to quantify the interdependence of all system metrics. The second criterion pertains to the capacity to anticipate the enduring ramifications of financial contagion and the transmission of volatility to the wider market system. The third is the capacity to accurately identify and analyze time series that are either incomplete or flawed and to offer informed hypotheses regarding the underlying reasons (Karim & Naeem, 2021). The objective of this study is to examine the origins of the linear structure by quantifying the likelihood of shocks or responses that arise from the overall expansion of the mechanism:

$$y_t = \beta_{0,t} + \beta_{1,t} Y_{t-1} + \ldots + \beta_{p,t} Y_{t-p} + \upsilon_t + \mathrm{X}_t^{'} \Theta_t + \upsilon_t \tag{1}$$

The time-varying coefficients $\beta_{0t} \ldots\ldots_{p,t}$ in (1), denoted by the $y_t$ vector of $n$ $X$ 1 dependent variables, are expressed as $\Theta_t$ matrix as suggested by Naeem and Karim (2021):

$$X_t^{'} = \left[1, y_{t-1}^{'} \ldots, y_{t-p}^{'}\right] \tag{2}$$

$$\Omega_t = M_t^{-1} H_t \left(M_t^{-1}\right) \tag{3}$$

The following assumptions are made regarding the temporal evolution of dynamic parameters:

$$\Theta_t = \Theta_{t-1} + \upsilon_t, \upsilon_t \approx N\left(0, S\right) \tag{4}$$

$$\alpha_t = \alpha_{t-1} + \xi_t, \xi_t \approx N\left(0, Q\right) \tag{5}$$

The time-varying parameters are estimated using (4) and (5) in accordance with the random walk process:

$$\ln h_{it-1} = Lnh_{i,t-1} + \sigma_t \mu_{i,t}, \mu_{i,t} \approx N\left(0,1\right) \tag{6}$$

Utilizing the connectivity of the random walk process allows for the acquisition of stochastic estimates using (6), as suggested by Kamal and Hassan (2022). In a general context, it has been observed that the error term exhibits no correlation with the transition equation. Consequently, it is possible to uphold efficient and simplified estimations while accommodating certain levels of variability in the coefficients across the variables (Naeem & Karim, 2021; Primiceri, 2005).

## RESULTS AND DISCUSSION

Table 1 presents the results of unit rot tests and descriptive statistics. The S&P-GLCEI is identified as the financial asset in the green sector that exhibits the highest level of volatility, and the S&P-GRBN exhibits the lowest. The distribution of log returns exhibits characteristics such as high peakedness, asymmetry, and non-normality. Given that each return series exhibits stationarity, it can be inferred that stationarity is assured.

These panels summarize the outcomes derived from examining the time-varying relationship between ICEA and green financial assets, as conducted through the TVP-VAR model. The ICEA is a significant conduit for transmitting volatility spillover to other green financial assets, thereby contributing to the overall system connectedness of 27.12%, as observed in Section A. The results of their study lend support to the argument made by Kamal and Hassan (2022) that ICEA functions as a net transmitter (receiver) in the lower quantiles of the distribution. Based on their findings, it was determined that S&P-GRBN and DJSAPI exhibit a positive relationship with volatility, thereby

**Table 1. Results of unit root tests and details of descriptive statistics**

| | ICEA | S&P-GLCEI | S&P-GRBN | DJWSI | DJSAPI |
|---|---|---|---|---|---|
| A: Descriptive Statistics | | | | | |
| μ (Mean) | 0.0000 | 0.0069 | 0.0009 | 0.0059 | 0.0019 |
| Maximum | 0.0239 | 0.0509 | 0.0089 | 0.0399 | 0.0269 |
| Minimum | -0.0991 | -0.0893 | -0.030 | -0.0651 | -0.0598 |
| σ (Standard Deviation) | 0.0019 | 0.0129 | 0.0030 | 0.0080 | 0.0080 |
| Skewness | 4.0550 | -1.0699 | -2.2922 | -1.400 | -1.8990 |
| Kurtosis | 63.0008 | 10.9970 | 23.9293 | 15.8976 | 18.0001 |
| Goodness-of-Fit Test (Jarque-Bera Test) | 70001.950* | 1301.329* | 8297.001* | 3521.739* | 4200.0009* |
| Augmented Dicky-Fuller Test | -21.001* | -16.214* | -17.022* | -18.111* | -13.980* |
| Unit Root Test (Phillips-Perron) | -20.990* | -14.659* | -17.223* | -16.222* | -15.001* |
| B: Correlation Matrix | | | | | |
| DJSAPI | 1.0000 | | | | |
| DJSWI | 0.7397 | 1.0000 | | | |
| S&P-GRBN | 0.1399 | 0.1200 | 1.0000 | | |
| S&P-GLCEI | 0.2530 | 0.2700 | 0.1739 | 1.0000 | |
| ICEA | -0.0231 | -0.0129 | 0.0049 | -0.0401 | 1.0000 |

*The significance level of 1% is indicated in both the correlation matrix and the descriptive statistics presented in the table.
Note: Section A represents the comprehensive sample, while Section B pertains specifically to the period during the COVID-19 pandemic.

benefiting from it. Additionally, S&P-GLCEI was identified as the second transmitter of volatility to green financial assets. Both DJWSI and DJSAPI exhibit a net positive impact resulting from the transmission of volatility across financial markets. Ferreras-Méndez et al. (2019) present compelling evidence of the collaborative efforts among the three organizations, namely DJWSI, DJSAPI, and S&P-GLCEI, in pursuing environmental and sustainable development objectives. The diversification of British investments in green financial assets is extensive despite the country's limited connections with international markets (Haq, 2011).

According to Section B of Table 2, the analysis of COVID-19 data reveals that S&P-GRBN exhibits the highest net transmission capacity. The findings suggest that the S&P-GLCEI played a significant role in transmitting shocks to global sustainability and the Asia/Pacific index during the COVID-19 pandemic, with its impact ranking slightly lower than that of the Sustainable Development Goals Index. The study by Kamal and Hassan (2022) revealed that the ICEA functioned as a recipient of shocks amid the COVID-19 pandemic, and their findings support their initial observation. The DJSAPI has experienced the greatest advantages in terms of volatility spillover resulting from the epidemic compared to other markets. The present study provides evidence of the transmission of shocks from the ICEA to the S&P-GLCEI, which stands in contrast to the findings reported by Kamal and Hassan (2022), who observed an opposite contagion effect in the context of the COVID-19 pandemic (Yao et al., 2022). The limited sample size of 69 observations utilized in their analysis may be a contributing factor. According to Ma et al. (2021), there was a notable increase in the aggregate connectivity score, reaching 32.79%, during the pandemic. As illustrated in Fig. 7, this assertion remains valid. Green

**Table 2. Results depicting the average dynamic connectedness**

| | ICEA | S&P-GLCEI | S&P-GRBN | DJWSI | DJSAPI | Others |
|---|---|---|---|---|---|---|
| A: Full Sample | | | | | | |
| ICEA | 94.00 | 0.59 | 0.50 | 0.44 | 0.39 | 2.00 |
| S&P-GLCEI | 1.69 | 69.62 | 2.98 | 10.00 | 6.56 | 19.08 |
| S&P-GRBN | 10.90 | 6.29 | 69.50 | 2.60 | 1.70 | 20.42 |
| DJWSI | 1.490 | 19.89 | 4.02 | 45.23 | 25.60 | 49.79 |
| DJSAPI | 1.76 | 11.04 | 2.03 | 30.40 | 50.01 | 41.23 |
| Contribution to Others | 16.87 | 36.18 | 7.09 | 43.01 | 35.81 | 140.01 |
| Inc. Owns | 120.01 | 117.00 | 87.01 | 90.00 | 90.32 | TCI |
| Net Directional Connectedness | 14.90 | 17.08 | -12.93 | -11.07 | -9.00 | 27.12% |
| B: During COVID-19 | | | | | | |
| ICEA | 89.23 | 0.90 | 0.89 | 1.00 | 1.19 | 3.99 |
| S&P-GLCEI | 2.29 | 79.09 | 6.12 | 6.23 | 6.60 | 18.97 |
| S&P-GRBN | 1.73 | 1.92 | 69.91 | 16.01 | 7.05 | 27.03 |
| DJWSI | 0.39 | 7.30 | 15.91 | 42.01 | 34.00 | 59.00 |
| DJSAPI | 0.59 | 11.90 | 10.31 | 32.01 | 44.00 | 57.01 |
| Contribution to Others | 5.20 | 25.10 | 32.90 | 49.40 | 51.00 | 150.81 |
| Inc. Owns | 100.29 | 113 | 102.13 | 97.20 | 89.09 | TCI |
| Net Directional Connectedness | 1.05 | 6 | 8.91 | -4.01 | -9.00 | 30.80% |

Note: Table 2 indicates the TVP-VAR estimation for the full sample along with the period of COVID-19.

**Figure 6. Dynamic total connectedness (Note: The overall interconnection of the four digital currencies is depicted in this graph. The associated events have been tagged with the respective trend labels.)**

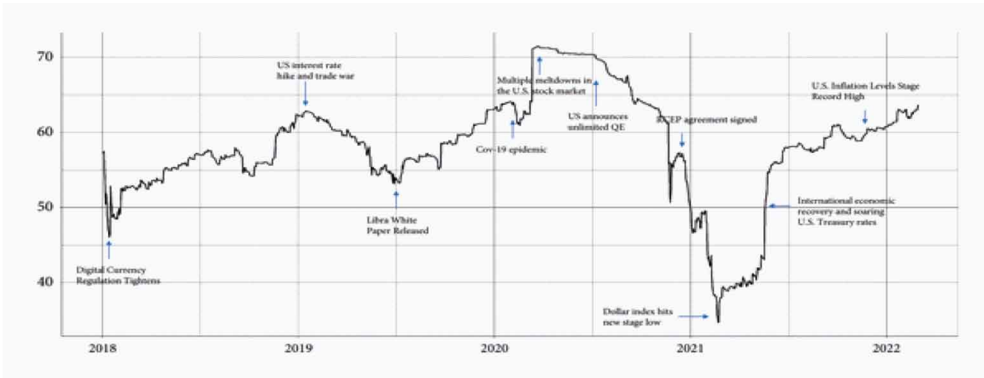
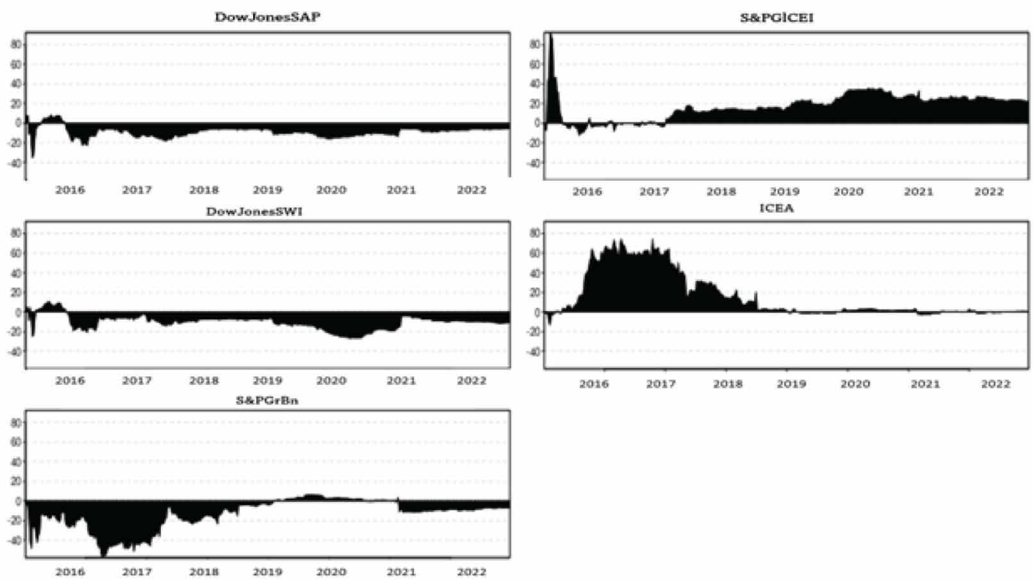



**Figure 7. Total net connectedness (Note: The figure above displays pairwise connectivity using a 200-day rolling window, a non-informative prior, and a 10-step lead time in forecasting)**




financial assets have the potential to serve as effective mechanisms for hedging against the impacts of COVID-19 due to their lower level of interconnectedness.

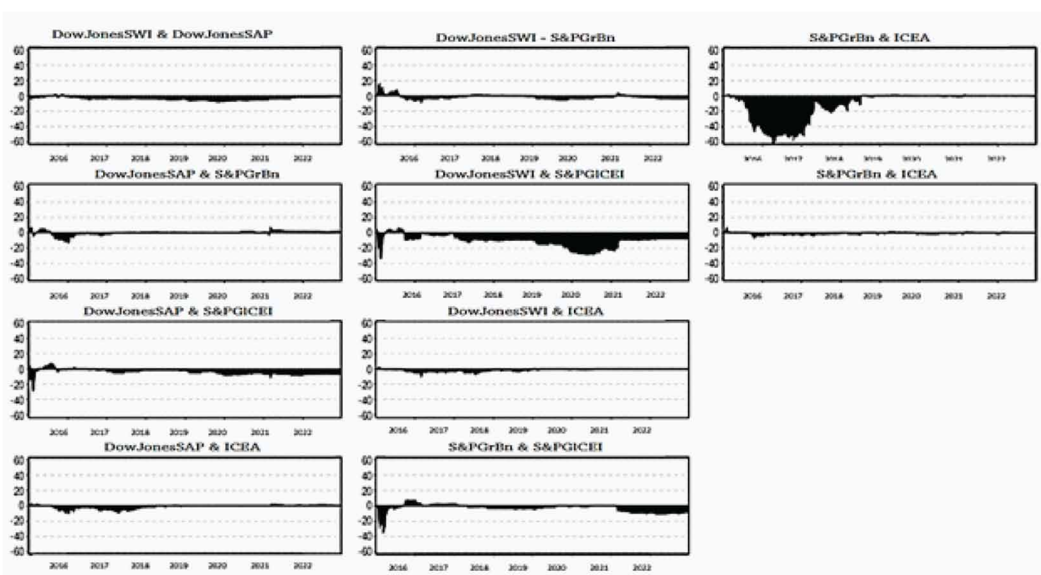
The extent of shock transmission experienced a significant decrease after 2018, while the ICEA exhibited a consistent pattern of transmitting volatility spillover from 2014 to 2018. Similarly, it can be observed that the S&P-GLCEI exhibits a consistent pattern of transmitting volatility spillover throughout the entire data analysis rather than being limited to S&P- the final weeks of 2014. During the period spanning from 2014 to 2021, it can be observed that the S&P-GRBN, DJWSI, and DJSAPI indices have generally experienced positive effects from volatility spillovers, with only a few instances of negative outcomes. The findings of this study indicate that it would be prudent for investors to incorporate S&P-GLCEI into their investment portfolios alongside other assets to mitigate their risk exposure to ICEA. Furthermore, it is evident that the sources and targets of environmental volatility transmission within the cryptocurrency domain exhibit dynamic temporal patterns.

Fig. 8 displays the dynamic pairwise associations among the ICEA and four financial assets recognized for their environmentally friendly characteristics. The impact of cryptocurrency volatility on the environment surpasses that of the Great Britain Consumer Price Index and falls short of the S&P-GLCEI. The findings of previous research conducted by Kamal and Hassan (2022) provide empirical evidence supporting the notion that the S&P-GLCEI can effectively mitigate the adverse effects of the ICEA phenomenon within investment portfolios. This study's findings support the assertion that virtual currencies can be considered a type of fraudulent currency (Naeem & Karim, 2021). Policymakers and environmental advocates may undertake requisite measures to mitigate the carbon emissions and energy demands associated with the cryptocurrency sector. As mentioned above, the findings hold significance for Asia/Pacific authorities and sustainable investors concerning their portfolio investments in green financial assets and their efforts to mitigate the impact of volatility transmission from the cryptocurrency market to green financial assets.

## CONCLUSION

This study investigates the interconnections between the Bitcoin environmental attention index and four green financial assets by applying the time-varying parameter vector autoregression model. Our research on the correlation between environmentally beneficial and polluting assets has the potential to inform policymakers in developing new legislative measures to address the worldwide need for sustainable and environmentally friendly financial products. The S&P-GRBN index played a significant role as a primary transmitter of network volatility during the COVID-19 pandemic. The ICEA and S&P-GLCEI indices exhibited the transmission of net volatility spillover during the investigation. Throughout the analyzed period, the ICEA has exhibited a favorable spillover effect on the S&P-GLCEI, S&P-GRBN, DJWSI, and DJSAPI. The ICEA system exclusively impacted the S&P-GLCEI and S&P-GRBN indices in the context of the COVID-19 pandemic. The DJWSI index experienced significant advantages due to the positive feedback loop established by the S&P-GRBN

**Figure 8. Pairwise Connectedness (Note: The figure above displays pairwise connectivity using a 200-day rolling window, a non-informative prior, and a 10-step lead time in forecasting)**



and S&P-GLCEI indices. The findings of the TVP-VAR study support the notion that financial contagion can profoundly impact the overall system. The study reveals a notable surge in connectivity during the pandemic. Furthermore, the limited capacity for hedging and diversification concerning ICEA risks is primarily attributed to the strong correlation between ICEA and green financial assets.

### Research Limitations

The TVP-VAR methodology is limited in capturing interdependence across various frequencies due to its failure to account for the comprehensive investment landscape encompassing both short-term and long-term prospects. Hence, it is recommended that future research endeavors include sustainable cryptocurrencies in portfolios of environmentally conscious financial assets. The objective should be to explore different aspects of connectivity and risk mitigation against the ICEA through wavelet models across various investment time frames. Besides this, the present study included only the ICEA index. In the future, researchers can develop their own index or modify the present index to suit their study requirements.

### Research Implications

The results of this study carry significant implications for investors who prioritize ethical and environmental considerations. The ICEA index has the potential to facilitate more informed policy decisions, thereby offering potential advantages to businesses operating in environmentally conscious sectors, such as those focused on the environment, green bonds, and commodities. In this scenario, they can consider utilizing blockchain technology that requires less energy. The correlation between environmental stocks and ICEA exhibits either a weak or a positive relationship, suggesting governments should consider promoting citizen investment in these stocks. Consequently, an ample supply of renewable energy will offset the energy requirements associated with cryptocurrency mining. An additional factor to be considered is the increasing recognition among the general public of the worldwide ramifications of cryptocurrencies in recent times. Hence, it is imperative for the authorities overseeing the financial markets under consideration to duly acknowledge and consider the potential long-term consequences of this scrutiny.

### Future Direction of Research

There exist various challenges that must be effectively addressed to advance our research. This study presents several potential avenues for future research. Incorporating a time-frequency framework into the analysis allows for consideration of the investment horizon, a critical factor in economic decisions. Our research could be advanced by exploring the implications of our findings on portfolios and devising suitable metrics for their evaluation.

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