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Cryptocurrency Environmental Attention, Green Financial Assets, and Information Transmission: Evidence From the COVID-19 Pandemic

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This paper explores the connectedness between the cryptocurrency environmental attention index and four major green financial assets using time-varying parameter vector autoregression model from January 2014 to December 2021. Findings reveal that connectedness follows a heterogeneous trajectory over time. Results show evidence of higher volatility transmission during the COVID-19 period relative to the entire sample period. The high volatility transmission is a source of concern to policymakers, green stakeholders, and investors, due to limited diversification options.

I. Introduction

Scholars have long argued about cryptocurrency's sustainable, environmental, and economic attributes (Karim et al., 2022). Volatility spillovers from the cryptocurrency market to green financial assets are increasingly prevalent in recent studies (Kamal & Hassan, 2022; Naeem & Karim, 2021). For instance, there is evidence of volatility spillovers from EPU (Haq et al., 2021) and VIX (Kamal & Hassan, 2022; Le et al., 2021) to green financial assets. However, the Cryptocurrency Environmental Attention Index (ICEA) captures cryptocurrency environmental attention (Karim et al., 2022) and hence it is pivotal to consider how cryptocurrency environmental uncertainty spillovers to the green financial assets to complement prior studies on spillovers from Bitcoin mining (Naeem & Karim, 2021) and crypto-specific uncertainty measures (Hasan et al., 2021; Hassan et al., 2021; Wang et al., 2022) to green financial assets. In addition, the health crisis caused by COVID-19[1] has increased the prospect of volatility transmission (Karim & Naeem, 2021). Therefore, COVID-19 may diminish hedging opportunities in financial markets.

This study draws inferences from the volatility spillover of cryptocurrency environmental attention to green financial assets using the time-varying parameter vector autoregression (TVP-VAR) approach during *COVID-19* and the full sample periods. The green financial assets are the S&P global clean energy index, S&P green bonds index, Dow Jones sustainability world index, and Dow Jones Sustainability Australia Index.

Undoubtedly, the cryptocurrency market has become an attractive avenue for diversification and hedging (Hasan et al., 2021). Cryptocurrency mining has become a negative predictor of the environment (Krause & Tolaymat, 2018). Despite the financial development, blockchain and cryptocurrency mining foster air pollution, high-energy consumption, climate change, and Carbon dioxide pollution issues (Wang et al., 2022). Hence, the motivations of the study are as follows. First, cryptocurrencies are dirty currencies, which influence the investment decisions of environmentalists and clean energy investors (Naeem & Karim, 2021). Second, cryptocurrency mining (Bitcoin mining in particular) requires huge electricity. Notably, the current energy consumption of Bitcoin is about 0.55% (110 TWh) of global electricity consumption per year according to the Cambridge Center of Alternative Finance (CCAF).[2] Therefore, it is crucial to study the information transmission from cryptocurrency environmental attention to green financial markets.

Earlier research lacks empirical evidence related to environmental concerns about cryptocurrency (Bariviera & Merediz-Solà, 2021; Naeem & Karim, 2021; Wang et al., 2022). Therefore, this study fills this research gap. Accordingly, the contributions of this study relate to three aspects of the literature: 1) the growing literature on COVID-19 induced attention on the environmental effects of cryptocur-

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1 See Akhtaruzzaman, Boubaker, and Sensoy (2021) for more descriptions of COVID-19.

2 See: https://www.bloomberg.com/opinion/articles/2021-01-26/is-bitcoinmining-worth-the-environmentalcost?Utm_source=url_link

Table 1. Descriptive statistics and Unit root tests

Panel A: Descriptive statistics	*ICEA*	*GCEI*	*GB*	*DJSWI*	*DJSAI*
Mean	0.0000	0.0007	0.0001	0.0006	0.0002
Maximum	0.0247	0.0532	0.0090	0.0406	0.0277
Minimum	-0.0103	-0.0951	-0.026	-0.0648	-0.0668
Std. Dev.	0.0020	0.0133	0.0027	0.0079	0.0079
Skewness	4.0642	-1.0785	-2.3044	-1.391	-1.9705
Kurtosis	65.5208	11.1761	24.4275	16.7648	17.9916
Jarque-Bera	69229.950[a]	1245.329[a]	8366.603[a]	3434.741[a]	4184.8610[a]
Augmented Dicky-Fuller	-20.708[a]	-15.374[a]	-16.687[a]	-17.272[a]	-14.600[a]
Phillips Perron	-21.200[a]	-15.415[a]	-16.528[a]	-17.130[a]	-14.326[a]
Panel B: Correlation matrix					
DJSAI	1.0000	0.7740	0.1410	0.2640	-0.0220
DJSWI	0.7740	1.0000	0.1120	0.2680	-0.0130
GB	0.1410	0.1120	1.0000	0.1650	0.0050
GCEI	0.2640	0.2680	0.1650	1.0000	-0.0430
ICEA	-0.0220	-0.0130	0.0050	-0.0430	1.0000

Note: The table shows descriptive statistics and correlation matrix, "[a]" shows a significance level of 1%.

rency mining (Kamal & Hassan, 2022; Karim et al., 2022; Wang et al., 2022), 2) the volatility spillover from cryptocurrency environmental attention to green financial assets (Kamal & Hassan, 2022; Naeem & Karim, 2021) in terms of uncovering the impact on Australian and world sustainability, and 3) providing useful implications for policymakers and green investors during normal and higher uncertainty periods (such as the COVID-19 period) using Antonakakis and Gabauer's (2017) TVP-VAR model.

II. Data and methods

A. Data and descriptive statistics

This study considered the closing prices of four green financial assets, namely the Dow Jones World Sustainability Index (*DJWSI*), Dow Jones Sustainability Australia Index (*DJSAI*), S&P Global Green Bonds (*GB*), and S&P Global Clean Energy Index (*GCEI)*, and an attention measure, Index of Cryptocurrency Environmental Attention (*ICEA*). The *ICEA* is a news-based index constructed by Wang et al. (2022). Using weekly data for green financial assets according to *ICEA*, the data sample spans the period of January 3, 2014 to December 31, 2021. The sub-sample analysis covers observations from December 1, 2019 to December 31, 2021. Data on financial assets and cryptocurrency environmental attention are sourced from DataStream and brianmlucey.wordpress.com, respectively.

The first differenced log-returns are illustrated in Table 1. The most (least) volatile green financial asset is *GCEI* (*GB*). The distribution of log returns is high-peaked, asymmetric, and, thus, non-normal. All return series are stationary, thus ensuring stationarity.

B. TVP-VAR Model

To investigate the dynamic connectedness between cryptocurrency environmental attention and green financial assets, author employed Antonakakis and Gabauer's (2017) TVP-VAR model. This empirical model was introduced by Primiceri (2005) and extended by Antonakakis and Gabauer (2017). It has several benefits over other methodologies. These include: 1) its ability to capture system-wide net connectedness among indices, 2) its specifying of the dynamic potential impact of financial contagion and volatility spillovers on the overall system of the markets over time, and 3) its ability to identify the potential structural breaks and relationships among time series. Overall, it validates whether the linear structure is derived from the probability of shocks (or response) from the extension of the change mechanism (Karim & Naeem, 2021).

The model equation is stated as follows:

$$y_t = \beta_{0,t} + \beta_{1,tYt-1} + \ldots + \beta_{p,tYt-p}$$
$$+u_t + X_t'\Theta_t + u_t \tag{1}$$

In Equation (1), y_t indicates the vector of $n\times 1$ dependent variables, $\beta_{0,t}\cdots_{p,t}$ are $n\times n$ dynamic coefficients over time, rewritten as Θ_t matrix (Naeem & Karim, 2021).

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

X_t' is an $n\times k$ matrix considering both intercept and lags of time-varying variables, where u_t represents structural shocks and n×1 follows zero mean with the heteroskedastic distribution. The term Ωt indicates the time-varying variance-covariance matrix. Therefore, the variance-covariance matrix of ICEA and green financial assets differenced returns can be written as:

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

where M_t^{-1} and H_t represent the simultaneous relationship between time series and stochastic connectedness, respectively.

The transition in dynamic parameters over time is assumed to be as follows:

$$\Theta_t = \Theta_{t-1} + v_t, v_t \approx N(0, S) \tag{4}$$
$$\alpha_t = \alpha_{t-1} + \xi_t, \xi_t \approx N(0, Q) \tag{5}$$

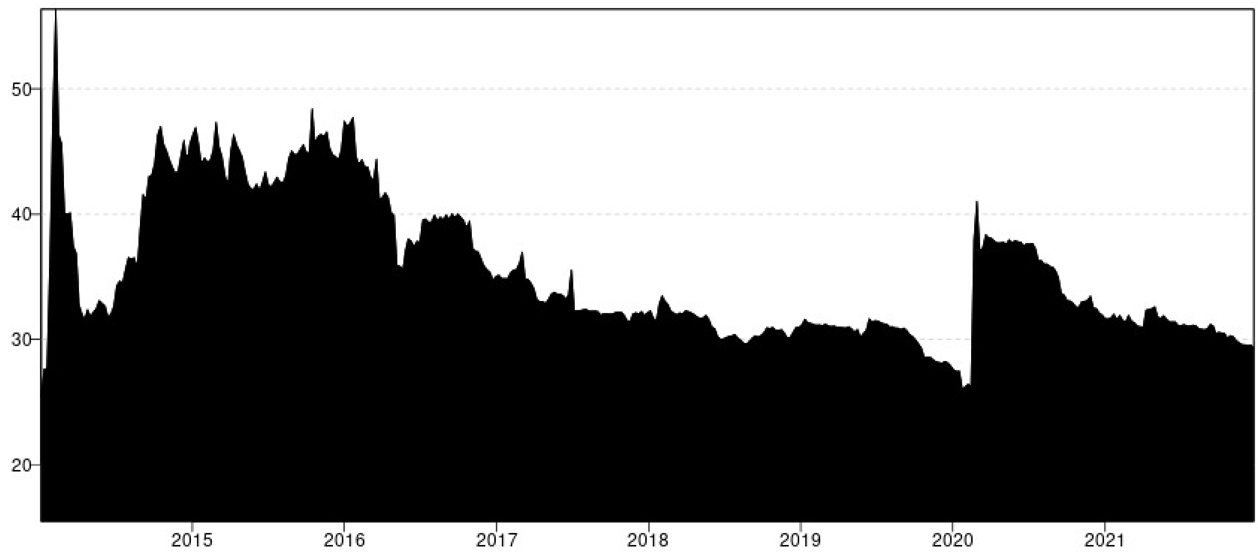

Figure 1. Dynamic Total Connectedness

Note: Figure 1 shows the dynamic total connectedness index (TCI), the output follows a 200-days rolling window, uninformative prior, with 10 steps ahead of the forecast horizon.

where the time-varying parameters are estimated through Equations (4) and (5) following the random walk process:

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

Equation (6) estimates the stochastic connectedness, using the random walk process (Kamal & Hassan, 2022). Overall, the error term is determined to be independent of the transition equation. Therefore, coefficients among variables vary independently to maintain efficient and simplified estimates (Karim & Naeem, 2021; Primiceri, 2005).

III. Empirical results

Table 2 reports the results of time-varying connectedness between *ICEA* and green financial assets for Panel A (full sample) and Panel B (during COVID-19) using the TVP-VAR model. In Panel A, the total system-wide connectedness is 28.29%, where *ICEA* is the net transmitter of volatility spillover to the other green financial assets. These findings partially corroborate Kamal and Hassan (2022), who documented that *ICEA* is a net transmitter (receiver) in lower quantiles (higher). The *GCEI* is the second volatility transmitter to the green financial assets and *GB* and *DJSAI* are the net volatility recipients, consistent with the work of Kamal and Hassan (2022), which found *GCEI* as a net transmitter of shocks in lower quantiles and *GB* as the net volatility recipient in both higher and lower quantiles. Notably, *DJSWI* and *DJSAI* are the net recipients of volatility spillovers.

The strong connectedness of *DJSWI*, *DJSAI*, and *GCEI* suggests their homogenous sustainable contribution to the environment and sustainable development goals (Ferrer et al., 2021). The weak connectedness of *GB* with other markets points to its strong diversification ability as a green financial asset (Haq et al., 2021).

Panel B represents the COVID-19 results from the TVP-VAR model, whereby the strongest (weakest) net transmitter is *GB* (*ICEA*). These results suggest that *GCEI* is the second-highest shock transmitter to the sustainability world and the Australian index during the *COVID-19* pandemic. These findings are consistent with previous work by Kamal and Hassan (2022), which found the *ICEA* to be a shock receiver during *COVID-19*. Notably, *DJSAI* is the strongest net receiver of volatility spillover during the pandemic. Findings reveal that the *ICEA* transmits shocks to the *GCEI*, which contradicts Kamal and Hassan (2022), who documented an opposite contagion effect during *COVID-19*. This may be due to the fewer number of observations Kamal and Hassan (2022) considered in their analysis (69 observations). The total connectedness index improved to 32.79% in the pandemic episode, indicating improved connectedness between *ICEA* and other green assets (Akhtaruzzaman et al., 2021; Kamal & Hassan, 2022). Figure 1 also verifies the fact. The lower connectedness suggests the hedging potential of green financial assets during the *COVID-19* period.

Figure 2 delineates *ICEA* as a net transmitter of volatility spillover from 2014 to 2018 and shock transmission lingered very low from 2018. Likewise, *GCEI* is a net transmitter of volatility spillover throughout the sample period, despite the last few weeks of 2014. The indices *GB*, *DJSWI*, and *DJSAI* are the net recipients of volatility spillovers from 2014 to 2021, except few positive connectedness movements. These findings confirm that the cryptocurrency environmental volatility transmission follows time-varying patterns for both transmitters and receivers and that investors can hedge *ICEA* considering *GCIE* in their portfolio with other assets.

Figure 3 represents the pairwise dynamic connectedness of *ICEA* and four green financial assets. The volatility spillover of cryptocurrency environmental attention is higher (lower) than *GB* (*GCEI*). The lower spillover suggests *GCEI* can be used in a portfolio to hedge *ICEA*, which is

Table 2. Average Dynamic Connectedness Table

Panel A: Full sample						
	ICEA	*GCEI*	*GB*	*DJSWI*	*DJSAI*	FROM others
ICEA	98.09	0.55	0.48	0.43	0.45	1.91
GCEI	1.75	79.12	2.13	9.79	7.21	20.88
GB	11.89	5.43	78.49	2.56	1.63	21.51
DJSWI	1.52	20.94	3.91	47.34	26.30	52.66
DJSAI	1.85	10.94	1.98	29.69	55.54	44.46
Contribution TO others	17.01	37.86	8.49	42.47	35.59	141.42
Inc. own	115.10	116.98	86.98	89.81	91.14	TCI
NET directional connectedness	15.10	16.98	-13.02	-10.19	-8.86	28.29%
Panel B: During COVID-19						
	ICEA	*GCEI*	*GB*	*DJSWI*	*DJSAI*	FROM others
ICEA	95.85	0.94	0.91	1.00	1.28	4.15
GCEI	2.29	80.92	5.56	5.73	5.49	19.08
GB	1.83	2.08	73.88	15.62	6.59	26.12
DJSWI	0.4	8.24	16.1	41.95	33.31	58.05
DJSAI	0.65	12.82	11.22	31.88	43.43	56.57
TO others	5.18	24.08	33.8	54.24	46.67	163.97
Inc. own	101.03	105	107.67	96.19	90.11	TCI
NET	1.03	5	7.67	-3.81	-9.89	32.79%

Note: This table shows TVP-VAR estimates full-sample and during COVID-19.

in line with the earlier research (Kamal & Hassan, 2022; Karim & Naeem, 2021). Therefore, these findings lend support to the growing belief that cryptocurrencies are dirty currencies (Naeem & Karim, 2021). Therefore, environmentalists and policymakers should take countermeasures to promote lower cryptocurrency energy consumption and carbon footprint.

Above findings are crucial for policymakers and sustainable investors, both international and Australian, in terms of investing in green financial assets in a portfolio and tackling the volatility transmission from the cryptocurrency market to green financial assets. Meanwhile, investors need to take heterogeneous and rational investment decisions during the COVID-19 pandemic.

IV. Conclusion

This study investigates the dynamic connectedness between cryptocurrency environmental attention index and four green financial assets, using the TVP-VAR model. Empirical analysis covers the COVID-19 pandemic period and reveals volatility spillover transmitted from *ICEA* to green financial assets. The *ICEA* and *GCEI* are the main net volatility spillover transmitters over entire sample period, whereas GB is a net volatility transmitter during the *COVID-19*. Conversely, *GCEI*, *GB*, *DJSWI*, and *DJSAI* are the net recipients of *ICEA* spillover over entire sample period, whereas only *GCEI* and *GB* are the recipients of *ICEA* shocks during the *COVID-19* pandemic. Notably, *DJSAI* is the highest receiver of spillover from *GB* and *GCEI*. The TVP-VAR results confirm the financial contagion effect on systemwide connectedness, with higher connectedness during the pandemic. Furthermore, pairwise connectedness between *ICEA* and green financial assets shows the minimal hedging and diversification potential to hedge *ICEA*.

Investors have heterogenous investment options (short-term and long-term) and the TVP-VAR approach cannot model the dependence over multiple frequencies. Therefore, it suggest that future studies consider sustainable cryptocurrencies in portfolios of green financial assets to examine various aspects of connectedness and hedging *ICEA* using wavelet models over multiple investment horizons.

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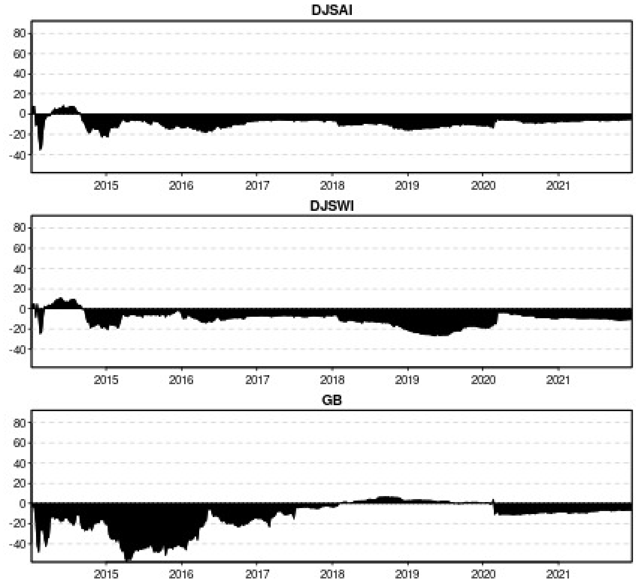

Figure 2. Total Net Connectedness

Note: Figure 2 shows total net connectedness where output follows a 200-days rolling window, uninformative prior, with 10 steps ahead of the forecast horizon.

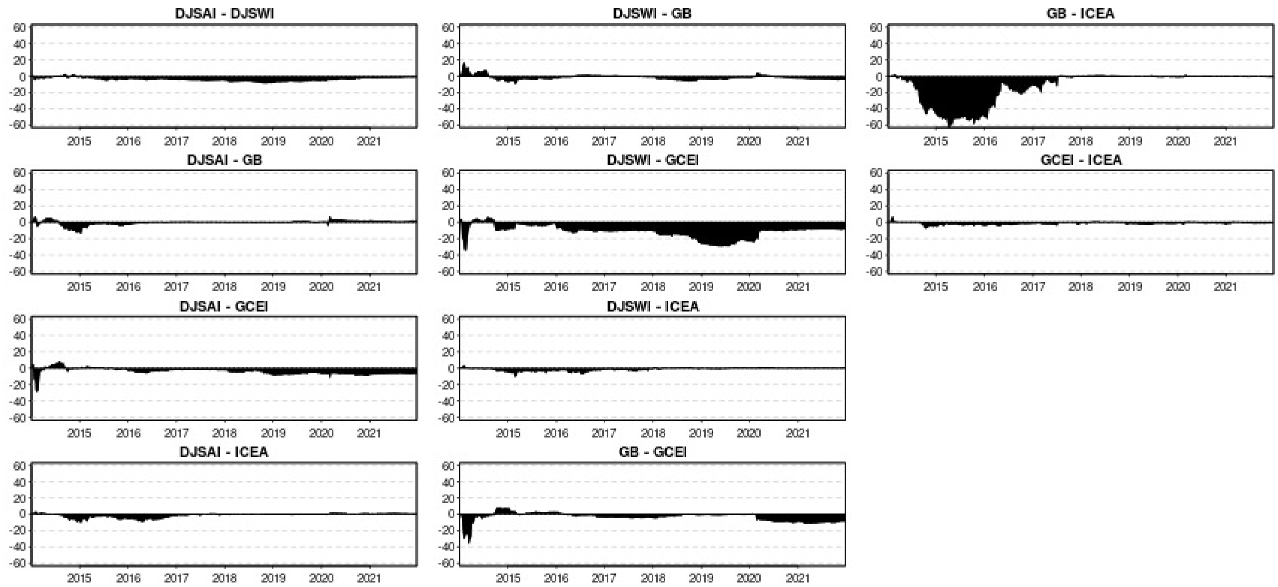

Figure 3. Pairwise Connectedness

Note: Figure 3 shows pairwise connectedness where output follows a 200-days rolling window, uninformative prior, with 10 steps ahead of the forecast horizon.

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