mathematics

MDPI

Article

Exploring the Driving Forces of Stock-Cryptocurrency Comovements during COVID-19 Pandemic: An Analysis Using Wavelet Coherence and Seemingly Unrelated Regression

Ruzita Abdul-Rahim [1,*], Airil Khalid [2], Zulkefly Abdul Karim [1] and Mamunur Rashid [3]

[1] Faculty of Economics and Management, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia; zak1972@ukm.edu.my
[2] School of Economics, Finance and Banking, Universiti Utara Malaysia, Sintok 06010, Kedah, Malaysia; airil@uum.edu.my
[3] Christ Church Business School, Canterbury Christ Church University, North Holmes Road, Canterbury CT1 1QU, UK; mamunur.rashid@canterbury.ac.uk
* Correspondence: ruzitaar@ukm.edu.my; Tel.: +60-3-8921-5764

Abstract: This paper estimates the comovement between two leading cryptocurrencies and the G7 stock markets. It then attempts to explain the comovement with the rational investment theory by examining whether it is driven by market uncertainty measures, public attention to COVID-19, and the government's containment and health responses to COVID-19. Wavelet Coherence heatmaps show that the stock-cryptocurrency comovements increase significantly and positively during the pandemic, indicating that cryptocurrencies lose their safe haven properties against stocks during the heightened market uncertainties. Over the longer investment horizons, Bitcoin reemerges as a safe haven or strong hedger while Ethereum's properties weaken. Seemingly Unrelated Regression results reveal that the stock-cryptocurrency comovements are rationally explained by market uncertainties, government responses to COVID-19, and market fundamentals. However, the comovements are also driven by the fear of COVID-19 to a certain extent. Our findings offer valuable insights for investors considering cryptocurrencies to rebalance their equity portfolios during market distress. For policymakers, the Economic Policy Uncertainty (EPU) results suggest that government policies and regulatory frameworks can be used to regulate speculation and investment activities in the cryptocurrency market.

Keywords: containment and Health Index; COVID-19 pandemic; hedge; investor sentiment; market uncertainties; public's attention; rational investment theory; safe haven; stock-cryptocurrency comovement

MSC: 91B55; 91G10

Citation: Abdul-Rahim, R.; Khalid, A.; Karim, Z.A.; Rashid, M. Exploring the Driving Forces of Stock-Cryptocurrency Comovements during COVID-19 Pandemic: An Analysis Using Wavelet Coherence and Seemingly Unrelated Regression. *Mathematics* **2022**, *10*, 2116. https://doi.org/10.3390/math10122116

Academic Editor: Manuel Alberto M. Ferreira

Received: 18 May 2022
Accepted: 15 June 2022
Published: 17 June 2022

1. Introduction

The movement control orders (MCO) imposed to halt the rapidly-escalating COVID-19 have morphed the pandemic from a health crisis to a global economic crisis. Stock markets worldwide plummeted even before the World Health Organization (WHO) declared the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) a pandemic on 11 March 2020. Business and financial risks skyrocket, derailing capital values directly and indirectly invested in companies. Financial markets experience unprecedented volatilities [1], forcing loss-averse investors to seek refuge in alternative investments with hedge and safe haven properties, including the cryptocurrencies [1–4]. As illustrated in Figure A1 (Appendix A), asset prices were negatively affected by the pandemic announcement. The G7 stock markets gradually progressed and fully recovered by the end of our study period, except in the US and UK. By mid-July 2021, US stocks reached a new peak while UK stocks still struggled to return to the pre-pandemic level. During the same time frame, cryptocurrency prices also

dropped around the WHO announcement period but proceeded to move in the opposite direction before climbing to new price heights (Panel C of Figure A1). Their unprecedented behaviors quickly attracted academic attention to re-evaluate their potential as hedgers or safe havens against stocks during the COVID-19 crisis [1–4].

Cryptocurrencies are risky investments due to uncertainties resulting from the limited knowledge about them and their independence from the central authorities [2,4]. At the same time, these features make them a potential safe haven asset: an asset that is negatively correlated or uncorrelated with other assets or portfolios during a specific period of increased uncertainty [5]. Investors typically resort to traditional safe haven assets like gold, crude oil, other commodities, or foreign currencies [1,5] and, only recently, to cryptocurrencies, to minimize their losses and risks [6]. Recent studies have shown the viability of cryptocurrencies as safe havens against stocks during the pandemic [2,7]. However, there is ample evidence against this finding [1,8,9]. Moreover, mixed empirical evidence from the extant studies could not explain the immense investment interest in cryptocurrencies. The surge in demand has caused price hikes that would make cryptocurrencies costly for portfolio rebalancing [6,10]. Given this paradox, it becomes indispensable to test whether the investors' influx into the cryptocurrency market during the COVID-19 pandemic is driven by rational investment decisions or fear of the uncertainties caused by the crisis. Rational decisions are critical in distressed situations as investors must carefully place withdrawn capital into assets that would preserve their utility or wealth [11]. We chose the G7 stock markets as the context to test the rationality versus the behavioral biases in the cryptocurrencies against stock markets, the reason being that the G7 markets represent the most informationally efficient investors capable of minimizing asymmetric responses to news [12].

Given this background, this paper contributes to the existing literature on portfolio management and behavioral finance during high market uncertainties in the following ways. Most studies have examined hedging or safe haven properties of the cryptocurrencies based on their comovements with various financial assets and commodities during the pandemic [3,8,9,13]. Others have investigated the properties of cryptocurrencies based on their relationship with market uncertainty measures [10,14–16] and government responses to COVID-19 [17,18]. This study fills the gap in the literature by examining whether the stock-cryptocurrency comovements can be explained by rational investment theory, which posits that investors are sophisticated and informed and act only on relevant information [19]. Since distressed markets stimulate cognitive biases [20], the comovements could also be driven by sentiment or fear of COVID-19 [21]. Specifically, we test whether the stock-cryptocurrency comovements are linked to market uncertainty, public attention, and government containment and health measures. In this study, we construct our own 'Public Attention to COVID-19 Index (PAI)' based on the frequency of searches for "coronavirus" or "COVID-19" on Google Trends. We adopt the market uncertainties, and containment and health from standard measures, such as the Economic Policy Uncertainty (EPU), Volatility Index (VIX), and Containment and Health Index (CHI).

Our results indicate that the stock-cryptocurrency comovements are time-varying and exhibit high variability in the short term. The comovements are aggravated during the medium investment horizon, especially during the pandemic. Bitcoin emerges as the safe haven asset against G7 stocks in the longer investment horizon. In clear contrast to the pandemic period, the cryptocurrency market does not prevail as a safe haven against G7 stocks before the pandemic. Consistent with the rational investment theory, we find a strong connection between market uncertainty measures and long-term stock-cryptocurrency comovement. Further evidence from the SUR results indicates a combination of rational and behavioral effects in the stock-cryptocurrency comovements during this pandemic. Market rationality during the crisis drives investors to hold more long-term stable stock investments while selling off their stakes in riskier cryptocurrencies. On the behavioral ground, behavioral biases, specifically the fear and sentiment related to uncertainties created during the COVID-19, negatively influence the comovements.

The remainder of this paper is organized as follows. Section 2 reviews the literature on the hedge and safe haven assets and the rational and irrational investment behavior during high market uncertainties. In Section 3, the methodology is discussed, Section 4 reports and discusses the results, and Section 5 concludes and discusses the implications of the results.

2. Literature Review

As with any other crisis, the COVID-19 pandemic-induced crisis has disrupted global financial markets and prompted equity investors to search for safe haven assets to preserve their wealth. During heightened economic and market uncertainties, investors' risk aversion increases, and they become more sensitive to news, creating a higher equity premium and amplifying return volatilities [22]. Investors can no longer rely on traditional hedge and diversification strategies during volatile times [1]. So et al. [23] examined the interconnectedness in the Hong Kong stock market during this pandemic and compared it to that of the three previous crises (i.e., subprime, European debt, and Chinese stock market crises). Unlike the earlier crises, they found extremely high interconnectedness among stocks with limited relevance to the market factors. Such a robust deflection from the earlier crises is rooted in the unique nature of the COVID-19 pandemic, which has been abrupt and conflated by factors [1]. In addition, identifying a safe haven asset is always challenging because the properties of these assets can differ by market and time [1,2,9,24]. Given the uniqueness of the pandemic, reassessment of the properties of traditional safe haven assets thus becomes critical [1,23].

Investors flock to assets known to be safe havens to offset the downside risk as the capital markets enter the extreme risk zone. Assets traditionally known as safe havens include bonds, gold, crude oil, other commodities, and foreign currencies [1]. Alongside the traditional safe haven assets, there is a growing trend in research on cryptocurrencies. After the introduction of Bitcoin in 2009, its success story has led thousands of new cryptocurrencies to mushroom in the digital currency markets. Investor acceptance has been so phenomenal that Bitcoin and other established cryptocurrencies have been quickly accepted as mainstream investments [25]. Their demand grew even stronger after the introduction of Bitcoin futures in December 2017. A study by [26] examines the volatility of Bitcoin against global financial assets (GFAs, i.e., gold, oil, US$/EUR) from December 2016 to December 2018. Using variants of the Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH) model, the study finds that Bitcoin negatively correlates with stocks (SP500 and N225), gold, and US$/EUR. This finding is among evidence positioning Bitcoin as one of the safe haven assets against stocks before the pandemic. Another study [27] provides evidence and a decent review of previous studies that corroborate the evidence in [26]. The attention to cryptocurrencies, particularly their safe haven properties, has propelled during the COVID-19 pandemic.

A mixed bag of results is reported on the safe haven properties of cryptocurrencies in several recent studies. On one side, cryptocurrencies have failed to shield investors against the pandemic [2,3]. Conlon et al. [2] have estimated that allocating Bitcoin and Ethereum to equity portfolios only adds downside risks. In a study that examines five cryptocurrencies (Bitcoin, Ethereum, Dash, Monero, and Ripple), ref. [3] discovered that these digital assets are highly correlated with the US stock indices (i.e., S&P500, Nasdaq, and VIX) during the pandemic. Other studies have found that the safe haven quality of the cryptocurrencies reduces to a weak hedge or diversifier [1,8,9] during the pandemic, making these digital assets less applicable to the investors' spree for safety. Bahloul et al. [13] have found a behavioral shift in Bitcoin investment against the conventional MSCI world stock index during the pandemic (from 1 January 2020 to 27 March 2020), but so do the Islamic index and gold. Ji et al. [1] tested Bitcoin and other traditional safe haven assets (i.e., gold, foreign currency, and commodities) against the MSCI US, Europe, and China indices. Their study found that Bitcoin's safe haven properties have weakened during the pandemic (December 2019 to March 2020), particularly against the MSCI US and Europe. A similar deduction can be made from evidence by [27]: the coherence between Bitcoin (along with gold and

crude oil) and Global traditional, sustainable, and Islamic stocks increase significantly during the pandemic (until January 2021). So do [8], who discovered that the CRIX (a cryptocurrency index) is weakly positively correlated with the world stock market during the pandemic, indicating its potential as a hedge asset. Similar evidence is discovered from the Bitcoin futures (besides VIX and gold futures) tested as safe havens against the BRICS equity indices [9].

From the opposing quarter, evidence supports the viability of cryptocurrencies as safe haven assets against stocks during the pandemic. For instance, ref. [2] reveal that Tether acts as a safe haven against all stock indices of MSCI World and countries known to be severely impacted by the pandemic (i.e., US-S&P 500, UK-FTSE 100, Italy-FTSE MIB, Spain-IBEX, and China-CSI 300). A possible explanation is that Tether successfully maintains its peg to the US Dollar during the pandemic [2]. Similarly, ref. [7] have discovered Bitcoin as a safe haven against equities in Brazil, South Africa, and Russia during the pandemic. Meanwhile, Dash and Ripple show safe haven properties against all BRICS stock markets during the pandemic (31 January 2020 to 17 September 2020). A study by [28] assesses the dynamic correlations between global financial assets (GFAs, i.e., Bitcoin, US dollar, crude oil, and gold) and stock yields from the US, UK, China, and Japan from January 2013 to June 2020. The study uses the quantile-coherence approach and causality-in-quantile method and reveals that the GFAs can be diversifiers in the short term when the stock markets are volatile. Exceptions are observed for Bitcoin, which is significantly correlated to stock yields. The coherences between GFAs, including Bitcoin and stock yields, weaken in the medium and longer terms, except between the US Dollar and low yield stocks. Similar results are documented by [29], who investigated the connectedness between US COVID-19 news, Dow Jones Index (DJI), green bonds, gold, and bitcoin prices during the pandemic period from 22 January 2020 to 3 August 2021. Using a stretch of the Wavelet Coherence technique, ref. [29] revealed that green bonds, gold, and Bitcoin have minimal connectedness with the US equity market, indicating their role as hedgers and safe havens against the US stocks during the pandemic.

Given the immense interest in cryptocurrencies as safe haven assets, we find it imperative to investigate whether rebalancing equity portfolios with these digital assets during the pandemic are driven by rational decisions and expectations aiming to preserve or maximize wealth. While many studies have addressed the safe haven properties of the established cryptocurrencies against stocks during the pandemic [30,31], little is known about the rationale behind the investor behavior during this turbulent time. Entering cryptocurrency markets during this pandemic has a vital investment implication because, as their prices have repeatedly broken record-highs, the shift would become very costly to investors [6,10]. Moreover, if the move towards cryptocurrencies is driven by the fear of uncertainties caused by COVID-19, it could introduce additional risks to the investors. We assess this conjecture by examining whether the stock-cryptocurrency comovements can be linked to market uncertainty, government containment and health measures, and public attention to COVID-19 during the pandemic. The G7 stock markets are the proper context to examine these relationships because the markets feature sophisticated investors who should be more likely to act on rational decisions [19].

Previous studies have adopted off-the-shelf market uncertainty measures, such as the Economic Policy Uncertainty (EPU) and Volatility Index (VIX). The EPU measures the economic uncertainties related to undefined future government policies and regulatory frameworks. In contrast, the VIX measures the market's expectations for the relative strength of near-term stock price changes. Empirical studies have shown that EPU is associated with high market volatilities [8,24] and positively affects cryptocurrency returns before and during the pandemic [10]. Qian et al. [8] have found that EPU influences the comovements between CRIX (cryptocurrency index) and the volatilities of the world stock index. VIX's effects are influenced by market frictions and the information processing capabilities of investors [12]. VIX weakens the relationship between stock returns and idiosyncratic volatility, suggesting that investors are prompted to rebalance their portfolios

due to the fear of the market uncertainties [14]. The VIX-EPU relationship is time-varying and not always positive [32].

Investors act irrationally when the market is inefficient. Their "animal spirit" can create wild fluctuations in asset prices unrelated to fundamentals and are often prompted by market shocks, as asserted by [20], and the effect of cognitive biases on the stock market volatility. In a period of heightened market uncertainties, investors make irrational decisions driven by their appetite for risk-taking and loss aversion. Investors are not always rational in making decisions because they are social creatures whose judgment and behavior are influenced by their surroundings and social circles [25,33]. Herding, irrational judgments, and fear of future uncertainties result in excessive trading that causes market volatilities. During the pandemic, fear of the uncertainties due to lockdown has impacted investors' ability to process information and make rational investment decisions. Jiang et al. [21] suggest that a 'sense of uncertainty' around COVID-19 is a primary cause of the stock market volatility. Their study uses COVID-19 and Baidu Index-based public awareness to measure market sentiment. In essence, the results imply that limited attention or attention disorder distorts equity investors' ability to reflect efficiently upon new firm-specific information.

Building on these behavioral premises, ref. [16] examined the role of Financial and Economic Attitude Revealed by Search (FEARS) to explain asset prices. Their study argues that uninformed noise traders are responsible for significant mispricing and extreme volatility due to excessive sentiment. The results exhibit a significant relation of FEARS with the volatility of the S&P500 ETF (SPY) and the VIX. Audrino et al. [15] investigated whether measures of investor sentiment and limited attention contain additional predictive power of the market volatility. Their study constructs an extensive attention index based on the number of company searches on Tweets, StockTwits, Google Trends, and Wikipedia. Results of the study show that the attention measures have the most predictive power when compared to sentiment, VIX, and turnover ratio, on the future stock market volatility of eighteen US companies.

Tuna [33] examined investor attention toward COVID-19 news by segregating negative and positive content by using the search terms, such as "health news", "COVID-19 cases", and "COVID-19 death" on Google Trends. Their study reveals that the COVID-19-related news is significant in predicting sector returns, but the asymmetric effect is present due to relatively stronger negative contents. Due to social conformity bias, investors will seek help from freely available internet resources, such as those on COVID-19, before making financial decisions. Drawing upon the behavioral biases, we propose that the Public Attention Index (PAI) on COVID-19 influences the stock-cryptocurrency comovement based on the premise that investors conduct an online search about the pandemic before reaching their decisions.

Governments worldwide took various measures to control the spread of COVID-19. Hale et al. [34] developed a Containment and Health Index (CHI) as part of Oxford University's COVID-19 Government Response Tracking (OxCGRT) project for all countries worldwide. The OxCGRT classifies government measures into Containment and Health, Stringency, Economic Support, and Risk of Openness. Since we argue that the pandemic adversely affects the investment value as it halts and disrupts economic activities, we focus on the containment and health measures imposed when the COVID-19 cases rose. Similar to this study, ref. [18] adopted OxCGRT's CHI and revealed that it has a significantly positive impact on the stock market performance of twenty OECD countries during the pandemic. The results show that the government's containment and health measures to control the virus's fast-spread infection boosted investor confidence. Furthermore, CHI's interaction with COVID-19 cases significantly and negatively affects stock market performance as the containment and health measures weaken the adverse effect of COVID-19 cases [18]. Except for the significant moderating effect of CHI on the growth of COVID-19 cases, the results are consistent with [17], which tests the impact of CHI in seventy-seven stock markets. The insignificant effect is perhaps due to the shorter pandemic period covered in [17], i.e., until 17 April 2020. Meanwhile, ref. [18] extended their study period until 1 October 2020.

The COVID-19 pandemic opens an opportunity for financial scientists to re-evaluate the safe haven properties of cryptocurrencies vis-à-vis other traditional safe haven assets like gold, commodities, and foreign currencies. Many studies determine the safe haven properties based on the comovements between cryptocurrencies and other assets. Others evaluate the properties based on their relationship with market uncertainties, attention, sentiment, and government responses to COVID-19. While the pandemic carries element that can cloud the judgments by the investors, our knowledge on fundamental as well as behavioral aspects of the pandemic remains conjectural and limited. This study fills the gap in the literature by examining whether the stock-cryptocurrency comovements can be explained by rational investment theory, which posits that investors are sophisticated, informed, and act only on relevant information. Since investors' cognitive biases change under distressed markets, the comovements may also be driven by their sentiment or fear of COVID-19. We examine this conjecture by linking the comovements to market uncertainty, public attention, and government containment and health measures, besides market fundamentals (i.e., interest and inflation rates).

3. Research Methodology

This section describes the two estimation techniques employed in this study. First, we use the Wavelet Coherence (WC) method to estimate the pair-wise comovements between the two leading cryptocurrencies (Bitcoin and Ethereum) and the G7 stock markets. Then, we use the Seemingly Unrelated Regression (SUR) analysis to estimate the relationship between the comovements and selected predictor variables.

3.1. Wavelet Coherence Technique

Following previous studies [24,27], we adopted the Wavelet Coherence technique to generate the comovement between two time series, $x(t)$ and $y(t)$, across the time-frequency domain, and identified the causality and phase differences between the time series. Both studies use the technique to determine specific assets' hedge or safe haven attributes. Cai et al. [24] examine these attributes in the gold futures prices against the EPU in the US and UK markets. Disli et al. [27] applied the technique to gold, crude oil, and Bitcoin against traditional, sustainable, and Islamic stock indexes. The cross-wavelet transform determines the common power between the two time series, pinpointing the regions in time-frequency space where the time series comove. W_x and W_y are the individual wavelet transforms for the time series $x(t)$ and $y(t)$, respectively. The cross-wavelet transform can be specified as:

$$W_{xy}(\tau, s) = W_x(\tau, s)W_y^*(\tau, s) \tag{1}$$

where W_y^* is the complex conjugate function of W_y. Through wavelet coherence, it is possible to infer the local covariance $|W_{x,y}|$ between x and y, and the phase relationships between x and y nonstationary power time series. The wavelet coherence can be written as:

$$WC_{xy}(\tau, s) = \frac{\left|S\left(W_{xy}(\tau, s)\right)\right|}{\sqrt{S(|W_x(\tau, s)|^2) \cdot S(\left|W_y(\tau, s)\right|^2)}} \tag{2}$$

where s is a time and frequency smoothing operator. Coherence term R_{xy} has a value between '0' and '1'. R_{xy} close to zero indicates a weak correlation, whereas R_{xy} close to unity indicates a strong correlation.

Wavelet coherence analyzes the phase pattern or phase difference (ϕ_{xy}), which reveals the lead and lag relationships and the in-phase (positive) and anti-phase (negative) dependency between the time series, $x = \{x_n\}$ and $y = \{y_n\}$. The phase difference can be written as:

$$\phi_{xy} = tan^{-1}\left[\frac{Im\{W_{x_n,y_n}\}}{Re\{W_{x_n,y_n}\}}\right], \ \phi_{xy} \in [-\pi, \pi] \tag{3}$$

where *Im* and *Re* denote the smooth power spectrum's imaginary and real parts, respectively.

In short, the WC technique fits the purpose of this study as it visualizes the dynamic comovements of different investment lengths by considering both time and frequency domains [27,35] within the study period in the form of a heat map. The hotter (red) color reflects a greater absolute value of asset comovement. The thick black contour represents a 95% confidence level. In addition, the WC map shows the phase patterns with directional arrows. Arrow points to the right (left) indicate x_t and y_t are in-phase (out-of-phase). Arrow points downward (upward) mean x_t leads (lags) y_t. In interpreting the comovement into safe haven properties, a strong safe haven asset is negatively correlated with another asset or portfolio in a specific period. Negative correlations or comovements approaching '−1.0' are denoted by a hot red area with an out-of-phase pattern (←). We follow [5] in defining uncorrelated (comovement less than 0.2) denoted with a dark blue area as an indicator of weak safe haven assets. A hedger is designated with the light blue to the greenish area (comovement between 0.2 and 0.6). A diversifier is represented by the yellowish to the reddish area, where the correlation or comovement approaches a perfect positive (+1.0).

3.2. Seemingly Unrelated Regression

The Seemingly Unrelated Regression (SUR) model was selected for this study because it uses a dataset of N countries across time T, with $T > N$. The method generates a higher efficiency due to the assumption that the error terms in a system of equations are contemporaneously correlated at any point in time. This assumption fits reasonably well with the G7 countries, since their economies and financial systems are highly integrated. SUR estimator addresses cross-sectional dependence among countries. The SUR estimates the individual coefficients (β_i) in a panel framework while generating the influence of the predictor variables on the dependent variable for each country individually [36].

The 7-equation system to be estimated using the SUR can be generally specified as follows:

$$\begin{aligned} WC_{CA,t} &= a + \beta_1 EPU_{CA,t} + \beta_2 \Delta PAI_{CA,t} + \beta_3 VIX_t + \beta_{4,i} \Delta CHI_{CA,t} + \gamma_1 IIR_{CA,t} + \gamma_2 \Delta CPI_{CA,t} + u_{CA,t} \\ WC_{FR,t} &= a + \beta_1 EPU_{FR,t} + \beta_2 \Delta PAI_{FR,t} + \beta_3 VIX_t + \beta_4 \Delta CHI_{FR,t} + \gamma_1 IIR_{FR,t} + \gamma_2 \Delta CPI_{FR,t} + u_{FR,t} \\ WC_{US,t} &= a + \beta_1 EPU_{US,t} + \beta_2 \Delta PAI_{US,t} + \beta_3 VIX_t + \beta_4 \Delta CHI_{US,t} + \gamma_1 IIR_{US,t} + \gamma_2 \Delta CPI_{US,t} + u_{US,t} \end{aligned} \quad (4)$$

where $WC_{i,t}$ corresponds to the stock-cryptocurrency comovement generated using the Wavelet Coherence technique in Equation (2) for the G7 stock markets at time t, β, and γ are the estimated coefficients, *EPU* is Economic Policy Uncertainty, *PAI* is Public's Attention Index, *VIX* is Volatility Index, ΔCHI is the change in Containment and Health Index, *IIR* is Interbank Interest Rates, ΔCPI is the change in Consumer Price Index (or inflation rate), and μ is the error term. Except for the *VIX*, each predictor variable is country-specific. Each 7-equation system (4) is estimated four times; the first two sets of WC_{xy} are for the stock–Bitcoin and stock-Ethereum comovements. The second pairs are for the stock-cryptocurrency comovements in the short investment horizon (4 holding days) and long investment horizon (128 holding days). Each 7-equation system is jointly estimated using a Generalized Least Squares (GLS) estimator by assuming cotemporaneous correlated error terms. The models control the effects of interest rates and inflation rates since investors with long-term investment objectives consider macroeconomic fundamentals [35].

3.3. Data Description

We ran the wavelet coherence analysis on daily closing prices of Bitcoin, Ethereum, and the MSCI stock market indices of the G7 countries (Canada, France, Germany, Italy, Japan, UK, and the US). The daily price (P_t) data were converted into log returns ($R_{i,t} = ln(P_{i,t}/P_{i,t-1})$) to ensure stationarity. In the wavelet coherence analysis, the observation period started on 1 January 2018 and ended on 15 July 2021, allowing us to compare the stock-cryptocurrency comovement pre-COVID-19 (1 January 2018–31 December 2019) and during the COVID-19 pandemic (1 January 2020–15 July 2021).

For the SUR analysis, we used monthly data from January 2020 to July 2021. The motive of this analysis was to determine the stock–cryptocurrency behavior during the pandemic. We collected the EPU data by [30] and VIX data from the Chicago Board Options Exchange (CBOE) website. CHI data were gathered from the *Oxford COVID-19 Government Response Tracker* (OxCGRT) available in World in Our Data (OWID) database published by Oxford University. CHI, the sum of eight containments and three health measures, was scaled from '0' to '100', with a higher value indicating heightened measures by the government to control the COVID-19 spread. CHI daily data were converted into the monthly frequency to be consistent with the other factors. Following [37], we constructed PAI as a collective attention index based on the number of hits from search terms "coronavirus" or "COVID-19" in the Google Trends. Country-level PAI was attained by scrutinizing the geographical areas of each of the G7 countries. The PAI value was between 0 and 100, with the higher value representing heightened public attention towards the pandemic. The MSCI stock market indexes, cryptocurrencies, Interbank Interest Rate (IIR), and Consumer Price Index (CPI) data were collected from the Bloomberg database.

4. Results and Discussions

4.1. Wavelet Coherence Results

Table 1 presents the summary statistics of the cryptocurrency and stock daily returns, including the pre-pandemic and pandemic sub-periods. First, in the whole period from January 2018 to July 2021, the average daily returns of Bitcoin and Ethereum are three times higher than that of the G7 stocks, except for the US, which records an average return close to those of the cryptocurrencies. However, the volatility of the cryptocurrencies is more than twice that of the stocks', causing the Sharpe ratios to be comparable to the stocks—again, except for the US stocks, which record the highest Sharpe ratio. Second, while comparing the performance over the two sub-periods, all assets surprisingly reported higher returns than before the pandemic, except for the UK. As expected, the standard deviations increased during the pandemic, resulting in mixed Sharpe ratios. Bitcoin and Ethereum show more notable results as the pandemic barely affects their volatilities. Meanwhile, their prices soar to new levels (exhibited in Panel C of Figure A1) due to capital flight from other financial markets and excessive interest from speculators and uninformed noise traders. Overall, the risk-taking behavior pays off since the Sharpe ratios of the cryptocurrencies increase to about twice their pre-pandemic level.

Figure 1 exhibits the Wavelet Coherence heatmaps that forward several important findings from the stock-cryptocurrency comovements. First, stock-cryptocurrency co-movements show high variabilities in the short investment horizon, including during the pandemic (time 500 onward). Since the study period (three years and seven months) is relatively short, we define the short investment horizon as the fluctuations within the 0–16 day frequency bands, while the long investment horizon ranges from 64–256 day frequency bands. The results indicate that the short-run comovements of these assets are difficult to predict, fitting the random behavior of the G7 as the most efficient stock markets. It also reflects the behavior of assets that appeal to speculators [2] and uninformed noise traders [20], whose excessive trading causes market volatilities [16]. Second, before the pandemic, the comovements over longer investment horizons (>128 days) suggest that Bitcoin is a weak hedger or diversifier for the G7 stock markets. Indeed, the most established cryptocurrency has moved closely with the G7 stocks since mid-2019 and even earlier in Germany. In contrast, Ethereum exhibits a strong hedger for Canada, France, Italy, and the US stock markets and a weak hedger for the others. For the pre-pandemic period, these findings thwart the claim that cryptocurrency is one of the traditional safe haven assets before the pandemic [1,24,26].

Table 1. Summary Statistics of Cryptocurrency and Stock Daily Returns.

Sub-Period	BTC	ETH	Canada	France	Germany	Italy	Japan	UK	US
All (1 January 2018–15 July 2021)									
Mean	0.0704	0.0556	0.0232	0.0189	0.0176	0.0098	0.0194	−0.0107	0.0511
Std Dev	0.0458	0.0633	0.0121	0.0130	0.0135	0.0147	0.0123	0.0118	0.0138
Sharpe *	1.5371	0.8784	1.9174	1.4538	1.3037	0.6667	1.5772	−0.9068	3.7029
Skewness	−0.6251	−0.8092	−2.0564	−1.3946	−0.9858	−2.7411	−0.1540	−1.2090	−1.0519
Kurtosis	5.6794	8.9173	42.6112	17.6901	16.4486	34.1412	5.2600	16.3190	17.7537
Pre-Pandemic (1 January 2018–31 December 2019)									
Mean	−0.1665	−0.4277	0.0083	0.0174	0.0001	0.0073	−0.0029	−0.0048	0.0322
Std Dev	0.0460	0.0577	0.0057	0.0085	0.0092	0.0104	0.0102	0.0077	0.0093
Sharpe *	−3.6196	−7.4125	1.4561	2.0471	0.0109	0.7019	−0.2843	−0.6234	3.4624
Skewness	−0.4071	−0.2280	−0.5022	−0.5365	−0.3633	−0.2935	−0.8424	−0.3615	−0.6068
Kurtosis	4.5514	2.6570	2.5617	1.6104	1.0390	0.8227	3.5911	1.6078	3.8581
Pandemic (1 January 2020–15 July 2021)									
Mean	0.3754	0.6778	0.0424	0.0209	0.0400	0.0131	0.0481	−0.0183	0.0754
Std Dev	0.0455	0.0695	0.0172	0.0172	0.0175	0.0189	0.0145	0.0157	0.0181
Sharpe *	8.2505	9.7525	2.4651	1.2151	2.2857	0.6931	3.3172	−1.1656	4.1657
Skewness	−0.9217	−1.3229	−1.6677	−1.3144	−0.9938	−2.9113	0.1394	−1.1323	−1.0081
Kurtosis	7.5260	12.8578	23.1258	12.4238	12.4400	28.0645	4.6572	11.1658	12.9125

Notes: Mean and standard deviation are in percentage. * Simple Sharpe ratio equals to mean return divided by the standard deviation.

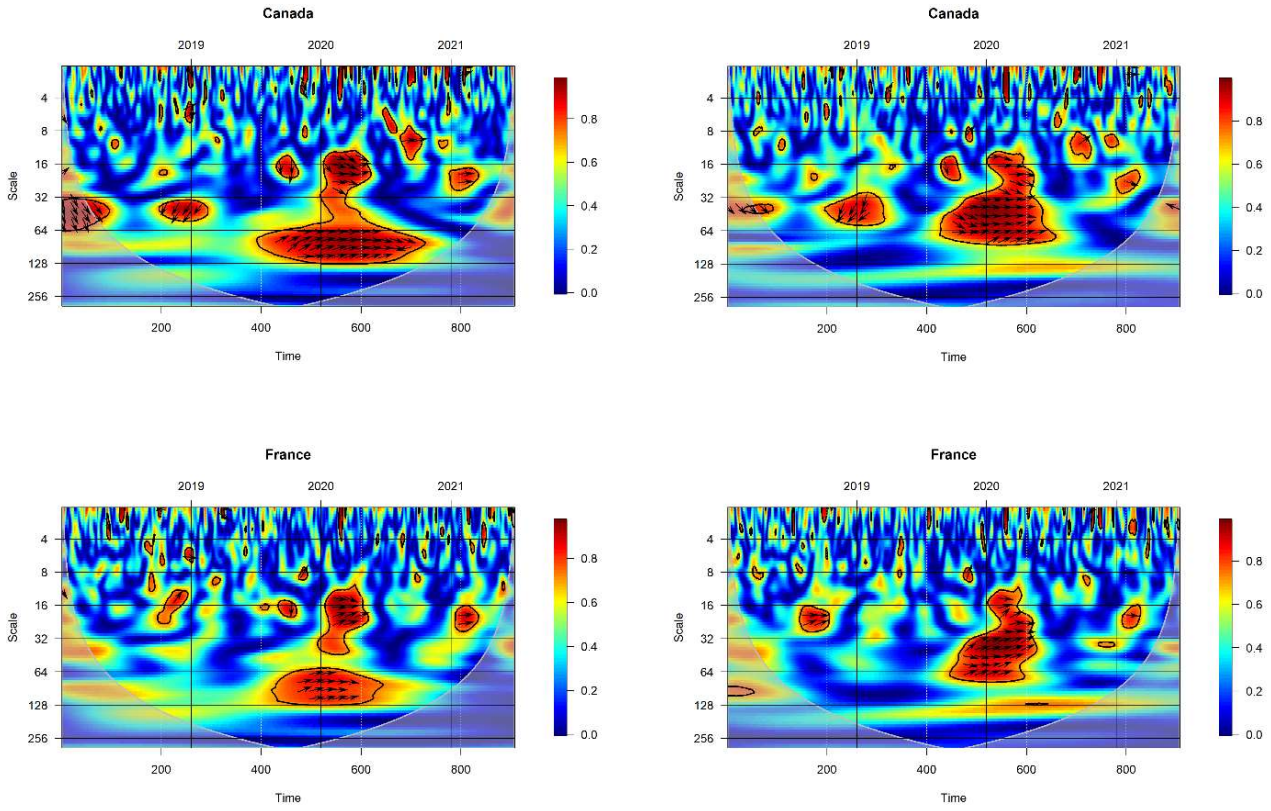


Figure 1. *Cont.*

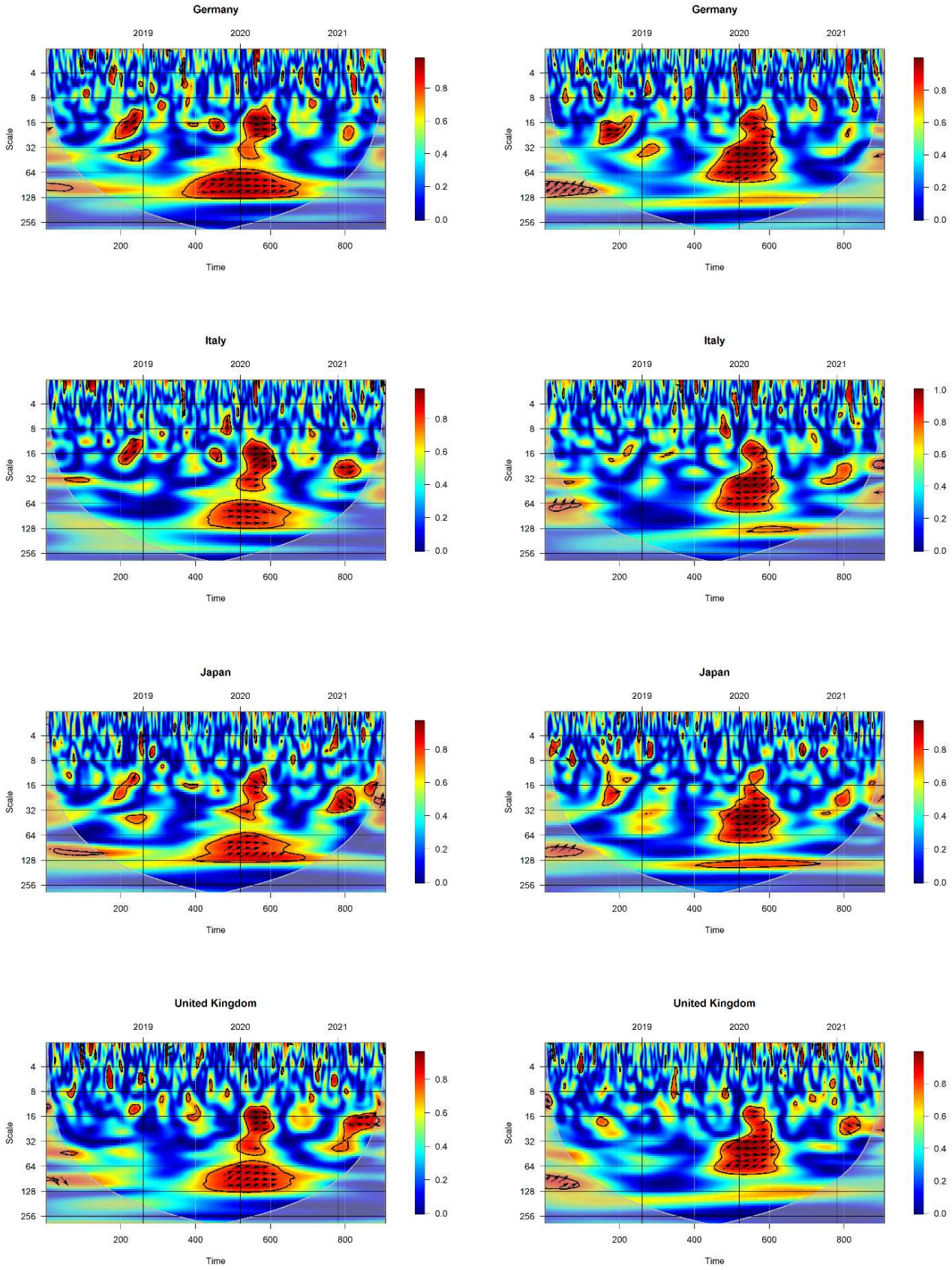
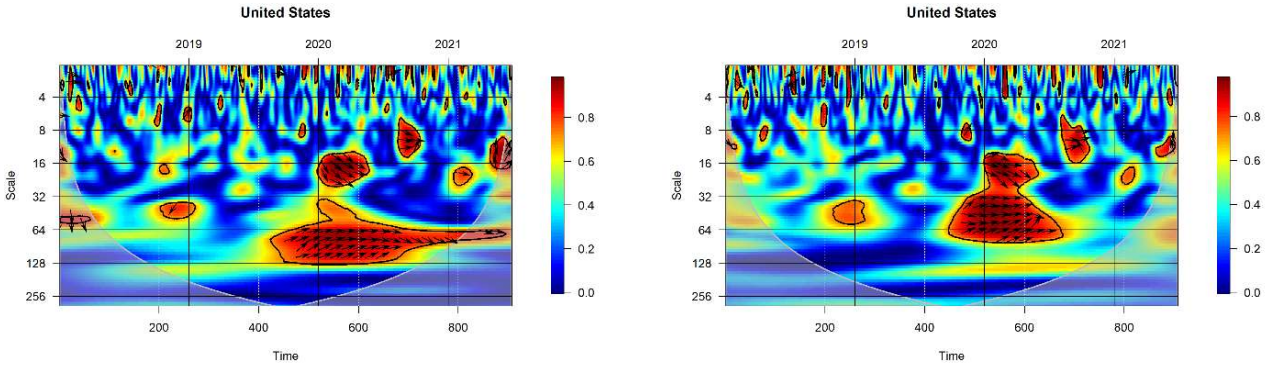


Figure 1. *Cont.*



(**a**) (**b**)

Figure 1. Wavelet Coherence Heatmaps. (**a**) Stock-Bitcoin Comovements; (**b**) Stock-Ethereum Comovements. Notes: The times on the horizontal axis of wavelet coherence map dates correspond to the following dates; Time 100—May 2018, Time 200—October 2018, Time 300—March 2019, Time 400—July 2019, Time 500—December 2019, Time 600—May 2020, Time 700—September 2020, Time 800—February 2021, and Time 900—July 2021.

Third, during the pandemic, the stock-cryptocurrency comovements increase significantly and positively (→), specifically in the medium investment horizon (scale 16–64 days). A similar pattern during the first few months of the pandemic has been detected earlier in [3,27]. The high comovement lasts longer for Bitcoin (over time 700) than for Ethereum, particularly for the US. Consistent with previous results [1,8,9], this pattern shows that Bitcoin and Ethereum could not serve as a safe haven or hedge against the G7 stocks during the pandemic. Fourth, the comovement patterns over the longer investment horizons (>128 days) reveal encouraging findings. The stock-Bitcoin coherence heatmaps corroborate the findings of [2,7,28] as they show the heat turns blue or even dark blue in some cases. The results indicate that Bitcoin can serve as a safe haven against the G7 stock markets during the pandemic [29], specifically for investors holding the cryptocurrency for a longer investment horizon. An exception is Italy, where Bitcoin appears as a strong hedger. In contrast, Ethereum behaves as a weak hedger or diversifier for G7 stock markets over the same investment period.

Overall, the stock-cryptocurrency behavior during the pandemic supports [38] the prediction that cryptocurrencies are likely to move with the financial markets amid increasing global uncertainties. The stock-Bitcoin comovements in the longer investment horizon explain why the currency is considered one of the traditional safe haven assets [1]. The findings also support previous studies [1,2]—that an asset's safe haven properties are time and market dependent. Finally, we discern causality between stock and cryptocurrency returns during the pandemic. Within the 16 to the 64-day band, stocks lead (↗) cryptocurrency markets, except in Canada and the US, where the relationships are bidirectional (↗ ↙). This finding supports our earlier conjecture that equity investors flock to the cryptocurrency markets to shield their investment during the height of the pandemic. It also implies that the G7 stock markets are generally more efficient than the cryptocurrency markets.

4.2. Seemingly Unrelated Regression (SUR)

The summary statistics of the variables tested in the SUR models, calculated on a monthly frequency from January 2020 to July 2021, are reported in Table 2. For reference purposes, we also plotted Figure A2 (Appendix A), depicting the COVID-19 situation in the G7 countries based on the number of new cases per million people. Consistent with the severity of COVID-19 cases in Italy, its government recorded the highest containment and Health Index (CHI). However, Italy reports the second-lowest EPU, indicating that its financial markets are not likely to be burdened by policy and regulatory uncertainties. In contrast, Canada recorded the highest EPU, although the number of COVID-19 cases

is more controlled. The least affected country, Japan, recorded the lowest EPU and CHI. The country also recorded the highest attention to COVID-19 news (PAI), implying diligent and vigilant behavior of people in Japan. As shown in Figure A2, France had the worst COVID-19 situation among the G7 countries. However, its EPU and CHI are average, and its PAI is the lowest, suggesting the opposite behavior of Japan. The table also reports IIR and ΔCPI that are controlled in the SUR models.

Table 2. Summary Statistics of Market Uncertainties and Macroeconomic Factors.

Variables	Mean	Std Dev	Skew	Kurtosis	Variables	Mean	Std Dev	Skew	Kurtosis
		Panel A. EPU					Panel D. PAI		
Canada	410.8	126.13	2.590	0.266	Canada	17.062	24.975	8.559	2.556
France	286.1	72.01	2.299	0.572	France	16.351	24.434	9.345	2.664
Germany	292.6	99.61	2.408	0.454	Germany	33.294	20.126	8.264	2.215
Italy	166.4	52.65	3.189	0.304	Italy	22.063	28.743	5.723	2.062
Japan	126.4	40.01	2.865	1.008	Japan	39.657	23.212	3.984	1.191
UK	271.7	72.02	1.831	0.054	UK	19.475	23.731	9.152	2.646
US	285.1	107.22	2.213	0.463	US	16.413	25.262	8.487	2.549
		Panel B. CHI					Panel E. IIR		
Canada	56.843	20.751	4.879	−1.818	Canada	0.503	0.571	4.521	1.794
France	56.531	19.482	5.146	−1.755	France	−0.459	0.095	2.957	1.005
Germany	56.772	19.252	5.278	−1.820	Germany	−0.459	0.094	2.887	0.988
Italy	66.914	20.661	7.421	−2.274	Italy	−0.459	0.095	2.957	1.005
Japan	39.221	11.544	5.936	−1.776	Japan	−0.043	0.030	3.564	1.450
UK	58.074	21.391	4.334	−1.515	UK	0.228	0.265	2.590	1.133
US	57.067	20.382	5.806	−2.102	US	0.419	0.550	3.633	1.550
		Panel C. ΔCPI					Panel F. VIX		
Canada	1.412	1.312	−0.970	0.575	VIX	28.173	9.492	3.999	1.115
France	0.705	0.541	−1.541	0.261					
Germany	1.101	1.133	−0.024	0.547					
Italy	0.307	0.705	0.009	0.849					
Japan	−0.243	0.553	−0.967	−0.169					
UK	1.204	0.581	−0.760	0.765					
US	2.131	1.667	−0.024	1.068					

We estimate the SUR models on the relationship between market uncertainty, public attention, and government response measures, and stock-cryptocurrency comovements. We first estimate the SUR models on the stock-cryptocurrency comovements in the short investment horizon (4 days). As predicted, the results do not demonstrate meaningful relationships, and thus are presented in Table A1 (Appendix B) for reference purposes only. The results suggest that the highly variable short-term comovements are driven by excessive trading and speculative activities. For robustness, we provide, in the last row of each panel, the SUR results from Feasible Generalized Least Squares (FGLS with CSD) in a panel setting.

We focus on the SUR estimations for the longer-term stock-cryptocurrency comovements reported in Table 3. Except for several countries, the predictor variables demonstrate significant and consistent roles in explaining long- and short-term stock-cryptocurrency comovements (average R^2 increases from 30.60% in Table A1 to 84.78% in Table 3). Starting with the stock and Bitcoin, their comovements strengthen as market uncertainties increase due to the economic policies and regulations (EPU) and the expected near-term volatilities in stock markets (VIX). The results suggest that the movement between Bitcoin and stocks is rationally founded on market conditions. The same conclusion generally applies to Ethereum. At the individual country level, its comovements with stocks are not always significantly linked to market uncertainties. In the panel setting, however, both EPU and VIX affect stock-Ethereum comovement significantly. Based on the results of EPU and

VIX, it can be surmised that investors' behavior in the stock and cryptocurrency markets during the pandemic is rational and not entirely driven by panic investing due to fear of COVID-19.

Table 3. SUR on Determinants of Long Investment Horizon Stock-Cryptocurrency Comovements.

Market	Constant	EPU	VIX	ΔPAI	ΔCHI	IIR	ΔCPI	R^2
Panel A. DV (Stock–Bitcoin)								
CAN	4.7067 ***	0.0004 ***	0.0057 ***	−0.0015 ***	0.0016 *	0.0630 ***	−0.0419 ***	0.8787
	(0.5211)	(0.0000)	(0.0020)	(0.0001)	(0.0010)	(0.0181)	(0.0047)	
US	5.3336 ***	0.0003 ***	0.0055 **	−0.0013 ***	−0.0006	0.0967 ***	−0.0465 ***	0.8772
	(0.8427)	(0.0001)	(0.0024)	(0.0002)	(0.0010)	(0.0232)	(0.0072)	
FRA	14.2124 ***	−0.0002 *	0.0031 ***	0.0022 ***	−0.0012 ***	1.4424 ***	−0.1256 ***	0.9122
	(1.7531)	(0.0001)	(0.0015)	(0.0003)	(0.0004)	(0.1216)	(0.0162)	
GER	5.4298 ***	−0.0001 ***	0.0052 ***	0.0010 ****	−0.0012 **	1.1379 ***	−0.0422 ***	0.9082
	(0.5128)	(0.0000)	(0.0015)	(0.0002)	(0.0005)	(0.0981)	(0.0043)	
ITA	8.3714 ***	0.0001	0.0061 ***	0.0006 ***	0.0001	1.0552 ***	−0.0739 ***	0.9049
	(0.8762)	(0.0001)	(0.0015)	(0.0002)	(0.0007)	(0.0810)	(0.0084)	
UK	10.7121 ***	0.0008 ***	0.0048	−0.0011 *	−0.0031 *	0.3813 ***	−0.0979 ***	0.8997
	(2.1391)	(0.0002)	(0.0034)	(0.0007)	(0.0017)	(0.0564)	(0.0190)	
JPN	−6.2945 **	0.0012 ***	0.0013	0.0002	−0.0040 ***	1.6043 ***	0.0674 **	0.7874
	(2.8018)	(0.0002)	(0.0016)	(0.0002)	(0.014)	(0.4689)	(0.0277)	
Panel FGLS	3.5100 ***	0.0002 ***	0.0054 ***	−0.0003	0.0005	0.1366 ***	−0.0299 ***	
	(0.2041)	(0.0000)	(0.0018)	(0.0002)	(0.0005)	(0.0153)	(0.0019)	
Panel B. DV (Stock–Ethereum)								
CAN	5.5122 ***	0.0000	0.0006	0.0002 ***	−0.0018 ***	−0.0173 ***	−0.0449 ***	0.9533
	(0.2997)	(0.0000)	(0.0004)	(0.0001)	(0.0001)	(0.0024)	(0.0026)	
US	7.5452 ***	−0.0002 ***	0.0003	0.0007 ***	−0.0008 **	−0.0550 ***	−0.0628 ***	0.9574
	(0.5711)	(0.0001)	(0.0008)	(0.0001)	(0.0003)	(0.0100)	(0.0050)	
FRA	10.5383 ***	0.0000	−0.0006	0.0010 ***	−0.0017 ***	0.4004 ***	−0.0922 ***	0.8483
	(1.7985)	(0.0001)	(0.0009)	(0.0002)	(0.0002)	(0.0551)	(0.0168)	
GER	2.2440 ***	−0.0000	0.0007 ***	0.0004 ***	−0.0008 ***	0.3308 ***	−0.0135 ***	0.9017
	(0.1681)	(0.0000)	(0.0004)	(0.0001)	(0.0002)	(0.0354)	(0.0015)	
ITA	7.6919 ***	0.0001	0.0023 ***	0.0002 **	−0.0014 ***	0.2412 ***	−0.0676 ***	0.8843
	(0.6170)	(0.0001)	(0.0006)	(0.0001)	(0.0003)	(0.0386)	(0.0060)	
UK	7.6807 ***	0.0003 ***	0.0004	−0.0004 ***	0.0001	−0.1291 ***	−0.0648 ***	0.9326
	(0.4959)	(0.0000)	(0.0007)	(0.0001)	(0.0003)	(0.0137)	(0.0044)	
JPN	−1.4735	0.0007 ***	0.0009	−0.0002	−0.0027 ***	1.1894 ***	0.0209	0.6521
	(2.0191)	(0.0002)	(0.0014)	(0.0002)	(0.0007)	(0.2870)	(0.0199)	
Panel FGLS	2.2100 ***	0.0001 ***	0.0017 ***	0.0002 ***	−0.0006 **	−0.0107 **	−0.0154 ***	
	(0.0767)	(0.0000)	(0.0006)	(0.0001)	(0.0003)	(0.0050)	(0.0007)	

Notes: The dependent variable is the wavelet coherence of stock-cryptocurrency comovements at the scale of 128 holding days. The robust standard errors are provided in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The Breusch–Pagan independence chi-square tests for Panels A and B are 104.73 *** and 63.00 ***, respectively.

The results also confirm the earlier findings that Bitcoin and Ethereum lose their safe haven properties against stocks during heightened market uncertainties [2,9,13]. Since market uncertainties have less definitive impacts on stock-Ethereum comovements, Ethereum is found to be better than Bitcoin in hedging or diversifying the G7 stocks during this pandemic crisis. The result on EPU carries policy implications. Although cryptocurrencies are independent of central authorities [2,4], these digital assets can be regulated through fiscal and monetary policies during high market uncertainties. This finding contradicts [14], who suggests that investors increase their diversifications, but it supports [32], who notes that VIX responds inversely against EPU.

The impact of the public's attention on COVID-19 (PAI) on the stock-Bitcoin comovements are mixed: positive for France, Germany, and Italy, and negative for Canada, the US, and the UK. PAI's impact is stronger in the stock-Ethereum comovements, positive in Canada, the US, France, Germany, and Italy, and negative in the UK stock markets. To a

certain extent, the results imply that investor sentiment or fear of the uncertainties triggered by COVID-19 plays a role in their investment decisions, as earlier asserted by [21,33]. In addition, the results also imply that Bitcoin is an investment choice for institutional and high-worth investors who have the resources and reliable sources of information to make longer-term investment decisions. Its appeal to a more sophisticated group of investors is not only through Bitcoin futures but also through cryptocurrency being widely used as a medium of exchange by firms and institutions. Ethereum, on the other hand, is more affordable for retail investors, who are more likely to use cryptocurrency for speculative or risk-taking activities.

Results on the Containment and Health Index (CHI) offer exciting implications. Unlike the market uncertainty and attention indicators, the CHI parameter is generally negative on stock-Bitcoin and stock-Ethereum comovements. Although Japan records the least severe COVID-19 cases, the negative impact also applies to Japan. These results suggest that the investors perceive responses by the governments to contain the pandemic as crucial to fight the health threats and anticipate a rebound in the economy and market activities. They are also consistent with [18] in suggesting that CHI reduces the adverse effect of COVID-19 on stock market performance. With an expectation of more bullish financial markets, the forward-looking equity investors move away from the highly volatile Bitcoin and Ethereum and rebalance their portfolios with more stocks and other conservative investments. Less demand for cryptocurrencies reduces their volatilities, causing them to be less appealing to speculators and traders. Finally, interest and inflation rates significantly explain stock–cryptocurrency long-term comovements. Consistent with [35], the results suggest that the investors rationally consider fundamental factors in setting their long-term objectives.

5. Conclusions

This paper examines the comovements between the leading cryptocurrencies (Bitcoin and Ethereum) and G7 stock markets before and during the COVID-19 pandemic using the Wavelet Coherence technique from 1 January 2018 to 15 July 2021. Our study is the first to investigate whether the comovements can be explained from a rational investment perspective, by examining the comovements' link with market uncertainties (EPU and VIX), public attention to COVID-19 (PAI), and the government's containment and health response to the pandemic (CHI), while controlling the effect of fundamental factors. We estimated the relationships using the Seemingly Unrelated Regression (SUR) method on monthly data from January 2020 to July 2021.

Results from the Wavelet Coherence technique show high variability in the stock–cryptocurrency short-term comovements, which fits the random behavior of efficient markets and excessive tradings by speculators and pastime activities during lockdowns. The comovements increase dramatically in the medium investment horizons during the pandemic, implying that it has triggered systemic risks in the financial systems that cause the asset prices to move closer together. Bitcoin reemerges as a safe haven or a strong hedger against the G7 stock markets in the longer investment horizons, while Ethereum dissipates into a weak hedger or diversifier. This is an interesting finding because neither cryptocurrency prevails as a safe haven asset against the G7 stock markets before the pandemic.

The SUR results show that the long-term stock-cryptocurrency comovements are significantly explained by market uncertainty measures (EPU and VIX), indicating that rational decisions drive market behavior. The relationships with PAI suggest that Bitcoin is relatively more appealing to the sophisticated investors. At the same time, Ethereum appeals more to retail investors since it is more strongly affected by public attention than the complex market uncertainty measures. Alongside this, the findings suggest that behavioral biases, specifically fear of and sentiment toward COVID-19, play a significant role in explaining the comovements. Change in the CHI negatively affects the comovements, indicating that investors expect the government's response would be able to revitalize the economy and market activities. In anticipation of more bullish traditional financial markets,

investors reduce holdings in the highly volatile Bitcoin and Ethereum and rebalance their portfolios with value stocks and other conservative investments. The significant impact of fundamental factors (IIR and ΔCPI) supports the rationality of the market behaviors. The results of this study lend support to the viability of Bitcoin and Ethereum as hedgers or safe havens against the G7 stock markets. In the case of Bitcoin, its safe haven properties emerge stronger than the pre-pandemic period for a longer investment horizon. This study shows that despite the abrupt disruption triggered by the pandemic, investors in these markets are rational in making their moves in stocks and cryptocurrencies. Spontaneously, the results dismiss the myth that investment in cryptocurrencies is exposed to speculation and excessive trading. The findings suggest that investing (rather than trading) in Bitcoin and Ethereum can shield portfolio values when the stock markets are under duress. Established cryptocurrencies are more promising than traditional safe haven assets like gold and foreign currencies since they are digital and decentralized. One of the significant lessons learned from this COVID-19 pandemic is to strive and thrive through similar shocks using digitalization.

In light of the ongoing COVID-19 pandemic and the increasingly dynamic financial markets, our findings offer valuable insights for investors who wish to incorporate cryptocurrencies for portfolio allocations and hedging strategies. Meanwhile, the results of the effect of EPU provide insights for policymakers that specific fiscal and monetary policies might be adequate to regulate these digital assets. This paper has two possible suggestions for future research. First, because our work is limited to analyzing the behavior of G7 stock markets against cryptocurrencies during this pandemic, we propose that future research investigates how they behave against other traditional safe haven assets like gold (and other precious metals), foreign currencies, and commodities, especially oil. The results are critical to identifying alternative assets capable of shielding investment values when the stock markets face eminent shocks like the COVID-19 pandemic. Second, in addition to the Wavelet Coherence method, future studies are recommended to use the Multifractal Detrended Fluctuation Analysis (MF-DFA) to characterize the behavior of stocks against cryptocurrencies. The MF-DFA method is suitable for capturing extreme volatility, sharp jumps, and significant long-range correlations detected in the G7 stock markets when the sales volumes and prices of digital currencies experience explosive behavior.

Author Contributions: Conceptualization, R.A.-R. and M.R.; methodology, A.K.; software, A.K.; validation, A.K., Z.A.K. and R.A.-R.; formal analysis, A.K. and Z.A.K.; investigation, R.A.-R., M.R. and Z.A.K.; resources, A.K. and R.A.-R.; data curation, A.K.; writing—original draft preparation, A.K. and R.A.-R.; writing—review and editing, R.A.-R., M.R. and Z.A.K.; visualization, A.K. and R.A.-R.; supervision, R.A.-R.; project administration, A.K. and R.A.-R.; funding acquisition, R.A.-R. All authors have read and agreed to the published version of the manuscript.

Funding: This research is funded by the Yayasan Tun Ismail Mohamed Ali (YTI) Distinguished Chair at UKM, grant number EP-2020-004.

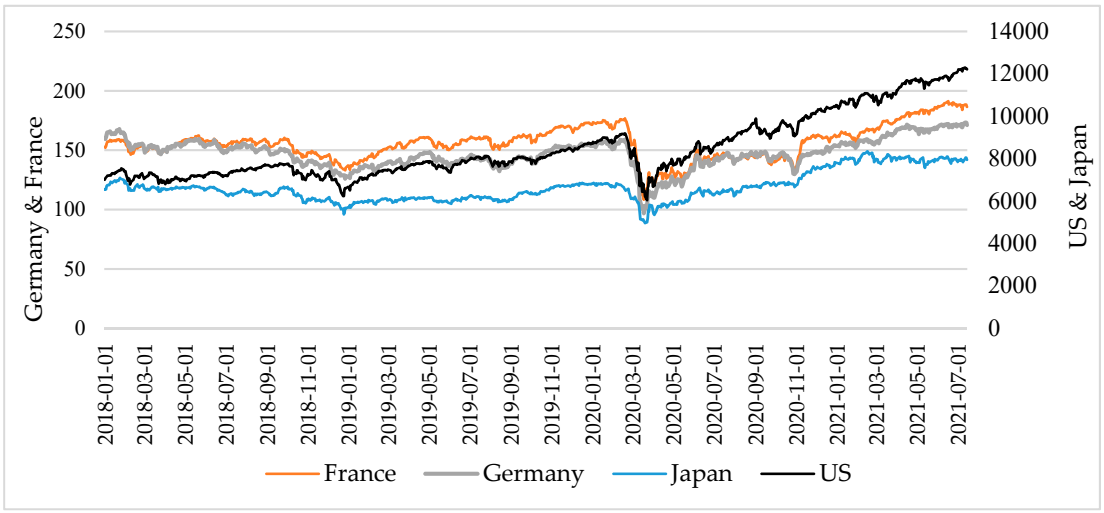
Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. However, restrictions apply to the availability of PAI data.

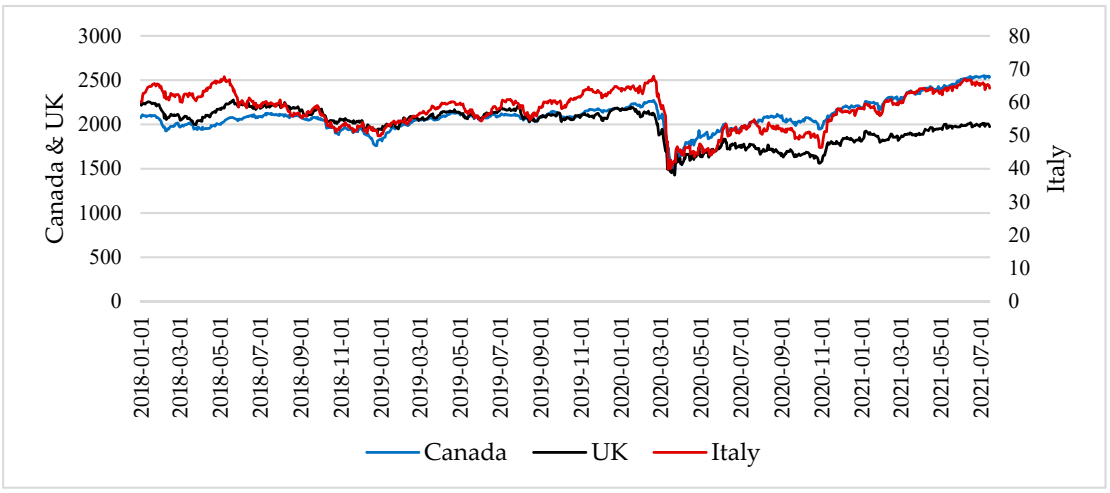
Acknowledgments: The authors wish to acknowledge the anonymous reviewers for their insightful and constructive comments.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

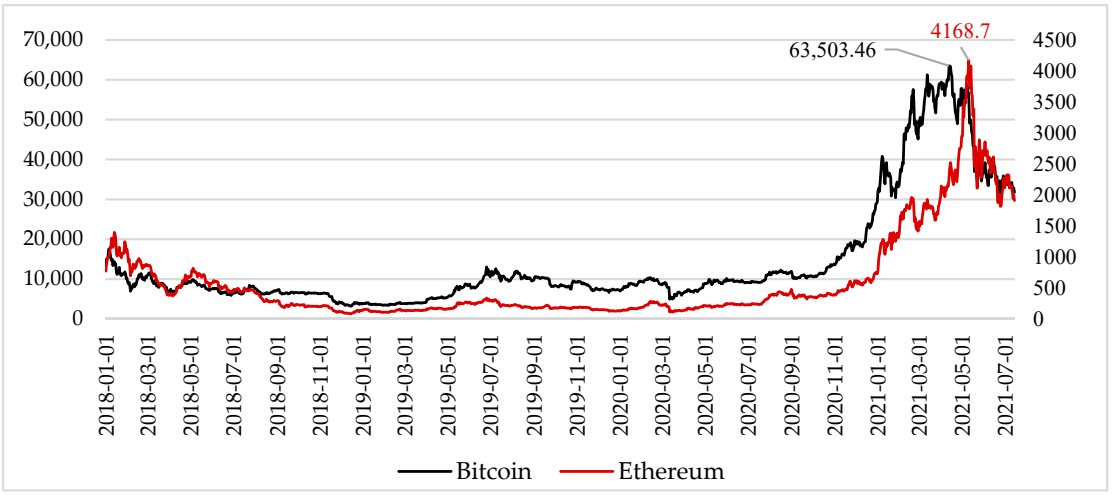
Appendix A



(**a**)



(**b**)



(**c**)

Figure A1. G7 MSCI Stock Market Index and Cryptocurrency Prices (in US$); (**a**) Japan, France, Germany, and US; (**b**) Canada, Italy, and UK; (**c**) Bitcoin and Ethereum.

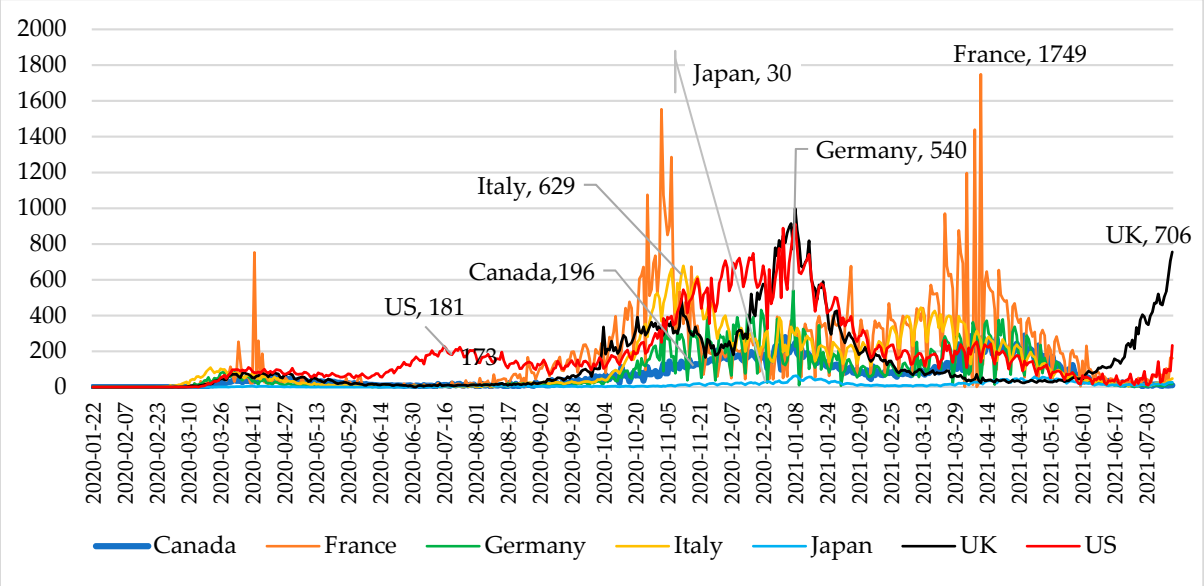


Figure A2. COVID-19, new cases per million population in G7 countries. Source of data: Oxford University's Our World in Data (OWID) database.

Appendix B

Table A1. SUR Estimation on Short Run Stock-Cryptocurrency Comovements.

Market	Constant	EPU	VIX	ΔPAI	ΔCHI	IIR	ΔCPI	R^2
Panel A. DV (Stock–Bitcoin)								
CAN	5.6915 (5.4186)	−0.0007 *** (0.0002)	−0.0079 * (0.0046)	0.0020 ** (0.0008)	−0.0081 *** (0.0026)	0.2458 *** (0.0374)	−0.0455 (0.0497)	0.1986
US	0.2571 (5.0548)	−0.0008 ** (0.0004)	0.0039 (0.0081)	−0.0021 ** (0.0010)	0.0072 ** (0.0033)	−0.1009 (0.0846)	0.0017 (0.0448)	0.0791
FRA	4.4294 (12.2266)	−0.0006 (0.0005)	0.0019 (0.0079)	0.0006 (0.014)	−0.0022 (0.0023)	−0.3541 (0.4467)	−0.0397 (0.1136)	0.1726
GER	−1.3441 (3.5983)	−0.0004 ** (0.0002)	0.0066 (0.0074)	−0.0011 (0.0013)	−0.0036 (0.0035)	−0.3527 (0.4435)	0.0133 (0.0313)	0.0881
ITA	5.5885 (5.8716)	−0.0012 ** (0.0005)	0.0016 (0.0049)	−0.0013 (0.0009)	−0.0007 (0.0027)	−0.2061 (0.3118)	−0.0513 (0.0563)	0.0319
UK	21.8349 *** (7.4665)	0.0012 *** (0.0004)	0.0098 (0.0074)	−0.0043 *** (0.0010)	−0.0004 (0.0028)	−0.0264 (0.1328)	0.1973 *** (0.0673)	0.1682
JPN	33.8370 *** (12.1187)	−0.0008 * (0.0004)	0.0039 (0.0081)	−0.0021 ** (0.0010)	0.0072 ** (0.0033)	−0.1009 (0.0846)	0.0017 (0.0448)	0.0791
Panel FGLS	−0.2441 (0.5950)	−0.0002 * (0.0001)	−0.0018 (0.0031)	−0.0007 (0.0006)	−0.0013 (0.0013)	0.0423 (0.0330)	0.0057 (0.0055)	
Panel B. DV (Stock–Ethereum)								
CAN	−12.6870 (8.2939)	−0.0000 (0.0004)	0.0076 (0.0072)	−0.0018 (0.0014)	0.0013 (0.0039)	0.0174 (0.0749)	0.1170 (0.0737)	0.1019
US	14.4458 *** (4.5944)	−0.0021 *** (0.0003)	−0.0063 (0.0039)	0.0014 * (0.0008)	0.0205 *** (0.0017)	−0.3817 *** (0.0463)	−0.1208 *** (0.0405)	0.7122
FRA	−6.6377 (9.9632)	0.0006 (0.0004)	0.0094 (0.0077)	−0.0001 (0.0016)	−0.0074 *** (0.0024)	−0.3875 (0.5237)	0.0597 (0.0920)	0.1817
GER	4.8691 (3.3779)	0.0004 (0.0003)	0.0125 ** (0.0064)	−0.0051 *** (0.0014)	−0.0103 *** (0.0037)	−1.5699 *** (0.4793)	−0.0538 * (0.0297)	0.3324
ITA	13.2943 *** (4.8685)	−0.0001 (0.0003)	0.0067 * (0.0036)	−0.0007 * (0.0004)	−0.0049 ** (0.0019)	−1.3370 *** (0.2759)	−0.1338 *** (0.0472)	0.5715
UK	0.7677 (12.4438)	0.0006 (0.0006)	0.0057 (0.0103)	−0.0006 (0.0024)	−0.0015 (0.0076)	−0.5228 ** (0.2613)	−0.0063 (0.1121)	0.3729

Table A1. *Cont.*

Market	Constant	EPU	VIX	ΔPAI	ΔCHI	IIR	ΔCPI	R^2
Panel B. DV (Stock–Ethereum)								
JPN	15.8674	0.0002	−0.0110	−0.0037 ***	−0.0139	6.4844 **	−0.1473	0.2931
	(19.4615)	(0.0011)	(0.0076)	(0.0014)	(0.0114)	(2.9995)	(0.1923)	
Panel FGLS	−0.1158	−0.0001	0.0002	0.0004	−0.0025	0.0204	0.0038	
	(0.7663)	(0.0002)	(0.0033)	(0.0009)	(0.0020)	(0.0451)	(0.0071)	

Notes: The dependent variable is the stock-cryptocurrency comovements from wavelet coherence at the scale of 4 holding days. The robust standard errors are provided in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Breusch–Pagan tests of independence chi^2 for Panels A to B are 89.52 *** and 68.02 ***, respectively.

References

1. Ji, Q.; Zhang, D.Y.; Zhao, Y.Q. Searching for Safe Haven Assets during the COVID-19 Pandemic. *Int. Rev. Financ. Anal.* **2020**, *71*, 101526. [CrossRef]
2. Conlon, T.; Corbet, S.; McGee, R.J. Are Cryptocurrencies a Safe Haven for Equity Markets? An International Perspective from the COVID-19 Pandemic. *Res. Int. Bus. Financ.* **2020**, *54*, 101248. [CrossRef] [PubMed]
3. Ghorbel, A.; Jeribi, A. Investigating the Relationship between Volatilities of Cryptocurrencies and Other Financial Assets. *Decis. Econ. Financ.* **2021**, *44*, 817–843. [CrossRef]
4. Hasan, M.B.; Hassan, M.K.; Karim, Z.A.; Rashid, M.M. Exploring the Hedge and Safe Haven Properties of Cryptocurrency in Policy Uncertainty. *Financ. Res. Lett.* **2022**, *46*, 102272. [CrossRef]
5. Baur, D.G.; McDermott, T.K. Is Gold a Safe Haven? International Evidence. *J. Bank. Financ.* **2010**, *34*, 1886–1898. [CrossRef]
6. Mensi, W.; Rehman, M.U.; Shafiullah, M.; Al-Yahyaee, K.H.; Sensoy, A. High Frequency Multiscale Relationships among Major Cryptocurrencies: Portfolio Management Implications. *Financ. Innov.* **2021**, *7*, 75. [CrossRef]
7. Jeribi, A.; Jena, S.K.; Lahiani, A. Are Cryptocurrencies a Backstop for the Stock Market in a COVID-19-Led Financial crisis? Evidence from the NARDL Approach. *Int. J. Financ. Stud.* **2021**, *9*, 33. [CrossRef]
8. Qian, L.; Jiang, Y.; Long, H.; Song, R. The Roles of Economic Policy Uncertainty and the COVID-19 Pandemic in the Correlation between Cryptocurrency and Stock Markets. *Singap. Econ. Rev.* 2020; *online ready*. [CrossRef]
9. Shahzad, S.J.H.; Bouri, E.; Rehman, M.U.; Roubaud, D. The Hedge Asset for BRICS stock Markets: Bitcoin, Gold or VIX. *World Econ.* **2022**, *45*, 292–316. [CrossRef]
10. Wu, W.; Tiwari, A.K.; Gozgor, G.; Huang, L. Does Economic Policy Uncertainty Affect Cryptocurrency Markets? Evidence from Twitter-Based Uncertainty Measures. *Res. Int. Bus. Financ.* **2021**, *58*, 101478. [CrossRef]
11. Bates, A.N. Investor Behavior in the Midst of a Global Pandemic. *Honor. Proj.* **2020**, 800. Available online: https://scholarworks.gvsu.edu/honorsprojects/800 (accessed on 20 June 2021).
12. Sarwar, G. US Stock Market Uncertainty and Cross-Market European Stock Returns. *J. Multinatl. Financ. Manag.* **2014**, *28*, 1–14. [CrossRef]
13. Bahloul, S.; Mroua, M.; Naifar, N. Are Islamic Indexes, Bitcoin and Gold Still Safe Haven Assets during the COVID-19 Pandemic Crisis? *Int. J. Islam. Middle East. Financ. Manag.* **2021**, *15*, 372–385. [CrossRef]
14. Qadan, M.; Kliger, D.; Chen, N. Idiosyncratic Volatility, the VIX and Stock Returns. *N. Am. J. Econ. Financ.* **2019**, *47*, 431–441. [CrossRef]
15. Audrino, F.; Sigrist, F.; Ballinari, D. The Impact of Sentiment and Attention Measures on Stock Market Volatility. *Int. J. Forecast.* **2020**, *36*, 334–357. [CrossRef]
16. Da, Z.; Engelberg, J.; Gao, P. The Sum of All FEARS Investor Sentiment and Asset Prices. *Rev. Financ. Stud.* **2015**, *28*, 1–32. [CrossRef]
17. Ashraf, B.N. Economic Impact of Government Interventions during the COVID-19 Pandemic: International Evidence from Financial Markets. *J. Behav. Exp. Financ.* **2020**, *27*, 100371. [CrossRef]
18. Yang, H.; Deng, P. The Impact of COVID-19 and Government Intervention on Stock Markets of OECD Countries. *Asian Econ. Lett.* **2020**, *1*, 18646. [CrossRef]
19. Simon, H.A. *A Behavioral Model of Rational Choice, in Models of Man, Social and Rational: Mathematical Essays on Rational Human Behavior in a Social Setting*; Wiley: New York, NY, USA, 1957.
20. Gärling, T.; Kirchler, E.; Lewis, A.; van Raaij, F. Psychology, Financial Decision Making, and Financial Crises. *Psychol. Sci. Public Interest* **2009**, *10*, 1–47. [CrossRef]
21. Jiang, B.; Gu, D.; Sadiq, R.; Khan, T.M.; Chang, H.-L. Does the Stringency of Government Interventions for COVID-19 Reduce the Negative Impact on Market Growth? Evidence from Pacific and South Asia. *Econ. Res.-Ekon. Istraž.* 2021; *epub ahead of printing*. [CrossRef]
22. Connolly, R.; Stivers, C.; Sun, L. Stock Market Uncertainty and the Stock-Bond Return Relation. *J. Financ. Quant. Anal.* **2005**, *40*, 161–194. [CrossRef]

23. So, M.K.P.; Chu, A.M.Y.; Chan, T.W.C. Impacts of the COVID-19 Pandemic on Financial Market Connectedness. *Financ. Res. Lett.* **2021**, *38*, 101864. [CrossRef]
24. Cai, Y.X.; Gong, Y.L.; Sheng, G.Y. The Gold Price and the Economic Policy Uncertainty Dynamics Relationship: The Continuous Wavelet Analysis. *Econ. Comput. Econ. Cybern. Stud. Res.* **2021**, *55*, 105–116. [CrossRef]
25. Guzman, A.; Pinto-Gutierrez, C.; Trujillo, M.A. Trading Cryptocurrencies as a Pandemic Pastime: COVID-19 Lockdowns and Bitcoin Volume. *Mathematics* **2021**, *9*, 1771. [CrossRef]
26. Cebrián-Hernández, Á.; Jiménez-Rodríguez, E. Modeling of the Bitcoin Volatility through Key Financial Environment Variables: An Application of Conditional Correlation MGARCH Models. *Mathematics* **2021**, *9*, 267. [CrossRef]
27. Disli, M.; Nagayev, R.; Salim, K.; Rizkiah, S.K.; Aysan, A.F. In Search of Safe Haven Assets during COVID-19 Pandemic: An Empirical Analysis of Different Investor Types. *Res. Int. Bus. Financ.* **2021**, *58*, 101461. [CrossRef]
28. Li, Z.; Ao, Z.; Mo, B. Revisiting the Valuable Roles of Global Financial Assets for International Stock Markets: Quantile Coherence and Causality-in-Quantiles Approaches. *Mathematics* **2021**, *9*, 1750. [CrossRef]
29. Siddique, A.; Kayani, G.M.; Ashfaq, S. Does Heterogeneity in COVID-19 News Affect Asset Market? Monte-Carlo Simulation-Based Wavelet Transform. *J. Risk Financ. Manag.* **2021**, *14*, 463. [CrossRef]
30. Baker, S.R.; Bloom, N.; Davis, S.J. Measuring Economic Policy Uncertainty. *Q. J. Econ.* **2016**, *131*, 1593–1636. [CrossRef]
31. Zhang, J.; He, Q.Z. Dynamic Cross-Market Volatility Spillover Based on MSV Model: Evidence from Bitcoin, Gold, Crude Oil, and Stock Markets. *Complexity* **2021**, *2021*, 9912418. [CrossRef]
32. Tiwari, A.K.; Jana, R.K.; Roubaud, D. The Policy Uncertainty and Market Volatility Puzzle: Evidence from Wavelet Analysis. *Financ. Res. Lett.* **2019**, *31*, 278–284. [CrossRef]
33. Tuna, G. Predicting Financial Market Returns in the presence of Health Crisis: Evidence from Conventional and Islamic Stock markets. *Econ. Res.-Ekon. Istraž.* 2021; *epub ahead of printing*. [CrossRef]
34. Hale, T.; Angrist, N.; Goldszmidt, R.; Kira, B.; Petherick, A.; Phillips, T.; Webster, S.; Cameron-Blake, E.; Hallas, L.; Majumdar, S.; et al. A Global Panel Database of Pandemic Policies (Oxford COVID-19 Government Response Tracker). *Nat. Hum. Behav.* **2021**, *5*, 529–538. [CrossRef]
35. Moya-Martinez, P.; Ferrer-Lapena, R.; Escribano-Sotos, F. Interest Rate Changes and Stock Returns in Spain: A Wavelet Analysis. *BRQ Bus. Res. Q.* **2015**, *18*, 95–110. [CrossRef]
36. Arouri, M.E.H.; Roult, C. Oil Prices and Stock Market in GCC Countries: Empirical Evidence from Panel Analysis. *Int. J. Financ. Econ.* **2012**, *17*, 242–253. [CrossRef]
37. Costola, M.; Iacopini, M.; Santagiustina, C.R.M.A. Google Search Volumes and the Financial Markets during the COVID-19 outbreak. *Financ. Res. Lett.* **2021**, *42*, 101884. [CrossRef] [PubMed]
38. Zhou, S. Exploring the Driving Forces of the Bitcoin Currency Exchange Rate Dynamics: An EGARCH Approach. *Empir. Econ.* **2021**, *60*, 557–606. [CrossRef]