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Examining the Dynamic Asset Market Linkages under the COVID-19 Global Pandemic

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Abstract

This study examines dynamic asset market linkages during the global COVID-19 pandemic based on market efficiency in the sense of Fama (1970). In particular, we estimate the joint degree of market efficiency by applying a generalized least squares (GLS)-based time-varying autoregressive (TV-VAR) model of Ito et al. (2014, 2017). The results show that (1) the joint degree of market efficiency changes widely over time, consistent with the adaptive market hypothesis of Lo's (2004), (2) the global COVID-19 pandemic may have eliminated arbitrage and improved market efficiency through enhanced linkages among asset markets, and (3) market efficiency has continued to decline due to the Bitcoin bubble that emerged at the end of 2020.

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1 Introduction

Since the development of Bitcoin as a cryptocurrency by Nakamoto (2008), the Bitcoin market has expanded its market capitalization while experiencing several price bubbles. The price bubble that has continued since 2020 is serious, and the market capitalization of Bitcoin reached approximately USD 1.2 trillion on April 14, 2021.[1] This means that the market capitalization of Bitcoin expanded more than ten times compared to before March 11, 2020, when the WHO declared the global COVID-19 pandemic. The changes in market capitalization suggest that investors regard Bitcoin as an asset – but this does not necessarily mean they do not also regard it as, for example, a safe haven. Therefore, economists have been examining the Bitcoin market from two perspectives: (i) whether the Bitcoin market is efficient in the sense of Fama (1970), and (ii) whether Bitcoin has the ability to hedge against other assets in the sense of Baur and Lucey (2010).

The first context is that of Urquhart (2016), who examines whether the price of Bitcoin is efficiently determined. Several studies have examined whether Lo's (2004) adaptive market hypothesis (AMH) holds in the Bitcoin market and have shown that market efficiency varies over time.[2] For example, Khuntia and Pattanayak (2018) and Chu et al. (2019) show that the AMH holds in the Bitcoin market, using a conventional statistical test with a rolling-window framework proposed by Domínguez and Lobato (2003). Noda (2021) measures directly the degree of market efficiency using Ito et al.'s (2016; 2017) generalized least squares (GLS)-based time-varying autoregressive (TV-AR) model. Accordingly, it was found that market efficiency in the Bitcoin market changes with time.

The second context is whether Bitcoin serves as a safe haven against other assets in the sense of Baur and Lucey (2010), that is, whether Bitcoin has the ability to hedge investors' portfolio diversification. Klein et al. (2018) argue that Bitcoin has no stable hedging capabilities and is not a new alternative to gold as a safe haven. However, there is controversy regarding whether Bitcoin is a safe haven in more recent studies. Conlon and McGee (2020) show that Bitcoin does not work as a safe-haven asset against the U.S. stock market index, the S&P 500. This implies that there are dynamic correlations between Bitcoin and traditional markets as shown in Corbet et al. (2020). In contrast, Chan et al. (2019) use monthly data to reveal that Bitcoin is a strong hedge for several stock market indices, and Pal and Mitra (2019) find effective hedging abilities of gold against Bitcoin.

Thus, the efficiency of the Bitcoin market and its hedging abilities against other assets have been examined in the literature. Now, recall the definition of "efficient market" by Fama (1970). If prices are informationally efficient, then there are no arbitrage opportunities among financial assets, and if there are no arbitrage opportunities, then asset market linkages should be confirmed. This is because investors search for "safe havens" to protect the financial risk in periods of financial instability and restructure their portfolios. Indeed, many prior studies have found the relationship between informational efficiency and linkages in the financial markets such as Tsutsui and Hirayama (2004) and Ito et al. (2014). Then, we have to measure market efficiency that takes into account the financial market linkages to indirectly

[1]The historical data for total market capitalization are available from CoinMarketCap (`https://coinmarketcap.com/charts/`).

[2]The AMH was proposed as an alternative to the efficient market hypothesis of Fama (1970), which explains why market efficiency (or return predictability) changes over time.

examine hedging abilities against other assets in the Bitcoin market. We should also consider the possibility that market efficiency and hedging abilities in the Bitcoin market vary with time, as discussed in Akhtaruzzaman et al. (2021) and Noda (2021).

This paper is organized as follows. Section 2 presents our method of examining the variation in market efficiency over time based on a GLS-based time-varying vector autoregressive (TV-VAR) model of Ito et al. (2014, 2017). Section 3 describes the daily prices in three asset markets (S&P500, Bitcoin, and gold) to calculate the returns, and presents preliminary unit root test results. Section 4 presents our empirical results and discusses the time-varying nature of the market linkages from the perspective of the AMH, which indicates that market efficiency changes over time. Section 5 presents the conclusion.

2 Model

In this section, we introduce Ito et al.'s (2014; 2017) GLS-based TV-VAR model to investigate the dynamics of asset market linkages between three securities (S&P500, Bitcoin, and gold) from the perspective of informational efficiency. Suppose that $\boldsymbol{p}_t$ is a price vector of the three securities in t period. Our main focus is reduced to the following condition:

$$\mathbb{E}\left[\boldsymbol{x}_t \mid \mathcal{I}_{t-1}\right] = 0, \tag{1}$$

where $\boldsymbol{x}_t$ denotes a return vector of the securities in t period, namely, the i-th component of $\boldsymbol{x}_t$ is $\ln p_{i,t} - \ln p_{i,t-1}$ for $i = S, B, G$. That is, all expected returns in period t given the information set available in period $t-1$ are zero.

When $\boldsymbol{x}_t$ is stationary, the Wold decomposition allows us to consider the time-series process of $\boldsymbol{x}_t$ as

$$\boldsymbol{x}_t = \boldsymbol{\mu} + \Phi_0 \boldsymbol{u}_t + \Phi_1 \boldsymbol{u}_{t-1} + \Phi_2 \boldsymbol{u}_{t-2} + \cdots,$$

where $\boldsymbol{\mu}$ is a vector of the mean of $\boldsymbol{x}_t$ and $\{\boldsymbol{u}_t\}$ follows an independent and identically distributed multivariate process with a mean of zero vector, and a covariance matrix of $\sigma^2 I$, $\sum_{i=0}^{\infty} ||\Phi_i' \Phi_i|| < \infty$ with $\Phi_0 = I$. Note that the efficient market hypothesis (EMH) holds if and only if $\Phi_i = 0$ for all $i > 0$, which suggests that how the market deviates from the efficient market reflects the impulse response, a series of $\{\boldsymbol{u}_t\}$'s. In this study, we construct an index based on the impulse response to investigate the dynamics of asset market linkages in the sense of whether the EMH holds.

The easiest way to obtain the impulse response is to use a VAR model and algebraically compute its coefficient estimates. Under some conditions, the vector return process $\{\boldsymbol{x}_t\}$ of securities is invertible. We consider the following TV-VAR(q) model

$$\boldsymbol{x}_t = \boldsymbol{\nu} + A_1 \boldsymbol{x}_{t-1} + A_2 \boldsymbol{x}_{t-2} + \cdots + A_q \boldsymbol{x}_{t-q} + \boldsymbol{\varepsilon}_t; \quad t = 1, 2, \ldots, T, \tag{2}$$

where $\boldsymbol{\nu}$ is a vector of intercepts and $\boldsymbol{\varepsilon}_t$ is a vector of error terms with $\mathbb{E}\left[\boldsymbol{\varepsilon}_t\right] = \mathbf{0}$, $\mathbb{E}\left[\boldsymbol{\varepsilon}_t^2\right] = \sigma_{\boldsymbol{\varepsilon}}^2 I$, and $\mathbb{E}\left[\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_{t-m}\right] = \mathbf{0}$ for all $m \neq 0$. We use the idea of Ito et al. (2014, 2017) when we measure market efficiency that varies over time.

Directly applying Equation (2) to the model, we obtain the degree computed through the VAR estimates, $A_1, \cdots, A_q$, as follows. First, we compute a cumulative sum of the coefficient matrixes of the impulse response,

$$\Phi(1) = (I - A_1 - A_2 - \cdots - A_q)^{-1}, \tag{3}$$

Second, we define the joint degree of market efficiency,

$$\zeta = \sqrt{\max\left[(\Phi(1) - I)'(\Phi(1) - I)\right]}, \tag{4}$$

to measure the deviation from the efficient market. Note that in the case of the efficient market where $A_1 = A_2 = \cdots = A_q = 0$, our degree ζ becomes zero; otherwise, ζ deviates from zero. For this reason, we call ζ the joint degree of market efficiency. When we find a large deviation of ζ from 0 (both positive and negative), we can regard some deviation from one as evidence of market inefficiency. If there are no arbitrage opportunities among the three markets, we consider that the degree improves because zeta should approach zero. That is, the deterioration of the degree implies that the market linkages weaken over time. Furthermore, we can construct this degree to vary over time when we obtain time-varying estimates in Equation (2).

Adopting a method developed by Ito et al. (2014, 2017), we estimate VAR coefficients in each period to obtain the degree defined in Equation (4) in each period. In practice, following the ideas of Ito et al. (2014, 2017), we use a model in which all VAR coefficients, except for the one that corresponds to the vector of intercepts, $\boldsymbol{\nu}$, follow independent random walk processes. That is, we assume

$$A_{l,t} = A_{l,t-1} + V_{l,t}, \quad (l = 1, 2, \cdots, q), \tag{5}$$

where an error term matrix $\{V_{l,t}\}$ $(l = 1, 2, \cdots, q$ and $t = 1, 2, \cdots, T)$ satisfies $\mathbb{E}[V_{l,t}] = \boldsymbol{O}$ for all t, $\mathbb{E}[vec(V_{l,t})'vec(V_{l,t})] = \sigma_v^2 I$ and $\mathbb{E}[vec(V_{l,t})'vec(V_{l,t-m})] = \boldsymbol{O}$ for all l and $m \neq 0$. The method of Ito et al. (2014, 2017) allows us to estimate the TV-VAR model:

$$\boldsymbol{x}_t = \boldsymbol{\nu} + A_{1,t}\boldsymbol{x}_{t-1} + A_{2,t}\boldsymbol{x}_{t-2} + \cdots + A_{q,t}\boldsymbol{x}_{t-q} + \boldsymbol{\varepsilon}_t, \tag{6}$$

together with Equation (5).

To conduct statistical inference on our time-varying degree of market efficiency, we apply a residual bootstrap technique to the TV-VAR model above. In practice, we build a set of bootstrap samples of the TV-VAR estimates under the hypothesis that all TV-VAR coefficients are zero. This procedure provides us with a (simulated) distribution of the TV-VAR coefficients, assuming the securities return processes are generated under the EMH. Then, we can compute the corresponding distribution of the impulse response and degree of market efficiency. Finally, by using confidence bands derived from such simulated distribution, we conduct statistical inference on our estimates and detect periods when the asset market linkages are weak from the perspective of market efficiency.

3 Data

We utilize the daily spot prices of Bitcoin, S&P500, and gold (London bullion market) obtained from Yahoo!Finance (`https://finance.yahoo.com/`). The start and end dates for all datasets are the same: September 14, 2014 to August 31, 2021. We take the log first difference of the time series of prices to obtain the returns of each asset.

Table 1: Descriptive Statistics and Unit Root Tests

	Mean	SD	Min	Max	ADF–GLS	Lags	$\hat{\phi}$	$\mathcal{N}$
R_S	0.0005	0.0115	-0.1277	0.0897	-10.5354	8	-0.1472	1685
R_B	0.0027	0.0472	-0.4647	0.2251	-4.1933	10	0.3780	1685
R_G	0.0002	0.0091	-0.0526	0.0513	-4.4568	11	0.3102	1685

Notes:

(1) "R_S," "R_B," and "R_G" denote the returns of S&P 500, Bitcoin, and gold, respectively.

(2) "ADF–GLS" denotes the augmented Dickey–Fuller GLS test statistics, and "Lag" denotes the lag order selected by the Bayesian information criterion.

(3) In computing the ADF–GLS test, a model with a time trend and constant is assumed. The critical value at the 1% significance level for the ADF–GLS test is -3.96

(4) "$\mathcal{N}$" denotes the number of observations.

(5) R version 4.1.3 was used to compute the statistics.

Table 1 shows the descriptive analysis for the returns. We confirm that the mean and standard deviation of returns on Bitcoin are higher than those of other assets. This indicates that Bitcoin is a risky asset and is not an alternative to gold, which is a representative risk-free asset. For estimations, all variables that appear in the moment conditions should be stationary; we confirm whether all our variables satisfy this condition using Elliott et al.'s (1996) augmented Dickey–Fuller GLS (ADF–GLS) test. The ADF–GLS test rejects the null hypothesis that all returns contain a unit root at the 1% significance level.

4 Empirical Results

We assume a standard VAR model with constants and select the optimal lag order for the model using Schwarz's (1978) Bayesian information criterion (BIC). Accordingly, we choose the first-order standard VAR model, hereafter called the standard VAR(1) model.

The preliminary results for the above model are shown in Table 2.

Table 2: Preliminary Estimation

	$R_{S,t}$	$R_{B,t}$	$R_{G,t}$
Constant	0.0006	0.0028	0.0003
	[0.0003]	[0.0012]	[0.0002]
$R_{S,t-1}$	−0.1910	−0.0026	−0.0417
	[0.0820]	[0.1160]	[0.0322]
$R_{B,t-1}$	−0.0057	−0.0011	0.0021
	[0.0119]	[0.0306]	[0.0042]
$R_{G,t-1}$	−0.0410	−0.1729	0.0004
	[0.0451]	[0.1342]	[0.0229]
$\bar{R}^2$	0.0389	−0.0006	0.0009
Granger	2.2812*	0.5878	1.5944
L_C		163.5671***	

Notes:

(1) "R_{t-p}," "$\bar{R}^2$," "*Granger*," and "L_C" denote the VAR(p) estimates, the adjusted R^2, the F statistics for Granger's (1969) causality test, and Hansen's (1992) joint L statistic with variance, respectively.

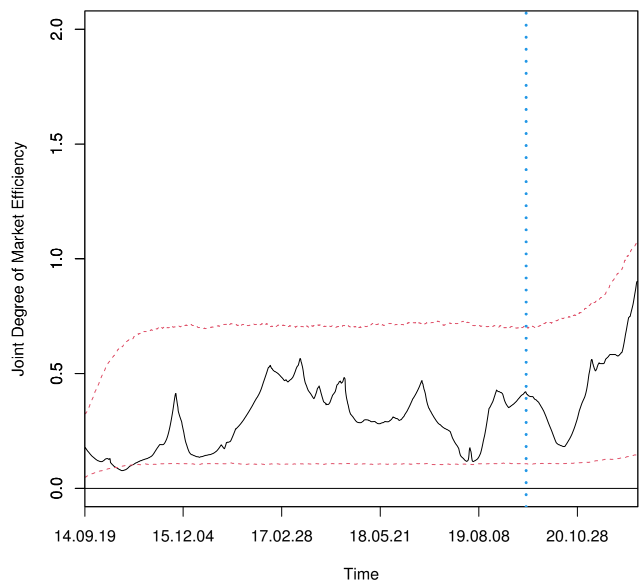
(2) "***" and "*" indicate that the null hypothesis of each test is rejected at the 1% and 10% significance levels, respectively.

(3) Newey and West's (1987) robust standard errors are within parentheses.

(4) R version 4.1.3 was used to compute the statistics.

The estimates of autoregressive terms are not statistically significant at conventional levels, except for the S&P500. Furthermore, the null hypothesis of Granger's (1969) causality test for the S&P 500 is rejected at the 10% significance level, suggesting that the S&P 500 is causal in the sense that it allows prediction of the other variables. Then, we employ Hansen's (1992) parameter constancy test to examine whether the parameters of the standard VAR(1) model were time stable. As shown in Table 2, we rejected the null hypothesis of constant parameters against the parameter variation as a random walk at the 1% significance level. Therefore, we estimated the time-varying joint degree of market efficiency using a GLS-based TV-VAR model Ito et al.'s (2014; 2017) to explore dynamic asset market linkages during the global COVID-19 pandemic.

Figure 1: Time-Varying Joint Degree of Market Efficiency



Notes:

(1) The dashed red lines represent the 95% confidence intervals of the efficient market degrees.

(2) The dotted blue line represents the time period when the World Health Organization declared the COVID-19 a "global pandemic" on March 11, 2020.

(3) We ran bootstrap sampling 10,000 times to calculate the confidence intervals.

(4) R version 4.1.3 was used to compute the estimates.

Figure 1 shows the variation of the joint degree of market efficiency among the three assets. We first find that market efficiency changes widely over time, as described in the AMH of Lo (2004), while the price formation function works well for the entire period. This is also consistent with Ito et al. (2016) and Noda (2016, 2021), who investigated the time-varying nature of market efficiency in the stock and cryptocurrency markets. We observe some periods for improving and declining market efficiency as follows: (1) the end of 2015, (2) mid-2019, and (3) early 2020.

The price of Bitcoin rose by more than 50% at the end of 2015, and increased price volatility reduced market efficiency. After that, the price of Bitcoin experienced a temporary increase until late 2017 and early 2018, but the price remained stable from mid-2018 to mid-2019. As a result, we believe that market efficiency improved significantly until mid-2019. These results are consistent with those of Noda (2021) who examines the weak-form market efficiency for the Bitcoin market. Moreover, market efficiency improved from March 11, 2020, when the WHO declared COVID-19 a global pandemic. Thus, the pandemic may have eliminated arbitrage and improved market efficiency through enhanced linkages among the asset markets. In fact, Caferra and Vidal-Tomás (2021) find a financial contagion in March 2020 since both cryptocurrency and stock prices fell steeply.

Subsequently, market efficiency has continued to decline due to the Bitcoin bubble that emerged at the end of 2020. Note that we measure the joint degree of market efficiency among the financial markets except for Bitcoin and find that market efficiency temporarily declines right after the declaration of COVID-19 as a global pandemic by WHO, and then market efficiency rapidly improves. This implies that S&P 500 and gold hardly contribute to decline in market efficiency. In particular, it is also known that prices are not formed as efficiently as those of other typical financial assets, such as gold, stocks, and foreign exchange, as shown in Al-Yahyaee et al. (2018). This suggests that during the bubble, price formation in the Bitcoin market was extremely speculative, which weakened the market linkage through a significant decrease in market efficiency.

5 Concluding Remarks

In this study, we examine dynamic asset market linkages during the global COVID-19 pandemic from the perspective of market efficiency in the sense of Fama (1970). If market efficiency changes over time, as suggested in Lo (2004), then the existence of arbitrage opportunities should also change over time. Moreover, when arbitrage opportunities between markets do not exist (or exist), the linkages between markets are expected to be stronger (weaker). In particular, we estimate the joint degree of market efficiency based on a GLS-based TV-VAR model of Ito et al. (2014, 2017). The empirical results show that (1) the joint degree of market efficiency changes widely over time, as shown in Lo (2004), (2) market efficiency improved immediately after the WHO's declaration of the global COVID-19 pandemic on March 11, 2020, and (3) market efficiency continued to decline due to the Bitcoin bubble that emerged at the end of 2020. Therefore, we conclude that the empirical results support the AMH, and the pandemic may have eliminated arbitrage and improved market efficiency through enhanced linkages among asset markets.

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