Cryptocurrency Contagion: How Does It Differ From the Commodity Contagion?

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Abstract

Given the recent substantial increase in market capitalization of bitcoin (BTC) and oil, both of them are considered alternative investments and could affect the traditional financial markets. This study compares the contagions between bitcoin (BTC) and oil to major American, European, and Asian equity markets. The contagion analysis follows the procedures from Forbes and Rigobon (2002) in analyzing the jumps in the correlation coefficients and suggests a new idea by extracting and evaluating the idiosyncratic components. The idiosyncratic part refers to the unique series after filtering the common/global part. Analyzing this part allows us to prevent bias due to global factors. This novelty analysis extends previous studies by filtering the common factor. Thus, allowing us to thoroughly investigate specific country. Using the daily return series from January 1, 2016, to January 1, 2024 (downloaded from the investing website), I document that both BTC and oil transmit contagion to the major equity markets, albeit in different directions. BTC (oil) tends to trigger positive (negative) contagion. The results are consistent regardless of whether the daily return or idiosyncratic series are used and when the correlations are adjusted for heteroskedasticity.

Keywords: contagion, cryptocurrency, commodity, correlation, equity markets

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1. INTRODUCTION

The immense monetary value of the two alternative assets, bitcoin (BTC; cryptocurrency) and oil (commodity), has attracted considerable interest in academic and practitioner attention. Recently, Bhutada (2023) estimated that the oil market capitalization was about 2.1 trillion USD, whereas bitcoin's market capitalization was about 1,2 trillion USD (CoinMarketCap, 2024). Therefore, we can see that bitcoin and oil act as one of modern alternative investments.

The modern alternative investments are more closely related to the traditional financial markets, especially after the COVID-19 pandemic. It is quite intuitive that

the pandemic severely disrupted the financial markets, so the investors were looking for alternative assets. Bitcoin and oil are currently well-known as examples of alternative investments, as shown by the tremendous increase in their market capitalizations. Several scholars have investigated the linkages between bitcoin or oil and financial markets. Several recent studies have explored interdependence and spillover between oil and equity markets, including Balli et al. (2023), Hao et al. (2023), Huszár et al. (2023), Zhong et al. (2023) and Hanif et al. (2024). Meanwhile, Abid et al. (2023), Dai et al. (2023), Hung et al. (2024a, 2024b), and Jia et al. (2024) have explored dependencies between bitcoin and equity markets. Other scholars (Annamalaisamy and Jayaraman, 2024; Choudhary et al., 2024; Özer et al., 2024; Tarchella et al., 2024) further examine the interconnectedness among the bitcoin, oil, and equity markets.

2. LITERATURE REVIEW

The theory of financial contagion can be referred to by Forbes and Rigobon (2002). They propose that a dramatic change in a financial market causes a significant impact on another market, and a contagion happens. In addition to the traditional financial markets (such as bonds and equity), we must look for alternative markets (commodities and cryptocurrency). Those commodity and cryptocurrency markets are exciting due to the recent huge market capitalization.

In addition, recent articles have discussed financial contagion in the cryptocurrency and commodity markets, such as Kumar et al. (2023), Umar et al. (2024), and Kyriazis et al. (2024). Yet, studies tend only to quantify the "raw" daily return of compared assets. To the best of my knowledge, a contagion analysis that filters the common global factor component is not yet available. This is an essential part of the novelty of the present study. My argument is quite intuitive because we live in global, digitally connected networks nowadays, unlike in the 1990s, when news did not spread as quickly. This argument is supported by at least two recent studies by Hasan et al. (2023) and Insaido et al. (2024), which indicate that global equity markets tend to move in a similar manner (herding) owing to inter-connectedness. Therefore, the standard contagion analysis (i.e., an analysis using daily returns without filtering from the common factor) may fail to differentiate whether the contagion is merely a common global movement. Specifically, I argue that an appropriate method should first filter the global factor and then perform a statistical analysis to evaluate whether there is a contagion.

The problem with existing studies of financial contagion, as documented by Forbes and Rigobon (2002), is that many of them merely analyze the daily return series without decomposing it into specific parts. Evaluating "raw" returns could be problematic because a common global factor (world index) might affect the return in a specific country. Therefore, a biased analysis could happen because the standard studies did not differentiate between common and specific parts.

A model called the capital asset pricing model (CAPM) is useful in decomposing a "raw return" into two parts: a common global factor and a specific/unique part. The specific/unique part is also referred to as an idiosyncratic risk. The traditional diversification theory states that we shall not pay attention to the idiosyncratic risk because we can eliminate this risk by adding many securities into a portfolio.

However, a seminal study by Goyal and Clara (2003) documented that idiosyncratic components are very important in asset pricing. Recent works by several scholars (Czapkiewicz et al., 2023; Carvajal and Zhou, 2024; Soliman and Saout, 2024) also emphasize the importance of examining the idiosyncratic component of equity markets in the asset pricing literature, especially the post-pandemic dynamics. I argue that different results may be obtained if the contagion analysis uses the idiosyncratic component rather than the daily return component.

Indeed, Forbes and Rigobon (2002) documented a contrasting result in equity markets. However, the authors reported only interdependence, rather than contagion, in several examined equity markets after adjusting for the heteroskedasticity component. Their results contradict those of previous studies, which concluded that financial contagion was present in the observed financial markets. My proposed approach is similar in terms of adjusting the common global factor for the contagion analysis. To my knowledge, this study is the first to use this approach in the cryptocurrency and commodity markets. Using Forbes and Rigobon's (2002) statistical procedure, I compare the results between the raw daily return and idiosyncratic component. I also compare the contagion between bitcoin and oil. In summary, this study made at least two contributions: 1. A new approach to contagion analysis using the idiosyncratic component, and 2. A comparison between the contagion transmitted by cryptocurrency and commodity markets into equity markets.

The remainder of this article is organized as follows. Section 3 discusses the statistical method used to analyze the financial contagion from the oil and bitcoin to equity markets. Section 4 presents the data and the empirical analysis. Section 5 presents the conclusion of this study.

3. THEORETICAL BASIS AND METHODOLOGY

The seminal paper from Forbes and Rigobon (2002) explains the fundamental theory of financial contagion. They argue that the contagion occurs when a dramatic change in a market causes a significant impact on another market. In the standard financial literature, we use a simple correlation analysis to evaluate how the markets are connected to each other. However, using only the correlation matrix will not give us a complete picture of contagion. As the size of cryptocurrency and commodity markets becomes larger and larger, there is a possibility that their markets will transmit their shocks into financial markets. Contagion is commonly defined as a significant increase in dependencies among examined markets (Forbes and Rigobon, 2002).

Forbes and Rigobon (2002) also highlighted the absence of a uniform definition of financial contagion. A thorough review of the empirical literature on financial contagion by Seth and Panda (2018) reveals more than 30 different methods of measuring financial contagion in more than 150 reviewed articles. Therefore, any study on financial contagion, including the present one, should clearly define contagion. I closely follow Forbes and Rigobon's (2002) definition of financial contagion as a significant jump in cross-market inter-connectedness measured by the spike in the computed correlations. One should carefully interpret the technical implications of this definition. That is, a change in the correlation from 0.80 to 0.90,

for instance, does not constitute a contagion. Meanwhile, a change from 0.10 to 0.40 may constitute a contagion because this is a significant jump. This is analogous to "weak sneezing" turning to "strong sneezing" when our doctors might conclude that we caught a flu disease. Forbes and Rigobon (2002) further argued that the standard correlation is biased due to heteroskedasticity. Therefore, they developed an adjusted factor to correct the standard correlation when evaluating the financial contagion between the two examined markets.

The next part will explain my study's innovation (novelty), complementing previous studies that focus only on the "raw" return. I suggest the use of idiosyncratic components between the two examined assets, which is a substantial distinction from Forbes and Rigobon (2002). The idiosyncratic components are obtained from Equation (1), which is the standard CAPM. RET refers to the daily return of asset i on day t, and e refers to the idiosyncratic components of asset i on day t. G is the global market. In this case, I use the MSCI World Index. The cut-off point refers to the first recorded outbreak on 1-January-2020 (WHO, 2020).

$$RET_{i,t} = \alpha_i + \beta_i RET_{G,t} + e_{i,t} \quad (1)$$

I then calculate and compare the standard correlation coefficients between the two idiosyncratic components before and after the COVID-19 pandemic as follows:

$$\rho_{e\,i,j} = \frac{Cov(e_i, e_j)}{\sigma_{ei}\sigma_{ej}} \quad (2)$$

Cov denotes the covariance between idiosyncratic components of asset i and asset j, σ refers to the standard deviation of asset. We can further formalize the compared correlations between the two sample periods as follows:

$$\begin{aligned} \text{H1} &: \rho_{\text{after}} > \rho_{\text{before}} \\ \text{H0} &: \rho_{\text{after}} \leq \rho_{\text{before}} \end{aligned} \quad (3)$$

We can conclude that the contagion occurs if the null hypothesis is rejected. Forbes and Rigobon (2002) further argued that the standard correlation might be biased because of heteroskedasticity when volatility is considered very high. They suggested an adjusted correlation calculated as follows:

$$\rho_{adjusted} = \rho \sqrt{\frac{1 + \theta}{1 + \theta\,\rho^2}} \; ; where\ \theta = \frac{\sigma^{high}_{global\ market}}{\sigma^{low}_{global\ market}} - 1 \quad (4)$$

θ denotes the factor adjustment, considering the period when the global market experiences high volatility. Here, we expect the volatility (σ) after the pandemic period to be higher. I then repeat the procedure from equations (1) to (3) with the adjusted correlation (equation (4)).

4. RESULT AND DISCUSSION

I use the daily return of bitcoin (BTC) for the cryptocurrency, oil (OIL) for the commodity, the MSCI World Index (MSCI) for the global market, and major equity markets (following Maitra et al., 2022): SP500 (US), FTSE 100 (UK), CAC40 (FRA), DAX30 (GER), FTSE MIB (ITA), IBEX35 (SPA), Nikkei 225 (JPN), and SSE composite (CHN) from January 1, 2016, to January 1, 2024. The sub-period covers the four years before the pandemic (from January 1, 2016, to December 31, 2019) and four years after the pandemic (from January 1, 2020, to December 31, 2023). The data are obtained from investing website1.

Figures 1 and 2 plot the daily return series between the MSCI World Index, and BTC (Figure 1) and oil (Figure 2), respectively. Clearly, oil tends to exhibit more volatility than BTC. Further, BTC's return dynamics tend to be similar before and after the pandemic. Recall the BTC crash that occurred prior to the pandemic. In that case, we expect that the pandemic will no longer cause significant volatility in BTC (because BTC has already been very volatile before!). BTC's risky nature is not always useless; there is also a positive side. At least, according to Hung et al. (2024a, 2024b), BTC may improve equity portfolio performance by implementing a volatility timing strategy to rebalance the portfolio daily using the standard mean-variance approach. Likewise, the risky nature of oil may benefit certain equity hedgers during a financial crisis (Kuang, 2023). This particular nature of risky BTC and oil is brought into this article by analyzing how they differ in terms of contagion to equity markets. The next subsection provides a deeper analysis of the comparison of contagion between BTC and oil to equity markets.

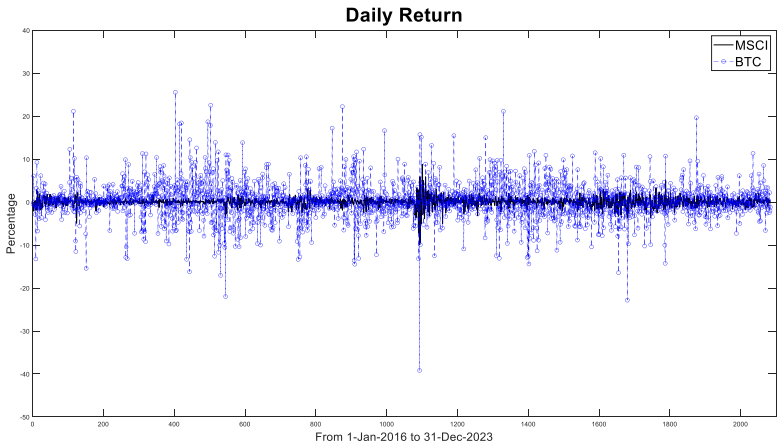

Figure 1. Daily return series for the global index (MSCI) and BTC.

[1] https://www.investing.com/, viewed 15 August 2024.

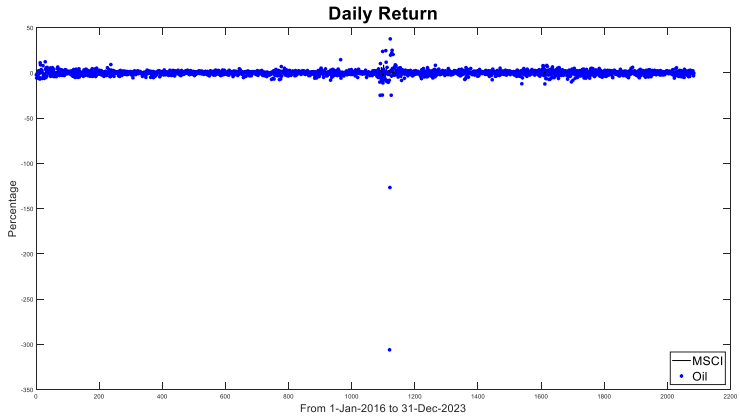

Figure 2. Daily return series for the global index (MSCI) and oil.

Table 1 reports the statistical descriptive parameters (mean, standard deviation, minimum, maximum, skewness, kurtosis, and Jarque-Berra normality test) of the global equity market (MSCI), cryptocurrency (BTC), commodity (OIL), and eight examined equity markets. I report both the daily return and the residual series extracted from equation (1). The volatility parameter (standard deviation) shows that volatility substantially increased in all examined series after the pandemic. Therefore, we could reasonably expect that the dependence will increase after the pandemic. If this happens, we can conclude that a contagion happens. The exceptions were the BTC and CHN series, which may be explained by the following: 1. The bitcoin crash primarily occurred before 2020 (see Zitis et al., 2022). 2. A significant number of Chinese firms were resilient during the pandemic because of their larger size, robust financing, or were state owned (Zhou et al., 2024).

Other parameters, such as skewness, kurtosis, and normality tests, indicate that all examined series tend to exhibit non-normality for both daily return and residual series, as well as before and after the pandemic periods. This suggests that we can reasonably expect heteroskedasticity. This suggests that the proposed method from Forbes and Rigobon (2002) is appropriate because their method factors the heteroskedasticity.

The mean parameters also indicate a mean reversion property in their series, except for the BTC and Oil series, which are slightly positive. However, they also exhibit greater volatility than the other series. This implies that their positive return is merely compensation for their higher risk.

Table 1. Descriptive statistics for the global equity market, cryptocurrency, commodity, and eight examined equity markets.

Return	MSCI	BTC	OIL	US	UK	FRA	GER	ITA	SPA	JPN	CHN
Before pandemic from 1-Jan-2016 to 31-Dec-2019											
Mean	0.04%	0.37%	0.07%	0.05%	0.02%	0.03%	0.03%	0.03%	0.01%	0.03%	-0.01%
Std Dev	0.67%	4.59%	2.20%	0.80%	0.79%	0.94%	0.96%	1.27%	1.06%	1.15%	1.36%
Min	-4.90%	-21.98%	-7.90%	-4.10%	-3.46%	-8.04%	-6.82%	-12.48%	-12.35%	-7.92%	-8.77%
Max	3.09%	25.56%	14.68%	4.96%	3.58%	4.14%	3.51%	5.29%	3.76%	7.16%	5.47%
Skewness	-0.75	0.39	0.40	-0.56	-0.08	-0.66	-0.46	-0.86	-1.59	-0.30	-1.05
Kurtosis	8.13	7.41	7.28	7.88	5.42	9.80	6.40	13.53	21.74	10.32	9.35
JB-Test	1,240	870	821	1,088	256	2,083	538	4,939	>10,000	2,338	1,941
# Observations	1,041	1,041	1,041	1,041	1,041	1,041	1,041	1,041	1,041	1,041	1,041

Return	MSCI	BTC	OIL	US	UK	FRA	GER	ITA	SPA	JPN	CHN
After pandemic from 1-Jan-2020 to 31-Dec-2023											
Mean	0.04%	0.26%	-0.28%	0.05%	0.01%	0.03%	0.03%	0.05%	0.02%	0.04%	0.00%
Std Dev	1.22%	4.20%	10.88%	1.42%	1.17%	1.37%	1.39%	1.50%	1.39%	1.25%	1.17%
Min	-9.91%	-39.18%	-305.97%	-11.98%	-10.87%	-12.28%	-12.24%	-16.92%	14.06%	-6.08%	-8.48%
Max	8.77%	21.15%	37.66%	9.38%	9.05%	8.39%	10.98%	8.93%	8.57%	8.04%	4.33%
Skewness	-0.76	-0.73	-22.74	-0.49	-0.90	-0.74	-0.40	-1.80	-1.03	0.16	-0.77
Kurtosis	15.83	13.24	616.68	15.30	16.72	14.38	15.31	23.81	17.81	6.68	7.54
JB-Test	7,259	4,648	>10,000	6,614	8,315	5,726	6,616	>10,000	9,719	592	998
# Observations	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042
Residuals MSCI Global Factor		**BTC**	**OIL**	**US**	**UK**	**FRA**	**GER**	**ITA**	**SPA**	**JPN**	**CHN**
Before pandemic from 1-Jan-2016 to 31-Dec-2019											
Mean		0.05%	0.17%	0.00%	0.01%	0.00%	0.00%	-0.01%	0.00%	-0.01%	-0.01%
Std Dev		4.46%	2.05%	0.30%	0.61%	0.65%	0.70%	0.99%	0.81%	1.09%	1.34%
Min		-18.98%	-6.96%	-1.38%	-2.54%	-3.82%	-2.92%	-7.84%	-8.28%	-5.92%	-8.31%
Max		25.02%	15.37%	1.99%	2.28%	2.76%	2.13%	5.14%	2.84%	6.65%	5.57%
Skewness		50.47%	46.03%	58.95%	1.41%	-36.29%	-31.12%	-35.23%	-120.50%	-22.85%	-105.59%
Kurtosis		7.17	7.98	8.84	4.69	5.91	4.51	8.73	14.40	9.47	9.34
JB-Test		797	1,114	1,542	124	391	116	1,444	5,893	1,825	1,939
# Observations		1,041	1,041	1,041	1,041	1,041	1,041	1,041	1,041	1,041	1,041
After pandemic from 1-Jan-2020 to 31-Dec-2023											
Mean		-0.06%	-0.17%	0.00%	-0.01%	0.00%	0.00%	0.01%	0.00%	0.01%	0,01%
Std Dev		3.87%	10.78%	0.34%	0.86%	0.95%	0.96%	1.07%	1.03%	1.18%	1.15%
Min		-29.05%	-304.42%	-1.65%	-4.17%	-3.96%	-4.37%	-7.53%	-5.84%	-8.54%	-8.56%
Max		20.01%	35.56%	2.63%	3.81%	7.22%	5.94%	4.19%	7.52%	6.99%	4.73%
Skewness		-14.30%	-2295.12%	65.82%	-15.97%	51.69%	24.84%	-65.44%	-2.55%	-25.53%	-75.71%
Kurtosis		8.88	626.36	8.65	5.17	9.71	7.38	8.25	7.68	7.75	7.82
JB-Test		1,509	>10,000	1,461	208	2,003	843	1,274	953	993	1,109
# Observations		1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042

Source: Data processed (2024).

Tables 2 and 3 report the contagion analysis using the standard correlation parameter between BTC (upper panel) or oil (lower panel), and the eight equity markets (US, UK, FRA, GER, ITA, SPA, JPN, and CHN). Table 2 reports the daily return series and Table 3 reports the residual (idiosyncratic) series. The test statistic refers to the statistical test value between correlations after and before the pandemic. A positive (+) direction indicates that the contagion occurs in the same direction, whereas a negative (-) direction indicates that the contagion occurs in the opposite direction.

Table 2. Contagion analysis of daily return series using the standard correlation parameter.

Daily Return Series								
Correlation	**US**	**UK**	**FRA**	**GER**	**ITA**	**SPA**	**JPN**	**CHN**
Before Pandemic								
BTC	0.0102	-0.0087	-0.0028	0.0041	0.0068	-0.0003	-0.0562	-0.0040
After Pandemic								
BTC	0.3786	0.2601	0.2818	0.2826	0.3292	0.2660	0.0661	0.0676
Relative Change	3604%	-3104%	-10218%	6731%	4737%	-79182%	-218%	-1777%
Test Statistic	628.81	458.72	485.77	475.33	550.31	454.58	208.62	122.26
Contagion	YES	YES	YES	YES	YES	YES	YES	YES
Direction	+	+	+	+	+	+	+	+
Correlation	**US**	**UK**	**FRA**	**GER**	**ITA**	**SPA**	**JPN**	**CHN**
Before Pandemic								
Oil	0.3102	0.3261	0.3019	0.2567	0.3181	0.2891	0.1108	0.0457
After Pandemic								
Oil	0.1342	0.1034	0.0886	0.0836	0.0977	0.1105	0.0812	0.0181
Relative Change	-57%	-68%	-71%	-67%	-69%	-62%	-27%	-60%

Correlation	US	UK	FRA	GER	ITA	SPA	JPN	CHN
Test Statistic	-300.48	-380.00	-364.06	-295.50	-376.24	-304.86	-50.53	-47.06
Contagion	YES	YES	YES	YES	YES	YES	YES	YES
Direction	-	-	-	-	-	-	-	-

Source: Data processed (2024).

Table 3. Contagion analysis of residual series using the standard correlation parameter

Residual / Idiosyncratic Series								
Correlation	US	UK	FRA	GER	ITA	SPA	JPN	CHN
Before Pandemic								
BTC	0.0285	-0.0267	-0.0321	-0.0157	-0.0205	-0.0293	-0.0778	-0.0136
After Pandemic								
BTC	-0.0233	-0.0171	-0.0121	-0.0140	0.0671	--0.0077	-0.0873	-0.0102
Relative Change	-182%	-36%	-62%	-11%	-428%	-74%	12%	-25%
Test Statistic	-88.34	16.32	34.03	2.85	149.42	36.77	-16.28	5.91
Contagion	YES	YES	YES	YES	YES	YES	YES	YES
Direction	-	+	+	+	+	+	-	+
Correlation	US	UK	FRA	GER	ITA	SPA	JPN	CHN
Before Pandemic								
Oil	-0.0654	0.1317	0.0589	0.0084	0.1185	0.0707	-0.0193	-0.0161
After Pandemic								
Oil	0.0086	0.0149	-0.0139	-0.0228	0.0024	0.0258	0.0367	-0.0073
Relative Change	-113%	-89%	-124%	-373%	-98%	-64%	-290%	-55%
Test Statistic	126.38	-199.46	-124.26	-53.22	-198.19	-76.71	95.65	15.01
Contagion	YES	YES	YES	YES	YES	YES	YES	YES
Direction	+	-	-	-	-	-	+	+

Source: Data processed (2024).

We can refer to the definitions of positive and contagion in recent studies by Elsayed et al. (2024) and Aljohani et al. (2024), although these authors used the term spillover rather than contagion. A positive contagion implies that a shock in an asset causes a significant increase in other financial markets in the same direction (i.e., increase versus increase or decrease versus decrease). Meanwhile, a negative contagion means that a shock in an asset causes a significant increase in other financial markets in the opposite direction (i.e., increase versus decrease or decrease versus increase).

Our focus is on comparing how the BTC contagion differs from that of oil. This can provide a bridging analysis between cryptocurrencies and commodities, revealing their linkages to the main equity markets. According to Table 2, both BTC and Oil are contagious to the major equity markets but differ in their direction of contagion. BTC (oil) tends to trigger positive (negative) contagion. A key role of contagion in the oil market has also been identified in previous research (e.g., Abid et al., 2019; Hsiao and Chiu, 2024). At first glance, BTC contagion seems to contradict the findings of Handika et al. (2019). However, the study by Handika et al. (2019) was conducted before the pandemic. So, another insight from this finding is

the pandemic tends to cause contagion, as defined by "a substantial increase in the cross-market linkages.

The following section will elaborate more about the result of negative contagion. The negative contagion from oil on the equity market can be interpreted as an inverse relationship between oil shocks and equity market performance. When oil prices increase, this tends to hurt many major firms worldwide after the pandemic (compared to before the pandemic). Thus, firms experience negative returns. However, a decrease in oil prices tends to benefit many firms after the pandemic. Koczar et al. (2024) reported similar findings. The positive contagion of BTC strengthens the linkages between BTC and global equity markets, especially after the pandemic. This may be related to the recent substantial interest among investors considering BTC as an alternative asset, as indicated by Palomino (2023). However, the author documented a different level of contagion depending on whether the horizon is short- or long-term.

The next section will elaborate on the results of Table 3 and further explanations about the directions of contagions. Interestingly, Table 3 shows that the directions of contagion tend to be similar regardless of whether we use the daily return or idiosyncratic series. We shall note that the idiosyncratic series refers to the specific characteristic of each country index. We find similarities in five equity markets: UK, FRA, GER, ITA, and SPA. All of these are European equity markets. However, differences are observed in the US and Asian (JPN and CHN) equity markets. This indicates that American and Asian equity markets tend to respond in opposite ways to European markets to shocks in BTC and oil. European equity markets' resilience from the contagion direction can be explained as follows: First, as Schulte (2014) found, the robust positional relationship between idiosyncratic risk and equity returns persists in European equity markets. Second, the liquidity component explains the resilience of European equity markets, as Czapkiewicz et al. (2023) showed. This herding behavior among European equity markets is not unusual, because Heil et al. (2022) also documented higher co-movements among European markets, and lower co-movements in American and Asian equity markets. Therefore, we confirm their findings on the homogeneity of European equity markets in terms of contagion responses from the BTC and oil markets, especially after filtering for the global factor. The global factor is the common factor causing each country's index changes. In this case, I use the world global equity index (MSCI).

Table 4. Contagion analysis of daily return series using the adjusted correlation (equation (4)) parameter.

				Daily Return Series				
FR Adj Correlation	**US**	**UK**	**FRA**	**GER**	**ITA**	**SPA**	**JPN**	**CHN**
				Before Pandemic				
BTC	0.0138	-0.0117	-0.0038	0.0056	0.0092	-0.0005	-0.0757	-0.0054
				After Pandemic				
BTC	0.4832	0.3416	0.3684	0.3694	0.4257	0.3489	0.0890	0.0910
Relative Change	3404%	-3024%	-9903%	6518%	4536%	-76983%	-218%	-1774%
Test Statistic	801	603	635	621	711	596	281	165
Contagion	YES	YES	YES	YES	YES	YES	YES	YES
Direction	+	+	+	+	+	+	+	+

FR Adj Correlation	US	UK	FRA	GER	ITA	SPA	JPN	CHN
				Before Pandemic				
Oil	0.4029	0.4219	0.3929	0.3374	0.4124	0.3773	0.1488	0.0616
				After Pandemic				
Oil	0.1797	0.1389	0.1192	0.1125	0.1313	0.1483	0.1093	0.024
Relative Change	-55%	-67%	-70%	-67%	-68%	-61%	-27%	-60%
Test Statistic	-381	-483	-467	-384	-480	-391	-67	-63
Contagion	YES	YES	YES	YES	YES	YES	YES	YES
Direction	-	-	-	-	-	-	-	-

Source: Data processed (2024).

Table 5. Contagion analysis of residual series using the adjusted correlation (equation (4)) parameter.

Residual / Idiosyncratic Series								
FR Adj Correlation	**US**	**UK**	**FRA**	**GER**	**ITA**	**SPA**	**JPN**	**CHN**
				Before Pandemic				
BTC	0.0384	-0.0360	-0.0432	-0.0212	-0.0276	-0.0395	-0.1047	-0.0184
				After Pandemic				
BTC	-0.0314	-0.0231	-0.0163	-0.0189	0.0903	-0.0104	-0.1174	-0.0137
Relative Change	-182%	-36%	-62%	-11%	-427%	-74%	12%	-25%
Test Statistic	-119	22	46	4	201	50	-22	8
Contagion	YES	YES	YES	YES	YES	YES	YES	YES
Direction	-	+	+	+	+	+	-	+
FR Adj Correlation	**US**	**UK**	**FRA**	**GER**	**ITA**	**SPA**	**JPN**	**CHN**
				Before Pandemic				
Oil	-0.0881	0.1765	0.0793	0.0113	0.1590	0.0952	-0.0260	-0.0217
				After Pandemic				
Oil	0.0117	0.0201	-0.0188	-0.0308	0.0032	0.0348	0.0495	-0.0099
Relative Change	-113%	-89%	-124%	373%	-98%	-63%	-290%	-55%
Test Statistic	170	-267	-167	-72	-266	-103	129	20
Contagion	YES	YES	YES	YES	YES	YES	YES	YES
Direction	+	-	-	-	-	-	+	+

Source: Data processed (2024).

The contrasting results between Tables 2 and 3 for the American and Asian equity markets are consistent with previous empirical studies on global linkages (Rahman and Mamun, 2021; Ahelegbey et al., 2024) documenting that the American and Asian equity markets tend to be different and more heterogeneous than those in Europe. In the sense of financial markets, we realize that Europeans tend to be more homogeneous, as they have European currency and central banks. On the other hand, Americans and Asians tend to be more heterogeneous because each country in those regions tends to have its own currency and central bank.

Tables 4 and 5 report the contagion analysis between BTC (upper panel) or oil (lower panel), and eight equity markets (US, UK, FRA, GER, ITA, SPA, JPN, and CHN) using the adjusted correlation, as expressed in equation (4). Tables 4 and 5 report the daily return and residual (idiosyncratic) series, respectively. Note that the test statistic refers to the statistical test value between correlations after and before the pandemic. A positive (+) direction indicates that the contagion occurs in the same

direction, whereas a negative (-) direction indicates that the contagion occurs in the opposite direction.

We find similar results in Tables 2 and 3, although the absolute numbers differ. This means that relative analysis, as Forbes and Rigobon (2002) define contagion, is strikingly more useful because we examine relative changes rather than absolute numbers. We also see that BTC and Oil are contagious to major equity markets but differ in direction. BTC (oil) tends to trigger positive (negative) contagion. Furthermore, the directions of the contagion tend to be similar regardless of whether we use daily returns or idiosyncratic series. We also find similarities in the five equity markets: UK, FRA, GER, ITA, and SPA. However, differences are observed in the US and Asian (JPN and CHN) equity markets.

Furthermore, the results in Tables 4 and 5 are somewhat robust and consistent with those in Tables 2 and 4 for both BTC and oil, as well as for the daily and residual series. Thus, while heteroskedasticity may exist, the relative bias before and after the pandemic periods is the same. Thus, the conclusions do not significantly change between standard and adjusted correlations, as shown by Forbes and Rigobon (2002) in the equity markets. Therefore, the correlation bias between cryptocurrencies and commodities is not something to worry about, as is the case in equity markets. However, equity markets have changed today, considering that Forbes and Rigobon's (2002) finding was from two decades ago. Similarly, cryptocurrency and commodity markets may also change.

5. CONCLUSION

Given the recent substantial emerging interest in studies on BTC and oil contagion, I compare the contagion between BTC and oil with major American, European, and Asian equity markets. I use Forbes and Rigobon’s (2002) procedure and propose a novel idea by evaluating daily returns and extracting the residual series.

I document that both BTC and oil transmit contagion to major equity markets. However, BTC and oil differ in terms of the direction of the contagion. BTC (oil) tends to trigger positive (negative) contagion. The results are consistent regardless of whether I use daily returns or idiosyncratic series. I also obtain a robust result when recalculating using the adjusted correlation analysis suggested by Forbes and Rigobon's (2002) method.

The findings imply that European firms tend to react as buyers for oil shocks, and that European equity markets tend to have market timing signals from the BTC movement. However, American and Asian firms tend to benefit from oil price jumps and suffer from oil price drops. European firms' resilience to contagion directions indicates that they tend to be less prone to global shocks.

Some important future research directions exist. First, a contagion analysis of time-varying volatility instead of returns can be of particular interest and complement research on volatility transmission. Second, deeper statistical methods, such as quantile analysis or the copula approach, can be used. Third, a more complex filtering analysis, such as simultaneously considering both time and global index

components, can be proposed. Overall, the present study is a pioneering work which can lead to further contagion investigations.

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