MONETARY AND CAPITAL MARKETS

Global Financial Stability Notes

No. 2022/01

Cryptic Connections: Spillovers between Crypto and Equity Markets

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January 2022

Crypto assets have emerged as an increasingly popular asset class among retail and institutional investors. Although initially considered a fringe asset class, their increased adoption across countries—in emerging markets, in particular—amid bouts of extreme price volatility has raised concerns about their potential financial stability implications. This note examines the extent to which crypto assets have moved to the mainstream by estimating the potential for spillovers between crypto and equity markets in the United States and in emerging markets using daily data on price volatility and returns. The analysis suggests that crypto and equity markets have become increasingly interconnected across economies over time. Spillovers from price volatility of the oldest and most popular crypto asset, Bitcoin, to the S&P 500 and MSCI emerging markets indices have increased by about 12-16 percentage points since the onset of the COVID-19 pandemic, while those from its returns have increased by about 8-10 percentage points. Spillovers from the most traded stablecoin, Tether, to these indices have also increased by about 4-6 percentage points. In absolute terms, spillovers from Bitcoin to global equity markets are significant, explaining about 14-18 percent of the variation in equity price volatility and 8-10 percent of the variation in equity returns. These findings suggest that close monitoring of crypto asset markets and the adoption of appropriate regulatory policies are warranted to mitigate potential financial stability risks.

INTRODUCTION[1]

Crypto assets are gaining increasing popularity among investors as an asset class. Launched in 2009, the total market capitalization of crypto assets has increased exponentially from less than $20 billion in January 2017 to more than $3 trillion in November 2021 (Figure 1, panel a). Much of this increase has occurred during the COVID-19 pandemic as trade in crypto assets has accelerated, leading to a twentyfold increase in the market capitalization of crypto assets between March 2020 and November 2021. While advanced economies, notably the United States, are among the most technologically prepared for the adoption of crypto assets (Cryptohead 2021), their adoption in recent times has been particularly pronounced in emerging market economies—with nine of the top 10 major adopters in 2021 being emerging market economies (Chainanalysis 2021). Bitcoin, the largest crypto

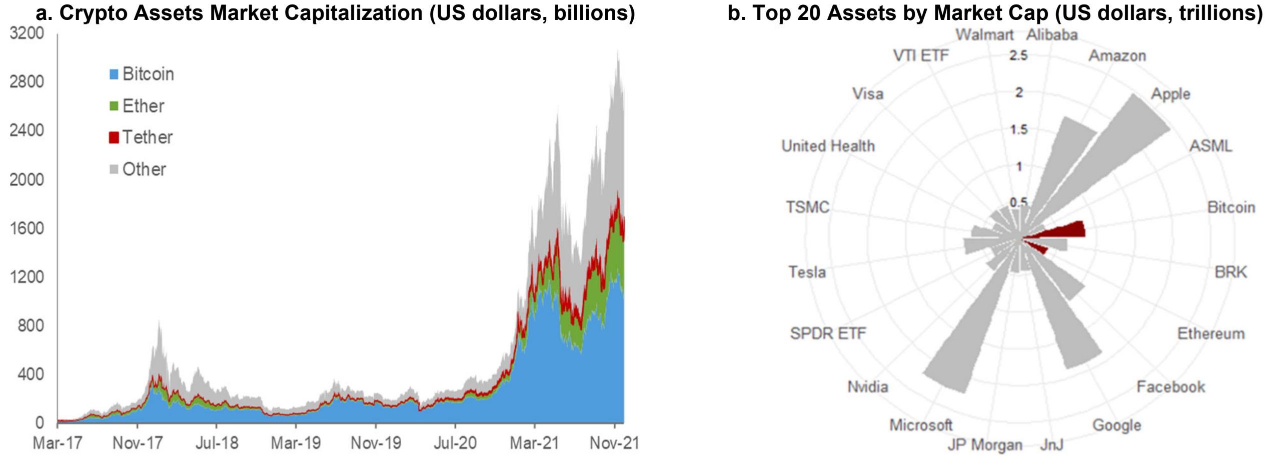
[1] The author would like to thank Tobias Adrian, Fabio Natalucci, Mahvash Qureshi, Jerome Vandenbussche, Evan Papageorgiou, and Tomohiro Tsuruga for many helpful suggestions, and reviewers at the IMF Monetary and Capital Markets Department, Research Department, Strategy, Policy, and Review Department, and Communications Department for useful comments.

asset by market capitalization, recently found its way beyond private markets with El Salvador becoming the first country to adopt Bitcoin as legal tender in September 2021.[2]

The rapid growth of the crypto ecosystem, including traditional crypto assets (such as Bitcoin and Ether) and stablecoins—which are digital tokens pegged to a market reference—has been fueled by technological innovation, the rise of decentralized finance, and increasing institutional and retail investor interest.[3] In September 2021, for example, Bitcoin and Ether ranked among the world's top 20 traded assets, competing with the market capitalization of some of the world's largest companies (Figure 1, panel b). The market capitalization and trading volume of stablecoins have also increased, with the trading volume of the largest stablecoin, Tether, almost double than that of Bitcoin in several months during 2021.[4]

Figure 1. The Rise of Crypto Assets

a. Crypto Assets Market Capitalization (US dollars, billions) **b. Top 20 Assets by Market Cap (US dollars, trillions)**



Sources: CoinMarketCap; CoinGecko; CryptoCompare; Statista; Yahoo Finance; author's calculations.
Note: Figure 1a uses daily data from January 2017 to November 2021 on the market cap of crypto assets. Figure 1b shows the world's top 20 assets, based on the universe of publicly traded companies, exchange traded funds (ETFs) and crypto assets, by their market cap on Sept 10, 2021. Crypto assets are in red and the other assets are in grey. ASML = Advanced Semiconductor Materials Lithography; BRK = Berkshire Hathaway; JnJ = Johnson and Johnson; SPDR ETF = SPDR S&P 500 ETF Trust; TSMC = Taiwan Semiconductor Manufacturing Company; VTI ETF = Vanguard Total Stock Market Index ETF.

Although the risks posed by crypto assets were deemed minimal until a few years ago because of the smaller size of crypto markets and the limited interconnectedness between crypto markets and the regulated financial system (IMF 2018; FSB 2018), their widespread adoption could pose financial stability risks given their highly volatile prices, the rising use of leverage in their trading, and financial institutions' direct and indirect exposures to these assets.[5] Because of the relatively unregulated nature of the crypto ecosystem, any significant disruption to financial conditions driven by crypto price volatility could potentially be largely outside the control of central banks and regulatory authorities.

Against this backdrop, this note investigates the extent of interconnectedness and potential for spillovers between crypto and global financial markets by focusing on equity markets in the United States and in emerging market economies and analyzing the following key questions:

- How correlated are movements in crypto and equity markets? Has this correlation changed over time?
- How strong are the spillovers between crypto and equity markets, and have they increased over time?

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[2] Adrian and Weeks-Brown (2021) discuss the risks associated with adopting crypto assets as a national currency, and Adrian, He, and Narain (2021) write about the risks associated with an unregulated crypto ecosystem. For a detailed discussion of the trends of crypto adoption ("cryptoization") in emerging market economies and the risks and opportunities, see IMF (2021).

[3] In November 2021, Bitcoin and Ether accounted for about 40 and 20 percentof total crypto market cap, respectively, while Tether, the largest stablecoin and in the top five crypto assets by market cap, accounted for about three percent of total crypto market cap.

[4] The increase in crypto asset market capitalization is quite stark even when compared to the total US stock market capitalization, which itself has increased significantly since the pandemic. In early 2019, crypto asset market cap was about 0.4 percent of total US stock market capitalization, but this has increased to close to 5 percent in September 2021.

[5] Several studies report limited interconnectedness between crypto and conventional assets such as equities and currencies in the pre-pandemic period (for example, Briere and others 2015; Dyhrberg 2016; Shahzad and others 2019; Guesmi and others 2019; Charfeddine and others 2020; Symitsi and others 2018; and Umar and others 2021), but note that spillovers increase during market stress episodes and may have been rising (Zeng and others 2020; Conlon and McGee 2020; and Maniff and others 2020).

The findings suggest that the interconnectedness between crypto and equity markets has increased notably over 2017–2021.[6] For example, compared to pre-pandemic years, the correlation between Bitcoin price volatility and S&P 500 index volatility has increased more than four-fold, while Bitcoin's contribution to the variation in the S&P 500 index volatility is estimated to have increased by about 16 percentage points in the post-pandemic period. For returns, the pattern is similar, with a significant increase in the correlation between Bitcoin and S&P 500 returns, as well as in the spillovers from Bitcoin returns to S&P 500 returns. Looking at Tether, the correlation between the volatility in its price and that in global equity indices has also increased significantly between the pre- and post-pandemic periods, though its returns have a small and negative correlation with equity returns indicating its possible use for risk diversification purposes.[7] Spillovers from Tether volatility and returns to global equity indices have also increased but by a smaller extent of about 4-6 percentage points. Together, Bitcoin and Tether explain about 19-23 percent of the variation in the volatility of major global equity indices, and about 12-17 percent of the variation in their returns in the post-pandemic period.

The results also show that spillovers in the reverse direction from equity markets to crypto assets have increased in recent times. Moreover, spillovers in both directions—that is, from crypto assets to equity markets and vice versa—tend to increase during episodes of market volatility.

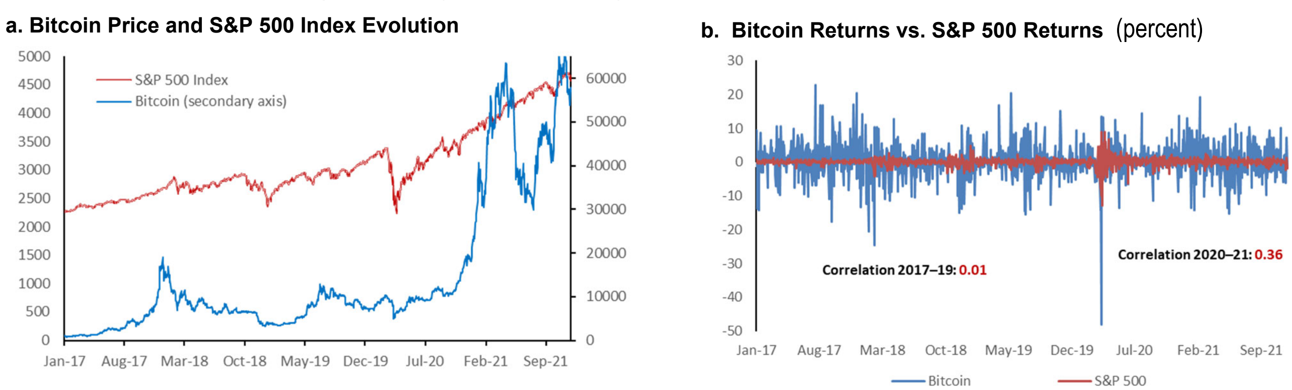
All in all, these findings suggest that crypto assets may no longer be considered as a fringe asset class and could potentially pose financial stability risks due to their extreme price volatility. Thus, regulators and supervisors need to closely monitor action in the crypto markets and the exposure of financial institutions to these assets, and design appropriate regulatory policies to mitigate systemic risks emanating from crypto price spillovers.

The analysis in this note extends the burgeoning literature on the interlinkages between crypto assets and other asset classes in several ways. First, while most of the studies have focused on the pre-pandemic period, the analysis here considers potential spillovers between crypto and equity markets in the post-pandemic period given the exponential growth in crypto asset adoption since the first quarter of 2020. Second, in contrast to earlier literature, which has focused mostly on traditional crypto assets such as Bitcoin, the analysis here also considers spillovers from the increasingly traded stablecoin, Tether. Furthermore, the study analyzes spillovers between crypto assets and equity indices in the United States and in emerging market economies, with the aim of generating a broader picture of the interconnectedness between crypto assets and international equity markets.

CRYPTO AND EQUITY MARKET CORRELATIONS

As the market capitalization of crypto assets, notably Bitcoin, started to pick up in 2017, its price showed little correlation with major stock price indices such as the S&P 500 index (Figure 2). This, however, seems to have changed since the second quarter of 2020, as both Bitcoin and US stock prices have surged against a backdrop of easy global financial conditions and increased investor risk appetite.

Figure 2. Crypto vs. Equity Markets, Jan 2017—Nov 2021



Sources: CryptoCompare; Yahoo Finance; author's calculations.

[6] Interconnectedness in this note is measured in terms of correlations, which provide a sense of the strength of the overall association between two variables, as well as spillovers, which indicate the impact of one variable on the other.

[7] There might, however, be other potential risks associated with Tether, including a high observed failure rate of stablecoins, and the fact that Tether may not be fully backed by reserves at all times (Mizrach 2021 and Griffin and Shams 2020).

Simple (unconditional) correlations computed for the pre-pandemic (Jan 2017-Dec 2019) and post-pandemic (Jan 2020-Nov 2021) periods corroborate these observations and show that crypto and equity market movements have indeed become much more correlated over time (Figure 3). Thus, the intra-day price volatility of two major crypto assets, Bitcoin and Ether, is now about 4 to 8 times more correlated with the volatility of the main US equity market indices S&P 500, Nasdaq, and Russell 2000 indices, compared to 2017–19.[8] Similarly, correlation between the price volatility of Tether and US equity indices has increased significantly, and has switched from being close to zero in 2017–19 to about 0.3-0.4 in 2020–21.[9] In absolute terms, the volatility correlation with US stock markets is the highest for Bitcoin followed by Tether, which have also been the two most traded crypto assets in recent months.[10]

A similar pattern holds for correlation with equity markets in emerging market economies captured by the MSCI emerging markets index.[11] The volatility correlation between Bitcoin and Ether and the MSCI index has increased three to four-fold between the pre- and post-pandemic periods, while that between Tether and the MSCI index has increased by more than that. It is also interesting to note that the magnitude of the correlation between volatility in crypto asset prices and the MSCI index is similar to that between crypto assets and the US stock indices.

Looking at the correlation in returns, those too have increased significantly over time, though the increase has been particularly pronounced for Bitcoin. In absolute terms, the correlation between Bitcoin and Ether and the US equity indices is positive and similar in the post-pandemic period. This is in contrast to the correlation between Tether and all major equity indices, which has been lower but negative in 2020–21—suggesting its use as a risk diversification asset during this time period. While it is interesting that stablecoins such as Tether could play a risk diversification role, other potential risks exist, including that they may not be fully backed by reserves in certain times (Griffin and Shams 2020) and the high observed failure rate of these digital currencies (Mizrach 2021).

Figure 3. Rising Crypto-Equity Correlations

a. Volatility correlations

Crypto	Equity Index	2017–19	2020–21
BTC	S&P 500	0.11	0.46
	Nasdaq	0.09	0.46
	Russell 2000	0.07	0.48
	MSCI EM	0.12	0.48
ETH	S&P 500	0.08	0.25
	Nasdaq	0.06	0.24
	Russell 2000	0.03	0.25
	MSCI EM	0.08	0.25
TTH	S&P 500	–0.02	0.35
	Nasdaq	–0.02	0.34
	Russell 2000	0.01	0.28
	MSCI EM	–0.01	0.31

b. Return correlations

Crypto	Equity Index	2017–19	2020–21
BTC	S&P 500	0.01	0.36
	Nasdaq	0.02	0.38
	Russell 2000	0.03	0.36
	MSCI EM	0.02	0.34
ETH	S&P 500	0.06	0.37
	Nasdaq	0.07	0.38
	Russell 2000	0.07	0.36
	MSCI EM	0.10	0.36
TTH	S&P 500	0.02	–0.10
	Nasdaq	0.02	–0.07
	Russell 2000	0.06	–0.06
	MSCI EM	0.02	–0.08

Sources: CryptoCompare; Yahoo Finance; author's calculations.
Notes: Correlations of returns and volatility are calculated using daily prices, excluding non-trading days, over the periods Jan 2017–Dec 2019 and Jan 2020–Nov 2021. Returns are defined in log difference terms, and volatility is based on intra-day prices. BTC = Bitcoin, ETH = Ether, TTH = Tether.

The increase in correlations between crypto asset and equity returns since 2020 has been much more pronounced than for other key asset classes such as the 10-year US Treasury ETF, gold, and selected currencies (euro, renminbi, and the US dollar). Correlation with corporate bonds has also increased significantly and—as tends to

[8] The S&P 500 index is considered among the best gauges of large-cap equity market movements in the United States, while the Nasdaq is a tech-heavy market-cap-weighted index of more than 2500 stocks, including some of the largest companies in the United States. The Russell 2000 index is a weighted index of 2000 small-cap companies in the United States and is a measure of the investment opportunities afforded by small cap stocks.

[9] While stablecoins are usually pegged to the US dollar and other fiat currencies, small deviations from the market reference are common and rapidly reversed through arbitrage, generating the observed variations in prices.

[10] Looking at the various sub-components of the S&P 500 index (such as consumer discretionary and staples, industry, healthcare, technology, and financials), the return (volatility) correlation of Bitcoin and Tether have increased significantly for all sectors and range between 0.27 to 0.38 (0.28 to 0.65) and –0.06 to –0.15 (0.19 to 0.35), respectively.

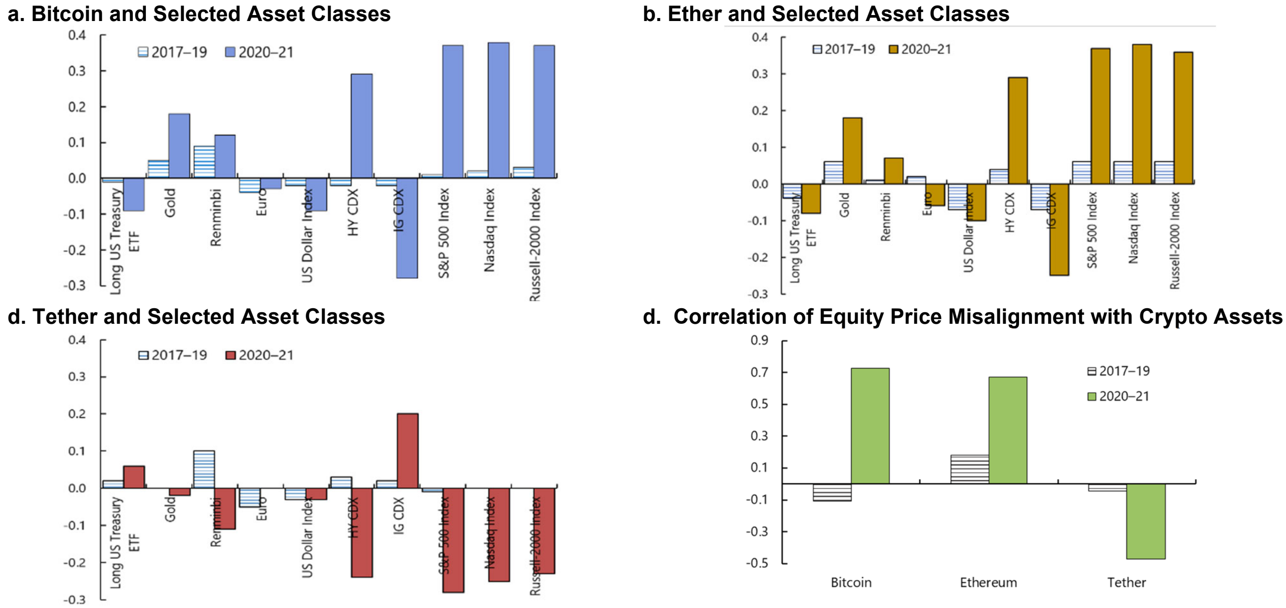
[11] The MSCI index is a widely quoted equity market index that tracks the performance of mid- and large-cap equities across 27 emerging market economies.

be the case for risky asset classes such as equities—is positive with high-yield bonds and negative with investment grade bonds for Bitcoin and Ether (Figure 4, panels a and b), but the reverse holds for Tether (Figure 4, panel c). Interestingly, crypto price movements also appear to have become more correlated with the misalignment in US equity prices compared to the pre-pandemic years (Figure 4, panel d), suggesting that perhaps some over-optimism on the part of investors may be contributing to the surge in their prices.

Overall, these results corroborate previous findings in the literature of a weak initial relationship between crypto price swings and equity price movements but indicate that the link has strengthened significantly over time. This could be attributed to several factors, including the increasing adoption of crypto assets alongside traditional assets such as stocks and bonds in retail and institutional investor portfolios in an environment of easy financial conditions since the onset of the COVID-19 pandemic, as well as the growing acceptance of crypto assets for payment purposes.

Crypto assets thus appeared to have moved from the fringes to the mainstream as an asset class, raising the potential for spillovers to other asset classes, especially to equity markets, as explored in the next section.

Figure 4. Correlation of Crypto Assets with Key Asset Classes



Sources: CryptoCompare; Yahoo Finance; October 2021 *Global Financial Stability Report*, Chapter 1; author's calculations.
Notes: In panels a, b, and c, correlations are calculated using daily prices, excluding non-trading days, and are computed over the periods January 2017–Dec 2019 and January 2020–November 2021. In panel d, correlations of equity price misalignment and crypto asset prices are calculated using weekly data. Equity price misalignment is estimated based on the divergence of US equity prices from their fundamental values (October 2021 *Global Financial Stability Report*, Chapter 1). HY = High-Yield, IG = Investment-Grade, CDX = Credit Default Swap Index.

CRYPTO-EQUITY SPILLOVERS IN THE U.S. MARKET

To formally assess the extent of interconnectedness between crypto and equity markets and how that has evolved, the econometric approach proposed by Diebold-Yilmaz (2012 and 2014) is followed here and a vector autoregression (VAR) model is estimated to analyze the system-wide as well as pair-wise spillovers across different asset classes.[12]

The model is estimated using daily data for crypto asset (Bitcoin, Tether) prices and US equity indices (S&P 500, Russell 2000) over the period Jan 2017-Nov 2021, excluding non-trading days.[13] The baseline specification considers crypto and equity prices as endogenous variables and includes oil prices and the 10-year US Treasury

[12] The underlying premise of the approach is that the variance decomposition matrix associated with an N variable data generating process forms a weighted and directed network that can be used to estimate the direction and magnitude of spillovers among the variables, based on the share of the forecast error variation attributable to other variables. See appendix for further details.

[13] The baseline model includes Bitcoin and Tether which have had the highest trading volumes for most of the pandemic (October 2021 *Global Financial Stability Report*, Chapter 2). Including Ether in the model does not significantly alter the results for the other assets in the VAR system, while its volatility and returns spillovers are estimated to be generally quite small. The Nasdaq index is also excluded from the model given its high correlation with the S&P 500 index, but the results are qualitatively robust to including it instead.

bill (T-bill) rate as exogenous variables to control for the potential effect of variations in commodity prices and financial conditions on asset prices.[14] The VAR is estimated both for asset returns and for asset price volatility to gauge the extent of portfolio connection and diversification strategies across asset classes over time.[15] Specifically, two estimation approaches are followed: first, the model is estimated for the pre-pandemic (Jan 2017-Dec 2019) and post-pandemic (Jan 2020-Dec 2021) periods separately and the magnitude of the spillovers is compared; second, a rolling-window estimation is done over the entire sample (2017–21) to compute the daily variation in spillovers to gauge the dynamics of spillovers during normal times versus those of market stress.[16]

Spillovers before and during COVID-19

Looking at the volatility and returns spillovers between crypto asset prices and US equity prices in the pre- and post-pandemic periods, several interesting findings emerge (Figures 5 and 6).

Figure 5. Crypto-Equity Volatility Spillovers in the United States

a. Spillovers Matrix: 2017–19 (percent)

	Bitcoin	Tether	S&P 500	Russell 2000
Bitcoin	97.5	0.0	1.8	0.7
Tether	0.1	99.6	0.1	0.1
S&P 500	1.0	0.0	61.0	38.0
Russell 2000	0.4	0.1	41.9	57.6

b. Spillovers Matrix: 2020–21 (percent)

	Bitcoin	Tether	S&P 500	Russell 2000
Bitcoin	55.0	12.0	15.0	18.0
Tether	27.0	40.9	15.0	17.0
S&P 500	17.0	6.1	48.0	29.0
Russell 2000	18.0	4.6	34.0	43.0

c. Change in Spillovers : Jan 2017–Nov 2021 (percentage points)

Pair-Wise Spillover	Change Over Time
BTC --> S&P	16.0
S&P --> BTC	13.2
TTH --> S&P	6.1
S&P --> TTH	14.9
BTC --> RUS	17.6
RUS --> BTC	17.3
TTH --> RUS	4.5
RUS --> TTH	16.9
S&P --> RUS	-7.9
RUS --> S&P	-9.0

Sources: CryptoCompare; Yahoo Finance; author's calculations.
Notes: The spillovers are based on a model estimation using daily volatility data over the periods January 2017–December 2019 and January 2020–November 2021. In panels a and b, for the i-th row and j-th column in the matrix, the ij-th entry represents the spillover from asset j to asset i, or the percent of forecast error variance of asset i due to shocks from asset j. Rows add up to 100 percent. In panel c, the numbers represent the percentage change in spillovers between 2017–19 and 2020–21. BTC = Bitcoin, ETH = Ether, TTH = Tether, S&P = S&P 500, RUS = Russell 2000.

Figure 6. Crypto-Equity Return Spillovers in the United States

a. Spillovers Matrix: 2017–19 (percent)

	Bitcoin	Tether	S&P 500	Russell 2000
Bitcoin	98.7	0.4	0.3	0.7
Tether	0.7	98.6	0.2	0.5
S&P 500	0.4	0.3	57.6	41.8
Russell 2000	0.5	0.7	42.4	56.5

b. Spillovers Matrix: 2020–21 (percent)

	Bitcoin	Tether	S&P 500	Russell 2000
Bitcoin	74.0	5.1	12.0	8.9
Tether	4.8	75.6	13.0	6.1
S&P 500	10.4	6.5	50.0	32.8
Russell 2000	10.3	4.4	38.0	46.9

c. Change in Spillovers: Jan 2017-Nov 2021 (percentage points)

Pair-Wise Spillover	Change Over Time
BTC --> S&P	10.0
S&P --> BTC	11.8
TTH --> S&P	6.3
S&P --> TTH	12.8
BTC --> RUS	9.8
RUS --> BTC	8.2
TTH --> RUS	3.7
RUS --> TTH	5.6
S&P --> RUS	-4.4
RUS --> S&P	-9.0

Sources: CryptoCompare; Yahoo Finance; author's calculations.
Notes: The spillovers are based on a model estimation using daily return data over the periods January 2017–Dec 2019 and January 2020–November 2021. In panels a and b, for the i-th row and j-th column in the matrix, the ij-th entry represents the spillover from asset j to asset i, or the percent of forecast error variance of asset i due to shocks from asset j. Rows add up to 100 percent. In panel c, the numbers represent the percentage change in spillovers between 2017–19 and 2020–21. BTC = Bitcoin, ETH = Ether, TTH = Tether, S&P = S&P 500, RUS = Russell 2000.

[14] Considering the T-bill rate in first differences rather than in levels does not affect the results. Moreover, while the VIX is excluded from the baseline specification for the volatility VAR model as it tracks S&P volatility closely, the results remain qualitatively robust when including it as an additional exogenous variable. The VIX is included in the VAR model for returns.

[15] Returns are defined as one-day log differences, whereas volatility is based on intra-day spreads with volatility = 0.361*[Ln (High Price) – Ln(Low Price)^2] following the formula used in Diebold-Yilmaz (2012). See the appendix for further details.

[16] As in Diebold-Yilmaz (2012), the length of the forecast horizon and rolling window is considered to be 10 days and 100 days, respectively, but the results are robust when considering longer durations (20 days and 150 days, respectively).

First, spillovers appear to have increased in both directions—that is, from crypto to equity prices, and vice versa. For example, volatility spillovers from Bitcoin and Tether to S&P 500 have increased by about 16 and 6 percentage points, respectively, between 2017–19 and 2020–21, whereas volatility spillovers from the S&P 500 to Bitcoin and Tether have increased by 13-15 percentage points (Figure 5). Similarly, return spillovers from Bitcoin and Tether to the S&P 500 have increased by 10 and 6 percentage points, while those in the reverse direction have increased by 12-13 percentage points (Figure 6).

Second, movements in Bitcoin prices are associated with a nontrivial share of the variation in US equity prices. Specifically, the volatility in Bitcoin prices explains about one-sixth of the volatility in US equity indices, while Bitcoin returns explain about one-tenth of the variation in US equity returns.

Third, Tether also contributes to US equity price movements though its share is smaller relative to Bitcoin given the relatively limited movement in its prices, and averages about 4-7 percent for volatility and returns.

Overall, these results are quite remarkable given that less than five years ago, the contribution of crypto assets to explaining the variations in US equity markets was one percent at the most and suggest a significant integration of the crypto asset markets with equity markets, most likely because of the increased adoption of crypto assets by retail and institutional investors, as noted earlier.[17]

Dynamic spillovers

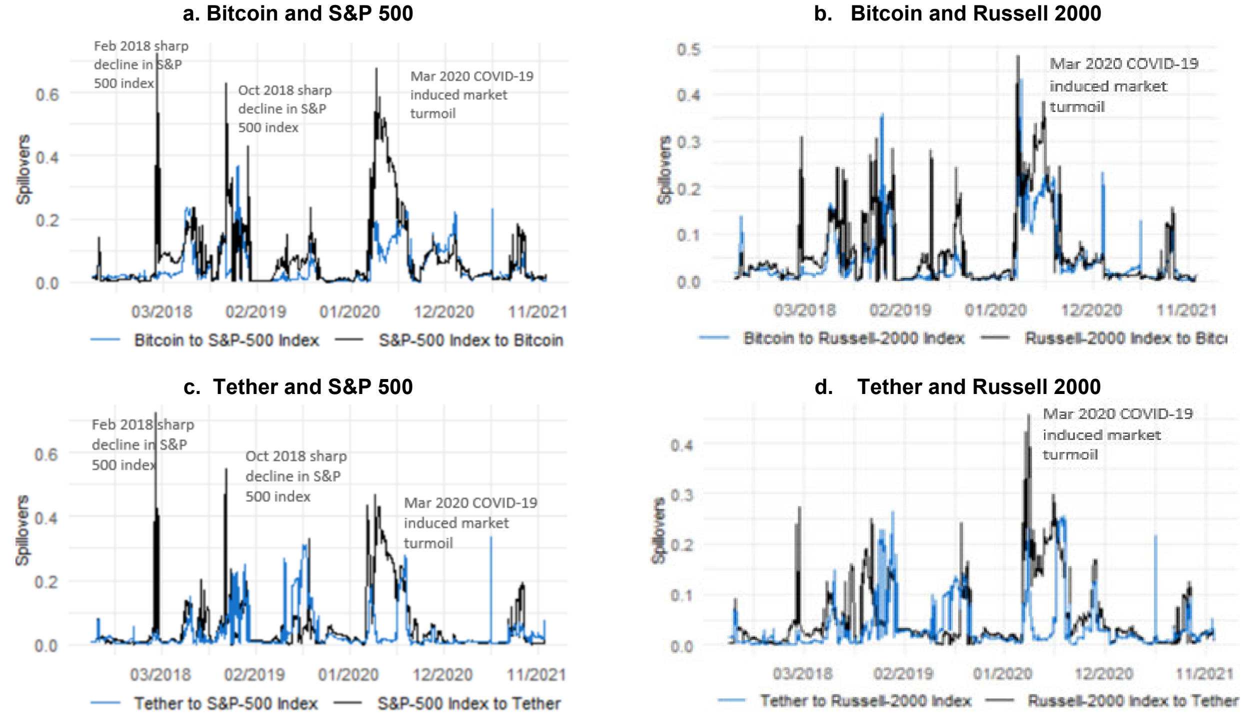
Although the results above suggest that crypto and US equity markets have become more integrated since the onset of the pandemic, it is also useful to analyze the daily variation in spillovers to assess the dynamics during times of market stress relative to normal times.

Figure 7 shows the pair-wise directional spillovers between Bitcoin/Tether and the S&P 500/Russell 2000 indices, which suggest that spillovers tend to increase during episodes of market stress. For example, the March 2020 generalized market collapse led to a pronounced and relatively extended rise in pair-wise directional volatility spillovers between the crypto and equity markets. In terms of the magnitude of spillovers, however, equities (black line) emitted more volatility spillovers to the crypto market (blue line) than vice versa. There were also sharp spikes in equity to crypto volatility spillovers in early and late 2018, corresponding to sharp declines of more than 10 percent in the S&P 500 index.

In terms of returns (Figure 8), the magnitude of spillovers is generally less than volatility spillovers suggesting that cross-market volatility shocks have more of an impact than return shocks. Crypto to equity spillovers (blue lines) and equity to crypto spillovers (black lines) appear to be tracking each other fairly closely over most of the sample apart from a few episodes, including the months following the March 2020 market collapse where cross-market spillovers noticeably increased, with equity to crypto spillovers increasing more than vice versa.

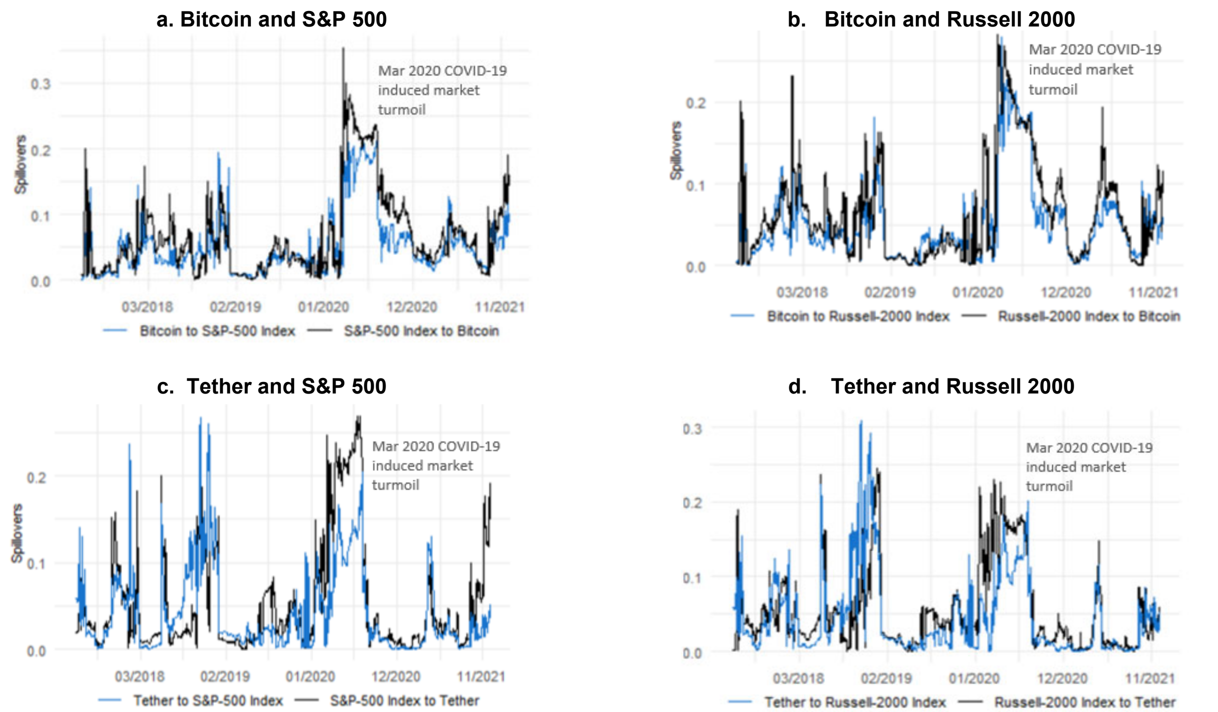
[17] While Bitcoin and Tether price movements are also highly correlated (the correlation is about 0.5 for price volatility and –0.25 for returns in 2020–21), the spillovers for Tether to equity prices are obtained controlling for Bitcoin prices in the VAR.

Figure 7. Time Variation in Crypto-Equity Volatility Spillovers



Source: Authors' calculations.
Note: These plots present the pair-wise directional volatility spillovers from Bitcoin and Tether to and from the S&P 500 and Russell 2000 indices. The blue lines denote spillovers from crypto to equity, whereas the black lines denote spillovers from equity to crypto. The estimation results are based on a VAR-X model with endogenous variables as Bitcoin, Tether, S&P 500, Russell 2000, and oil prices and the US 10-year bond yield as exogenous variables. The rolling window length is 100 days and the forecast horizon for the underlying generalized variance decomposition is 10 days. Volatility is defined based on intra-day low and high prices and non-trading days, including weekends and national holidays, are excluded.

Figure 8. Time Variation in Crypto-Equity Return Spillovers



Source: Author's calculations.
Note: These plots present the pair-wise directional return spillovers from Bitcoin and Tether to and from the S&P 500 and Russell 2000 indices. The blue lines denote spillovers from crypto to equity, whereas the black lines denote spillovers from equity to crypto. The estimation results are based on a VAR-X model with endogenous variables as Bitcoin, Tether, S&P 500, Russell 2000, and exogenous variables as oil prices, the VIX, and the US10-year bond yield. The model is estimated with the rolling window length at 100 days and the forecast horizon for the underlying generalized variance decomposition at 10 days. Returns are defined based on one-day log differences and non-trading days, including weekends and national holidays, are excluded.

CRYPTO-EQUITY SPILLOVERS IN EMERGING MARKETS

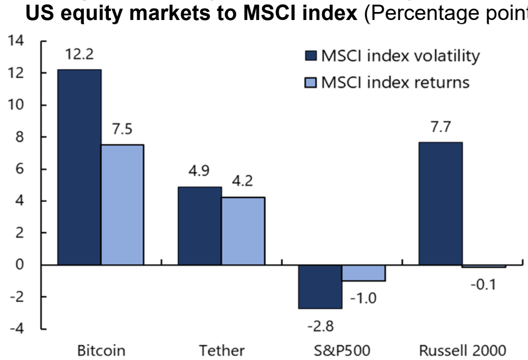
This section extends the previous analysis to emerging market economies and analyzes the spillovers between Bitcoin and Tether and equity prices in emerging markets.[18] As before, the spillovers are computed over two time periods: pre-pandemic (2017–19) and post-pandemic (2020–21). The baseline VAR specification includes the MSCI emerging markets index, Bitcoin, Tether, the S&P 500 index, and the Russell 2000 index as endogenous variables, while oil prices and the US10-year bond yield are included as exogenous variables to control for the potential direct impact of commodity prices and US monetary policy.[19]

The results show that as in the case of the United States, both volatility and return spillovers have increased from crypto assets to the MSCI index and vice versa (Figure 9). Specifically, volatility spillovers from Bitcoin to the MSCI index have increased by 12 percentage points (panel 1), while those from the MSCI index to Bitcoin have increased by 5 percentage points (panel 2). The same holds for return spillovers, with the contribution of both Bitcoin and the MSCI index to each other's returns having increased by about 8-9 percentage points between the pre- and post-pandemic periods.

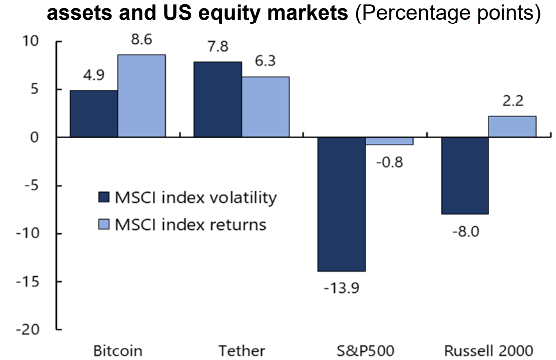
In absolute terms, Bitcoin explains about 10 percent of the volatility in the MSCI emerging markets index in 2020–21 and about 8 percent of the variation in its returns (see appendix, Tables A2 and A3). At the same time, the MSCI index explains about 7-9 percent of the variation in the volatility and returns of Bitcoin.

Figure 9. Change in Crypto-Equity Spillovers in Emerging Markets, Jan 2017-Nov 2021

a. Change in volatility spillovers from crypto assets and US equity markets to MSCI index (Percentage points)



b. Change in return spillovers from MSCI index to crypto assets and US equity markets (Percentage points)



Sources: CryptoCompare; Yahoo Finance; author's calculations.
Notes: Panel 1 shows the variation in the MSCI index volatility and returns explained by the specified crypto assets and US equity markets in Jan 2020-Nov 2021 relative to that in Jan 2017-Dec 2019 (that is, the change in spillovers from crypto assets and US equity markets to the MSCI index). Panel 2 shows the variation in the volatility and returns of the specified crypto assets and US equity markets explained by the MSCI index volatility and returns in Jan 2020-Nov 2021 relative to that in Jan 2017-Dec 2019 (that is, the change in spillovers from the MSCI index to crypto assets and US equity markets). The estimation results are based on a VAR-X model (for returns and volatility separately) with endogenous variables as the MSCI index, Bitcoin, Tether, S&P 500, Russell 2000, and exogenous variables as oil prices, and the US10-year bond yield.

The interconnectedness between Tether and the MSCI index has also increased over time. Volatility spillovers from Tether to the MSCI index have jumped by about 5 percentage points from 2017–19 to 2020–21, while the spillovers from returns have increased by 4 percentage points. The contribution of the MSCI index to the volatility in Tether has increased by 8 percentage points while that to its returns has increased by 6 percentage points.

The spillovers between crypto assets and the US equity indices are qualitatively similar in magnitude and direction to the baseline model estimated earlier, indicating that the findings are robust to extending the model to emerging markets. Moreover, although spillovers from the S&P 500 index to the MSCI emerging markets index are still the largest in magnitude across all the asset classes considered here, it is interesting to note that they have declined over time, suggesting that the equity markets in emerging market economies are increasingly influenced by crypto price swings.

[18] This note considers emerging market economies as countries that are included in the MSCI emerging market index.

[19] The baseline specification of the VAR was checked against various alternative specifications for robustness, including using the VIX as an exogenous variable and replacing the S&P 500 index with the Nasdaq index. The core set of findings remain qualitatively similar.

CONCLUSION

Crypto asset market capitalization is growing rapidly amid increasing demand from retail and institutional investors. The analysis in this note suggests that the interconnectedness between crypto assets and equity markets has increased significantly in the post-pandemic period, with two of the most traded crypto assets—Bitcoin and Tether—individually explaining about 12-16 percent of the variation in the volatility of global equity prices and about 7-11 percent of the variation in global stock returns. The extent of spillovers from crypto to equity markets tends to increase during episodes of greater market volatility and is significant for emerging markets, given their increased adoption of crypto assets in recent months.

The analysis here points to the need for further research to better understand these “cryptic” connections by investigating the channels of spillovers between crypto and equity markets, the direction of causality, and the risks crypto assets could pose to the financial system more broadly. Key drivers of the increased interconnectedness could include growing acceptance of crypto-related platforms and investment vehicles in the stock market and at the over-the-counter market, or more generally growing Bitcoin adoption by retail and institutional investors, many of whom have positions in both the equity and crypto markets. Given the increased interconnectedness between crypto and financial markets at large, the hitherto “light touch” regulatory approach toward crypto assets needs to be reviewed. Regulations should correspond to the risks crypto assets pose (BIS 2021), and oversight of the crypto ecosystem needs to be strengthened, including by addressing data gaps (IMF 2021).

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I. CRYPTO-EQUITY SPILLOVER MODEL

The Diebold-Yilmaz (2012 and 2014) interconnectedness and spillover model used in the empirical analysis is outlined below, with further details available in the original papers.

Consider an N variable covariance-stationary data-generating process $\boldsymbol{x}_t = \Theta(L)\boldsymbol{u}_t$, where $\Theta(L) = \Theta_0 + \Theta_1 L + \Theta_2 L^2 + \cdots$ and $E[\boldsymbol{u}_t \boldsymbol{u}_t'] = I$, which is estimated using a vector autoregression (VAR) model. Taking the variance decomposition of this process yields the following forecast error variance decomposition (FEVD) matrix, with each element d_{ij} indicating the spillover from the j^{th} variable to the i^{th} variable:

	x_1	x_2	. . .	$x_{j=N}$	Total spillover to *i*
x_1	d_{11}^H	d_{12}^H	. . .	d_{1N}^H	$\sum_{j=1}^N d_{1j}^H$, $j \neq 1$
x_2	d_{21}^H	d_{22}^H		d_{2N}^H	$\sum_{j=1}^N d_{2j}^H$, $j \neq 2$
.	.	.	.	.	.
$x_{i=N}$	d_{N1}^H	d_{N2}^H	. . .	d_{NN}^H	$\sum_{j=1}^N d_{Nj}^H$, $j \neq N$
Total spillover by *j*	$\sum_{i=1}^N d_{i1}^H$ $i \neq 1$	$\sum_{i=1}^N d_{i2}^H$ $i \neq 2$	. . .	$\sum_{i=1}^N d_{iN}^H$ $i \neq N$	$\frac{1}{N}\sum_{i,j=1}^N d_{ij}^H$, $i \neq j$

The diagonal elements in the matrix (d_{ii}) contain the spillovers to self, while the off-diagonal elements capture the spillovers from other variables. For the purpose of the analysis here, only the cross-variance decompositions are counted, and self-spillovers are excluded. The last column of the table above provides the total spillovers to variable *i* from all other variables in the model, while the last row contains the total spillovers from variable *j* to all other variables in the system. Thus, the total spillover to each variable i in the VAR is derived as the sum of the off-diagonal elements in the row for that particular variable i, so that the total directional connectedness *from* others to i, $C_{i\leftarrow\bullet}^H$, is

$$C_{i\leftarrow\bullet}^H = \sum_{\substack{j=1 \\ j\neq i}}^N d_{ij}^H \tag{1}$$

Similarly, total spillovers to other variables in the system from each variable j, or $C_{\bullet\leftarrow j}^H$, is the column sum associated with j, excluding self-spillovers, that is,

$$C_{\bullet\leftarrow j}^H = \sum_{\substack{i=1 \\ i\neq j}}^N d_{ij}^H \tag{2}$$

Net spillovers are defined as the difference between (1) and (2). Total interconnectedness, C^H, among the variables in the system is defined as the sum of all the off-diagonal entries of the FEVD, so that

$$C^H = \frac{1}{N}\sum_{\substack{i,j=1 \\ i\neq j}}^N d_{ij}^H \tag{3}$$

Diebold and Yilmaz use the generalized forecast error variance decomposition (GVD) method derived in Pesaran and Shin (1998) to identify the VAR. GVDs have the advantage of being order-invariant unlike Cholesky ordering schemes, which can potentially be arbitrary.[20] GVDs allow for correlated shocks, implying that the H-step ahead variance decomposition matrix $D^{gH} = [d_{ij}^{gH}]$ has entries

$$d_{ij}^{gH} = \frac{\sigma_{jj}^{-1}\sum_{h=0}^{H-1}(e_i'\Theta_h\Sigma e_j)^2}{\sum_{h=0}^{H-1} e_i'\Theta_h\Sigma\Theta_h' e_i} \tag{4}$$

As inputs to the VAR model to estimate the sequence of FEVDs, we use two transformations of the relevant variables: returns and volatility. Returns are defined as the percentage daily change in the closing price of crypto assets and equity indices, excluding trading holidays, while volatility is computed as the standard deviation of absolute percentage changes in intra-day prices (see Table A1). The VAR is estimated over a rolling window of 100 days over two different sample periods: Jan 2017-Dec 2019 and Jan 2020-Nov 2021.

[20] Pesaran, H., and Y. Shin. 1998. "Generalized Impulse Response Analysis in Linear Multivariate Models." *Economic Letters* 58, 17–29.

II. DATA

The variables used in the VAR analysis and the data sources are described in Table A1. All variables are in daily frequency, unless otherwise noted.

Table A1. Variable Description and Data Sources

Variable	Description	Source
Bitcoin-USD	Daily closing price of Bitcoin in US dollars based on direct quote prices and CryptoCompare's volume-weighted index calculation methodology for digital assets	CryptoCompare
Tether-USD	Daily closing price of Tether in US dollars based on direct quote prices and CryptoCompare's volume-weighted index calculation methodology for digital assets	CryptoCompare
Ether-USD	Daily closing price of Ether in US dollars based on direct quote prices and CryptoCompare's volume-weighted index calculation methodology for digital assets	CryptoCompare
S&P 500 Index	Equity index comprised of 500 large-capitalization companies in the United States	Yahoo Finance
Nasdaq Index	Tech-heavy equity index comprised of more than 2,500 common equities in the United States	Yahoo Finance
Russell 2000 Index	Equity index comprised of 2,000 small-capitalization companies in the United States	Yahoo Finance
10-Year Yield	US 10-year sovereign bond yield	Yahoo Finance
VIX Index	30-day expected volatility of the US stock market, based on S&P 500 options	Yahoo Finance
Oil Price Index	Brent crude oil price index	Yahoo Finance
MSCI Emerging Market Index	Equity index with large and mid-cap representation for 27 emerging markets	Yahoo Finance

III. ADDITIONAL RESULTS

Table A2. Crypto-Equity Volatility Spillovers in Emerging Markets

a. Spillovers Matrix: 2017–19 (percent)

	Bitcoin	Tether	S&P 500	Russell 2000	MSCI EM
Bitcoin	95.3	0.0	1.9	0.8	2.0
Tether	0.1	99.6	0.1	0.2	0.1
S&P 500	1.0	0.0	42.6	27.1	29.3
Russell 2000	0.5	0.1	32.0	46.0	21.5
MSCI EM	1.8	0.0	31.8	18.3	48.1

b. Spillovers Matrix: 2020–21 (percent)

	Bitcoin	Tether	S&P 500	Russell 2000	MSCI EM
Bitcoin	51.0	11.1	14.0	16.0	6.9
Tether	25.0	38.4	14.0	15.0	7.9
S&P 500	14.0	5.4	41.0	25.0	15.4
Russell 2000	15.0	4.2	30.0	37.0	13.5
MSCI EM	14.0	4.9	29.0	26.0	25.9

Sources: CryptoCompare; Yahoo Finance; author's calculations.
Notes: The spillovers are based on model estimation using daily volatility data for the time periods January 2017–December 2019 and January 2020–November 2021. In tables a and b, for the i-th row and j-th column in the matrix, the ij-th entry represents the spillover from asset j to asset i, or the percent of forecast error variance of asset i due to shocks from asset j. Rows add up to 100 percent. EM = emerging market.

Table A3. Crypto-Equity Return Spillovers in Emerging Markets

a. Spillovers Matrix: 2017–19 (percent)

	Bitcoin	Tether	S&P 500	Russell 2000	MSCI EM
Bitcoin	99.2	0.1	0.1	0.3	0.3
Tether	0.7	98.2	0.2	0.4	0.6
S&P 500	0.3	0.2	44.4	32.0	23.1
Russell 2000	0.4	0.5	34.3	46.2	18.6
MSCI EM	0.3	0.4	28.0	21.1	50.3

b. Spillovers Matrix: 2020–21 (percent)

	Bitcoin	Tether	S&P 500	Russell 2000	MSCI EM
Bitcoin	67.7	5.0	10.0	8.1	8.9
Tether	4.2	73.6	10.0	5.2	6.9
S&P 500	8.0	5.0	39.0	25.9	22.3
Russell 2000	8.1	3.7	30.0	37.0	20.8
MSCI EM	7.8	4.6	27.0	21.0	39.5

Sources: CryptoCompare; Yahoo Finance; author's calculations.
Notes: The spillovers are based on model estimation using daily returns data for the time periods January 2017–December 2019 and January 2020–November 2021. In tables a and b, for the i-th row and j-th column in the matrix, the ij-th entry represents the spillover from asset j to asset i, or the percent of forecast error variance of asset i due to shocks from asset j. Rows add up to 100 percent. EM = emerging market.