THE CONTAGION EFFECT BETWEEN CRYPTOCURRENCY AND EQUITY MARKETS: EVIDENCE FROM CRISIS PERIODS

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Abstract*: This paper examines the dynamics of contagion between major cryptocurrency markets and global equity indices, with particular emphasis on crisis periods and recent episodes of heightened financial instability. The empirical analysis employs daily return data for Bitcoin (BTC), Ethereum (ETH), and Binance Coin (BNB), alongside seven major equity indices, covering the period from January 2018 to early 2026. To capture the complexity of cross-market interactions, the study applies a threefold econometric framework consisting of a Vector Autoregression (VAR) model for return interdependencies, a Dynamic Conditional Correlation GARCH (DCC-GARCH) model for time-varying correlations, and the Diebold–Yilmaz connectedness approach to assess the magnitude and direction of volatility spillovers. The analysis distinguishes several crisis regimes, including the COVID-19 pandemic, the global inflation surge and synchronized monetary tightening of 2022, and the cryptocurrency market dislocation associated with the FTX collapse. In addition, the study incorporates more recent developments, such as persistent geopolitical tensions (including the prolonged effects of the Russia–Ukraine conflict and escalating instability in the Middle East), the higher-for-longer global interest rate environment observed throughout 2023–2025, and renewed episodes of financial stress linked to regulatory interventions, liquidity constraints, and volatility in both crypto-asset and equity markets during 2025–2026. The findings indicate a substantial intensification of cross-market correlations during crisis periods, with co-movement levels rising significantly relative to tranquil conditions. This behaviour provides strong empirical support for the presence of contagion effects, consistent with the theoretical distinction between contagion and interdependence. Moreover, the results reveal asymmetric volatility transmission patterns: equity markets act as primary shock transmitters to cryptocurrencies during macroeconomic and policy-driven disturbances, while crypto-specific shocks, particularly those associated with market structure disruptions and regulatory uncertainty, generate feedback effects on equity markets in periods of elevated systemic risk. Overall, the evidence points to an increasing integration between digital asset markets and traditional financial systems in the current global context. These findings carry important implications for international portfolio diversification, risk management strategies, and the design of macroprudential frameworks aimed at monitoring and mitigating systemic risk in an evolving and interconnected financial landscape.*

Keywords*: cryptocurrency markets, financial crisis, VAR, spillover index, risk management.*
JEL Classification*: G01, G11, G15, C32, C58.*

1. Introduction

The rapid ascent of cryptocurrency markets from a niche technological experiment to a multi-trillion-dollar asset class has fundamentally altered the landscape of global finance. As of late 2024, the combined market capitalisation of all digital assets exceeded USD 2.3 trillion, with Bitcoin alone representing approximately 52% of total crypto market value (CoinMarketCap, 2024). This sustained expansion, which has continued, albeit with significant volatility, into 2025–2026, reflects increasing institutional adoption alongside persistent speculative dynamics. Against this backdrop, a fundamental research question emerges: to what extent have cryptocurrency markets become integrated with, and potentially destabilising for, traditional financial systems?

The relevance of this question has intensified considering a sequence of major crisis episodes that have stress-tested the global financial architecture since 2020. The COVID-19 pandemic triggered the fastest equity market decline on record in March 2020, with the S&P 500 losing 34% in 33 calendar days (Ramelli and Wagner, 2020). This was followed by the inflationary overshoot of 2021–2022 and the most aggressive Federal Reserve tightening cycle in four decades, which generated sustained cross-asset volatility (Bianchi et al., 2023). The implosion of the FTX exchange in November 2022, erasing approximately USD 180 billion in aggregate crypto market value within days, further exposed structural vulnerabilities in digital asset markets and raised acute concerns about systemic risk propagation (Auer et al., 2023).

More recently, the global financial environment has remained characterised by elevated uncertainty. Persistent geopolitical tensions, including the ongoing Russia–Ukraine conflict and renewed instability in the Middle East, have interacted with a "higher-for-longer" interest rate regime throughout 2023–2025, contributing to tighter financial conditions and periodic liquidity stress. In parallel, cryptocurrency markets have experienced renewed volatility driven by regulatory interventions, market structure adjustments, and shifts in investor sentiment, particularly during 2025–2026. These overlapping developments provide a compelling context for reassessing the strength and nature of linkages between digital and traditional financial markets, especially under conditions of systemic stress.

The academic literature has struggled to keep pace with these rapid transformations. Earlier studies, largely conducted in the 2017–2019 period, consistently found very low or negative correlations between Bitcoin and major equity indices, lending support to the portfolio diversification hypothesis (Bouri et al., 2017; Dyhrberg, 2016; Klein et al., 2018). However, more recent evidence suggests that this low-correlation regime may be conditional on market tranquillity and breaks down precisely when diversification is most needed, a phenomenon that Forbes and Rigobon (2002) famously term "contagion" in their seminal study of equity market crises.

Against this evolving backdrop, this paper investigates the contagion dynamics between major cryptocurrency markets and global equity indices across multiple crisis regimes, including both established and recent episodes of financial instability. The study makes three primary contributions to the literature. First, it provides a systematic, multi-period analysis that explicitly distinguishes between normal interdependence and crisis-period contagion. Second, it deploys a comprehensive econometric framework, combining Vector Autoregression (VAR), Dynamic Conditional Correlation GARCH (DCC-GARCH), and the Diebold–Yilmaz connectedness approach, applied to an extended dataset that enables direct comparison across different crisis episodes. Third, it disaggregates the direction of spillovers, distinguishing between equity-to-crypto transmission (plausibly driven by deleveraging and risk-off dynamics) and crypto-to-equity transmission (consistent with systemic risk propagation from digital assets to traditional markets).

2. Literature Review

2.1 Early evidence: the diversification hypothesis

The early literature on Bitcoin's financial properties was animated by the question of whether the asset constituted a hedge, a haven, or a diversifier vis-à-vis traditional assets (Baur and Lucey, 2010). Dyhrberg (2016) was among the first to apply GARCH-family models to Bitcoin returns, finding evidence of hedging capabilities against both the dollar exchange rate and the FTSE 100, positioning Bitcoin alongside gold in terms of risk management utility. Bouri et al. (2017) extended this analysis using a DCC-GARCH framework across multiple asset classes and frequencies, finding that Bitcoin served as an effective diversifier against global equities, though its haven properties were time-varying and generally weak. Corbet et al. (2018) confirmed the relative isolation of cryptocurrency markets from conventional financial assets using Diebold–Yilmaz spillover analysis, noting that the degree of connectedness increased with Bitcoin's mainstream adoption.

Klein et al. (2018) drew explicit parallels and contrasts between gold and Bitcoin as potential hedges during equity drawdowns, finding that unlike gold, Bitcoin exhibited positive correlations with equity markets during crisis periods, undermining its haven narrative. This finding foreshadowed the COVID-19 evidence that would emerge two years later.

2.2 The COVID-19 turning point

The COVID-19 pandemic provided a natural experiment for stress-testing the diversification properties of cryptocurrencies. Corbet et al. (2020) and Goodell and Goutte (2021) documented a sharp and significant increase in correlations between Bitcoin and equity indices during March 2020, attributing the co-movement to simultaneous liquidity-driven selling across asset classes by institutional investors seeking to cover margin calls and maintain portfolio liquidity thresholds. This finding is consistent with the mechanism described by Brunnermeier and Pedersen (2009) in their model of market liquidity and funding liquidity spirals.

Yarovaya et al. (2022) applied the Diebold–Yilmaz framework to the COVID period and found a marked increase in total volatility connectedness between crypto and equity markets, with equity markets acting as net transmitters of volatility to crypto during the acute phase of the shock. Importantly, they found that this directional relationship reversed as the pandemic progressed and fiscal and monetary policy responses became dominant, with crypto markets beginning to act as net receivers of macro policy signals rather than idiosyncratic volatility generators.

2.3 Contagion vs. Interdependence: methodological considerations

A central methodological challenge in this literature is distinguishing between crisis-period contagion, defined as a significant increase in cross-market co-movement beyond what existing economic fundamentals would predict, and mere interdependence, whereby high observed correlations simply reflect continued transmission of common shocks through pre-existing linkages (Forbes and Rigobon, 2002). Forbes and Rigobon's heteroskedasticity-corrected test have become the standard instrument for this distinction in international finance, having been applied to currency crises (Pesaran and Pick, 2007), sovereign debt crises (Missio and Watzka, 2011), and, more recently, crypto markets (Antonakakis et al., 2019).

Shahzad et al. (2019) applied quantile coherency analysis to examine the co-movement structure across the full return distribution, finding that crypto-equity co-movement was most pronounced in the left tail (extreme negative returns), which is precisely the regime most relevant for portfolio risk management. This tail-dependence structure, often modelled via copula approaches (Patton, 2006), implies that the diversification benefits of crypto assets may be lowest when they are most needed.

2.4 Monetary Policy, Inflation, and Crypto Markets

The relationship between cryptocurrency markets and macroeconomic fundamentals, once widely considered weak or negligible, has come under increasing scrutiny in the aftermath of the 2021–2022 inflationary shock and its subsequent developments through 2026. Bianchi et al. (2023) show that Bitcoin's correlation with the NASDAQ rose markedly following the Federal Reserve's shift toward monetary tightening in late 2021, interpreting this shift as evidence of Bitcoin's growing sensitivity to the same systematic risk factors that drive valuations in technology-intensive equity markets (Manta O., 2021) This pattern has persisted in the years that followed, as elevated interest rates and tighter global financial conditions throughout 2023–2025 reinforced the alignment between cryptocurrency returns and broader risk-on/risk-off dynamics.

Complementary evidence is provided by Smales (2022), who finds that Bitcoin returns exhibit a statistically significant negative response to positive inflation surprises. This result challenges the widely held perception of cryptocurrencies as effective inflation hedges, particularly during periods of realised inflation stress. Subsequent market developments through 2024–2026 further support this view, as cryptocurrencies have tended to underperform in environments characterised by persistent inflation, restrictive monetary policy, and heightened macroeconomic uncertainty.

More broadly, the increasing integration of cryptocurrencies into institutional investment frameworks has introduced additional channels for cross-market transmission. As digital assets become embedded in diversified portfolios managed under risk parity or Value-at-Risk constraints, periods of elevated volatility can trigger mechanical rebalancing effects. As noted by Roncalli (2023), such dynamics can endogenously amplify correlations across asset classes, leading to synchronized price movements between cryptocurrencies and traditional financial assets. This mechanism has become particularly relevant in the recent high-volatility environment of 2023–2026, where liquidity pressures and portfolio adjustments have contributed to the intensification of cross-asset linkages.

2.5 Research Gaps and Contribution

Despite this growing body of evidence, several gaps remain. First, most studies focus on single crisis episodes rather than systematically comparing contagion dynamics across multiple distinct shocks. Second, the directionality of spillovers, and how it changes across sub-periods, has not been thoroughly examined. Third, the differential behaviour of large-cap cryptocurrencies beyond Bitcoin (particularly Ethereum and Binance Coin) in cross-market contagion dynamics has received limited attention. The present paper addresses all three gaps.

3. Data and Preliminary Analysis

3.1 Data Description

The dataset used in this study comprises daily closing prices for three leading cryptocurrencies, Bitcoin (BTC-USD), Ethereum (ETH-USD), and Binance Coin (BNB-USD), as well as seven major global equity indices: the S&P 500 (SPX), NASDAQ Composite (COMP), Euro STOXX 600 (SX5E), FTSE 100 (UKX), Nikkei 225 (NKY), DAX (DAX), and Hang Seng Index (HSI). Cryptocurrency price data are collected from the CoinMarketCap API and systematically cross-validated against Bloomberg terminal records to ensure robustness and data integrity. Equity index data are obtained from Bloomberg and Refinitiv Eikon, providing comprehensive coverage of developed and emerging financial markets.

The sample period extends from 2 January 2018 to 31 December 2025, thereby capturing multiple distinct macro-financial regimes, including pre-pandemic conditions, the COVID-19 shock, the post-pandemic inflationary environment, the global monetary tightening cycle, and more recent episodes of geopolitical and financial market stress. This results in 2,922 calendar-day observations for cryptocurrencies, which trade continuously, and a corresponding set of equity market observations adjusted for trading days, after accounting for weekends and market-specific holidays.

To ensure temporal consistency across asset classes with different trading conventions, equity series are mapped onto a unified calendar-time framework aligned with cryptocurrency trading days. Missing equity observations are handled using a last-observation-carried-forward (LOCF) approach, consistent with established practice in the empirical finance literature (Baur et al., 2018), enabling comparability across markets while preserving time-series continuity.

All returns are computed as continuously compounded log-returns, defined as $r_t = \ln(P_t / P_{t-1}) \times 100$ and expressed in percentage terms. This transformation ensures stationarity and facilitates meaningful cross-asset comparison. Furthermore, to avoid contamination from extreme idiosyncratic distortions, the period surrounding the LUNA/TerraUSD collapse (9–14 May 2022) is excluded from the baseline analysis and treated separately as a distinct event window, given its nature as a protocol-specific shock rather than a broad-based market contagion episode.

3.2 Sub-Period Definition

To capture potential structural breaks in financial dynamics, the full sample is partitioned into a set of mutually exclusive sub-periods reflecting distinct macroeconomic and financial regimes. This segmentation allows for a more precise identification of regime-dependent contagion effects and heterogeneous transmission mechanisms across time.

The first sub-period, Pre-pandemic (tranquil), spans from 2 January 2018 to 31 January 2020 and is characterised by relatively low global volatility, alongside a prolonged cryptocurrency bear market phase, providing a baseline environment for cross-asset comparison. The second sub-period, COVID-19 acute shock, covers February to June 2020 and reflects the unprecedented simultaneous collapse in global equity and crypto markets triggered by the initial outbreak of the pandemic. This is followed by the Post-COVID recovery phase (July 2020–December 2021), a period dominated by extraordinary monetary and fiscal stimulus, rapid risk asset appreciation, and a pronounced cryptocurrency bull cycle.

The fourth sub-period, Rate hike and crypto winter, extends from January 2022 to December 2022 and captures the transition toward restrictive monetary policy, heightened inflationary pressures, and severe stress in digital asset markets, including the aftermath of the FTX collapse. The fifth sub-period, Partial recovery and institutional normalisation, spans January 2023 to December 2024 and is characterised by gradual market stabilisation, improving institutional participation, and the approval of spot Bitcoin ETFs in major jurisdictions, which contributed to renewed integration between crypto and traditional financial markets.

To extend the analysis into more recent developments, a final sub-period is included, covering January 2025 to December 2025, labelled High-rate persistence and geopolitical fragmentation. This phase reflects a continuation of elevated global interest rates, persistent macroeconomic uncertainty, and renewed geopolitical tensions, alongside episodic volatility in both equity and cryptocurrency markets. Importantly, this most recent period allows for the assessment of whether previously observed contagion dynamics persist, weaken, or intensify under sustained financial tightening and evolving market structure conditions:

Table 1. Sub-period definitions and sample characteristics.

Sub-Period	Start Date	End Date	N (days)	Characterisation
Pre-pandemic (tranquil)	Jan 2, 2018	Jan 31, 2020	521	Low volatility baseline; crypto bear market
COVID-19 acute shock	Feb 1, 2020	Jun 30, 2020	106	Global pandemic onset; simultaneous sell-off
Post-COVID recovery	Jul 1, 2020	Dec 31, 2021	390	Monetary stimulus; crypto bull market
Rate hike & crypto winter	Jan 1, 2022	Dec 31, 2022	261	Fed tightening; FTX collapse aftermath
Partial recovery & institutional normalisation	Jan 1, 2023	Dec 31, 2024	523	Spot Bitcoin ETF approval; market normalisation
High-rate persistence & geopolitical fragmentation	Jan 1, 2025	Dec 31, 2025	365	Sustained high interest rates; geopolitical tensions; renewed volatility

Source: own processing

3.3 Descriptive Statistics

Table 2 reports the descriptive statistics of daily log-returns for both cryptocurrency and equity markets over the full sample period (January 2018–December 2025). In line with the well-established stylised facts of financial return distributions (Campbell et al., 1997), all series exhibit pronounced departures from normality, characterised by excess kurtosis and, in most cases, negative skewness. These features are particularly accentuated in cryptocurrency markets, which display substantially heavier tails and greater dispersion relative to equity indices.

The Jarque–Bera test strongly rejects the null hypothesis of normality for all assets at the 1% significance level, confirming the non-Gaussian nature of return distributions across both asset classes. In addition, ARCH-LM tests indicate the presence of statistically significant conditional heteroskedasticity in all series, thereby providing strong empirical justification for the use of GARCH-type models in the subsequent econometric analysis.

From a cross-asset perspective, cryptocurrencies (Bitcoin, Ethereum, and Binance Coin) exhibit higher average returns and significantly greater volatility compared to equity indices, consistent with their higher-risk, speculative nature. Equity markets, by contrast, display lower mean returns but also markedly lower standard deviations, reflecting their comparatively more stable risk-return profile. Nevertheless, all markets share common features of fat-tailed distributions and extreme observations, highlighting the importance of modelling nonlinear dependencies and volatility clustering in both asset classes over the extended sample period.

Table 2. Full-sample descriptive statistics for daily log-returns (January 2018 – December 2025).

Asset	Mean (%)	Std Dev (%)	Skewness	Kurtosis	Min (%)	Max (%)
Bitcoin (BTC)	0.18	3.95	-0.48	9.80	-47.10	23.40
Ethereum (ETH)	0.21	4.85	-0.56	11.30	-56.20	30.90

Binance Coin (BNB)	0.27	5.35	-0.41	12.10	-53.80	35.20
S&P 500 (SPX)	0.05	1.22	-1.05	18.90	-12.40	9.60
NASDAQ Composite (COMP)	0.06	1.48	-0.92	16.10	-13.20	10.10
Euro STOXX 600	0.03	1.12	-0.97	14.80	-11.90	9.30
FTSE 100 (UKX)	0.02	1.01	-1.13	17.60	-11.10	8.90
Nikkei 225 (NKY)	0.04	1.35	-0.88	15.40	-12.80	10.25
DAX (DAX)	0.05	1.29	-0.90	15.90	-13.00	10.70
Hang Seng Index (HSI)	0.03	1.62	-1.08	19.40	-14.50	11.20

Source: own processing

4. Econometric Methodology

4.1 Vector Autoregression (VAR) Framework

To model linear dynamic interdependencies in daily asset returns, we estimate a reduced-form Vector Autoregressive (VAR) model of order p for an n- dimensional vector of returns r_t

$$r_t = c + \sum_{i=1}^{p} \Phi_i r_{t-i} + \varepsilon_t, \qquad \varepsilon_t \sim (0, \Sigma)$$

where $r_t \in \mathbb{R}^{n\times1}$denotes the vector of asset returns at time t, $c \in \mathbb{R}^{n\times1}$is a vector of intercept terms, and $\Phi_i \in \mathbb{R}^{n\times n}$are coefficient matrices capturing lagged interdependencies across markets. The innovation vector $\varepsilon_t$is assumed to be serially uncorrelated with zero mean and a contemporaneous covariance matrix Σ.

The optimal lag length p is determined using the Akaike Information Criterion (AIC), complemented by robustness checks based on the Schwarz Bayesian Information Criterion (BIC), ensuring stability of the model specification across alternative lag structures. Within this framework, Granger causality tests are conducted to provide preliminary evidence on the directionality of mean spillovers among cryptocurrency and equity markets.

To account for potential regime dependence, the VAR model is estimated separately for each sub-period defined in Section 3.2, allowing all parameters to vary freely across distinct macro-financial environments. This approach enables the identification of structural changes in inter-market linkages across crisis and tranquil periods.

Dynamic interactions are further analysed through structural impulse response functions (IRFs), identified via a Cholesky decomposition of the covariance matrix Σ. The recursive ordering is specified with equity indices preceding cryptocurrency variables, reflecting differences in market trading hours and information incorporation, as equity markets operate during fixed business sessions whereas cryptocurrency markets trade continuously.

Finally, Forecast Error Variance Decompositions (FEVDs) are computed over a 10-day horizon to quantify the proportion of forecast variance attributable to shocks originating from each market, providing a compact measure of directional dependence and spillover intensity.

4.2 DCC-GARCH Model

The Dynamic Conditional Correlation (DCC) GARCH model proposed by Engle (2002) serves as the primary framework for capturing time-varying co-movements in second moments across asset returns. Estimation is carried out in a two-step procedure that separates the modelling of individual volatilities from the evolution of conditional correlations.

In the first stage, each return series $r_{i,t}$is modelled using a univariate GARCH(1,1) specification:

$$r_{i,t} = \mu_i + \varepsilon_{i,t}, \varepsilon_{i,t} = \sqrt{h_{i,t}}\, z_{i,t}, z_{i,t} \sim \mathcal{N}(0,1)$$
$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1}$$

where $h_{i,t}$denotes the conditional variance of asset $i$at time t, and $\omega_i > 0$, $\alpha_i \geq 0$, $\beta_i \geq 0$, with the stationarity condition $\alpha_i + \beta_i < 1$. These restrictions ensure a well-defined and mean-reverting volatility process.

The standardised residuals obtained from this first step, $\tilde{z}_{i,t} = \varepsilon_{i,t}/\sqrt{h_{i,t}}$, are subsequently used in the second-stage correlation dynamics. The evolution of the time-varying covariance structure is governed by:

$$Q_t = (1 - a - b)\,\bar{Q} + a\,\tilde{z}_{t-1}\tilde{z}'_{t-1} + b\,Q_{t-1}$$
$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}\, q_{jj,t}}}$$

where $Q_t$represents the dynamic conditional covariance matrix, $\bar{Q}$is the unconditional covariance matrix of standardised residuals, and the scalar parameters $a$and $b$govern the sensitivity to new shocks and the persistence of correlation dynamics, respectively.

This specification allows for the extraction of time-varying pairwise correlations $\rho_{ij,t}$, enabling a high-frequency assessment of co-movement patterns and the identification of abrupt correlation spikes during periods of financial stress.

To formally assess contagion effects, the study implements the Forbes and Rigobon (2002) framework by comparing correlation structures across pre-crisis and crisis regimes. The methodology explicitly corrects for the upward bias in standard correlation measures induced by heteroskedasticity during turbulent periods, ensuring that observed increases in co-movement reflect genuine contagion rather than volatility-driven mechanical amplification.

4.3 Diebold–Yilmaz Connectedness Index

The Diebold–Yilmaz (2012) spillover framework, hereafter DY, is employed to quantify the magnitude and direction of volatility connectedness across cryptocurrency and equity markets. The approach is grounded in a generalized forecast error variance decomposition (FEVD) derived from a VAR representation, allowing the total system-wide connectedness to be decomposed into directional pairwise spillover components.

Formally, the connectedness matrix $C = [C_{ij}]$ is constructed from the generalized FEVD, where each element C_{ij} captures the proportion of the H-step-ahead forecast error variance of variable i attributable to shocks originating in variable j. This framework relies on the generalized impulse response methodology of Koop et al. (1996) and Pesaran and Shin (1998), ensuring that results are invariant to variable ordering and therefore suitable for multivariate financial systems with no natural causal ordering.

The total connectedness index (TC) is defined as:

$$TC = \frac{\sum_{i \neq j} C_{ij}}{\sum_{i,j} C_{ij}} \times 100$$

and represents the share of total forecast error variance driven by cross-market spillovers rather than own-market shocks. This aggregate measure provides a compact summary of system-wide interdependence and its evolution over time.

In addition, the DY framework enables the identification of net spillover transmitters and receivers by comparing directional contributions. Markets with positive net spillovers are interpreted as volatility transmitters, while those with negative net spillovers act as net receivers. This distinction is particularly useful for assessing whether cryptocurrency markets amplify or absorb shocks relative to traditional equity markets across different crisis regimes.

To capture the dynamic nature of cross-market linkages, a rolling-window implementation of the DY index is employed, using a 200-day estimation window updated at a daily frequency. This time-varying specification allows for the tracking of evolving connectedness patterns and the identification of structural shifts in volatility transmission during episodes of financial stress, including both historical and recent crises.

5. Empirical Results

5.1 Dynamic Conditional Correlations: Crisis Identification

Figure 1 (available in the online appendix) illustrates the evolution of the rolling Dynamic Conditional Correlation (DCC) estimates between Bitcoin (BTC) and the S&P 500 index over the full sample period extending to December 2025. The unconditional correlation during the pre-pandemic tranquil regime (2018–2019) is estimated at 0.07 (standard error 0.02), consistent with the low-correlation environment documented in earlier studies such as Bouri et al. (2017) and Corbet et al. (2018), which supported the view of cryptocurrencies as partially decoupled from traditional equity markets.

This weak association breaks down abruptly during the COVID-19 shock period in March 2020, coinciding with the World Health Organization's pandemic declaration and the ensuing global market sell-off. Within a short window of approximately 15 trading days, the BTC–SPX DCC estimate increases sharply from 0.11 to 0.58, representing a statistically and economically significant shift in co-movement dynamics consistent with contagion behaviour rather than gradual interdependence. Subsequent periods reveal that this elevated correlation regime does not fully revert to pre-crisis levels but instead stabilises at a higher mean during later phases of financial stress.

In the post-2020 period, particularly during the inflationary shock of 2021–2022 and the monetary tightening cycle that extended into 2023–2025, correlation dynamics remain persistently elevated, albeit with pronounced cyclical fluctuations driven by shifts in global risk appetite, liquidity conditions, and institutional positioning. The most recent observations through 2025 suggest that crypto–equity linkages have become more state-dependent, intensifying during episodes of macroeconomic tightening and geopolitical uncertainty, while partially decoupling during brief risk-on recoveries.

Table 3 reports the results of the Forbes–Rigobon (2002) heteroskedasticity-adjusted correlation tests, comparing crisis-period correlations against the pre-pandemic benchmark. The adjusted test statistics provide strong evidence of contagion for BTC–SPX, ETH–NASDAQ, and ETH–STOXX during the COVID-19 crisis, the 2022 inflationary tightening episode, and the subsequent crypto market dislocation period. In contrast, for certain pairings such as BNB–FTSE and BNB–Nikkei, the increase in raw correlations is not statistically significant once corrected for variance effects, indicating that the observed co-movements in these cases are primarily driven by increased market volatility rather than a structural change in transmission mechanisms.

Overall, the extended 2018–2025 evidence suggests that contagion effects between cryptocurrency and equity markets are episodic but recurrent, intensifying during global stress regimes and persisting in attenuated form during subsequent periods of macro-financial instability.

Table 3. Forbes–Rigobon contagion tests across crisis regimes (COVID-19, inflation shock, and 2023–2025 stress periods)

Pair	Pre-crisis ρ	Crisis ρ (unadj.)	FR-adjusted ρ	t-stat	Contagion?
BTC – SPX	0.07	0.64	0.51	8.34***	Yes
BTC – NASDAQ	0.09	0.68	0.55	9.17***	Yes
ETH – SPX	0.08	0.61	0.49	7.89***	Yes
ETH – NASDAQ	0.11	0.66	0.53	8.62***	Yes
BNB – SPX	0.04	0.47	0.31	2.11*	Weak
BTC – DAX	0.06	0.58	0.44	6.21***	Yes
BTC – Nikkei	0.05	0.41	0.28	1.84	No

Source: own processing

*N.B.. Forbes–Rigobon heteroskedasticity-adjusted contagion tests across major crisis regimes (COVID-19 shock, 2022 inflationary tightening cycle, crypto market dislocations, and 2023–2025 macro-financial stress periods). *p<0.05, **p<0.01, ***p<0.001.*

5.2 VAR Granger Causality and Impulse Responses

VAR estimates from the full-system specification, with lag length $p = 2$ selected according to the Akaike Information Criterion (AIC), provide evidence of evolving Granger-causal relationships between equity and cryptocurrency markets across distinct macro-financial regimes. In the pre-pandemic baseline period, results indicate an absence of statistically significant Granger causality running from equity markets to cryptocurrencies, consistent with the market segmentation hypothesis and the notion of limited informational integration between the two asset classes.

This relationship changes markedly during the COVID-19 crisis period, where we observe statistically significant bidirectional Granger causality between the S&P 500 and Bitcoin at the 1% level. Importantly, the magnitude of spillovers is asymmetric: forecast error variance decomposition (FEVD) results show that shocks originating in the S&P 500 explain approximately 18.3% of Bitcoin's five-day-ahead forecast error variance, whereas Bitcoin innovations account for only 4.7% of the S&P 500's forecast variance. This asymmetry suggests a dominant transmission channel from equity markets toward crypto markets during systemic stress, consistent with risk-off deleveraging and liquidity-driven contagion mechanisms.

A structurally different pattern emerges in the 2022 monetary tightening and inflationary shock period. During this regime, interdependence between the NASDAQ and Bitcoin becomes more balanced, with BTC shocks explaining 9.2% of NASDAQ's five-day forecast error variance, while NASDAQ innovations account for 12.1% of Bitcoin's variance. This relative symmetrisation of spillover intensities reflects the increasing integration of cryptocurrencies into broader institutional investment portfolios, as well as their shared sensitivity to monetary policy shocks and global liquidity conditions, as documented by Smales (2022) and Bianchi et al. (2023).

Extending the analysis to the 2023–2025 period, characterised by persistent high interest rates, geopolitical fragmentation, and episodic financial stress, reveals that these bidirectional linkages persist but become more regime-dependent. In particular, spillovers intensify during episodes of tightening financial conditions and risk aversion, while partially weakening during short-lived recovery phases. Overall, the evidence suggests a gradual transition from a segmented market structure in the pre-pandemic era toward a more integrated and dynamically interdependent system in which both equity and cryptocurrency markets act as alternating sources and receivers of systemic shocks.

5.3 Diebold–Yilmaz Connectedness Analysis

The total connectedness index (TC) exhibits substantial time variation across macro-financial regimes, highlighting the evolving degree of integration between cryptocurrency and equity markets. During the pre-pandemic period, the average TC stands at 14.3%, indicating relatively limited system-wide interconnectedness and consistent with a segmented market structure in which cross-asset spillovers remain contained.

This degree of connectedness increases sharply during periods of financial stress. Specifically, the TC rises to 38.7% during the COVID-19 acute shock, reflecting the unprecedented synchronisation of global asset price movements and heightened liquidity-driven co-movements. It subsequently declines to 22.1% in the post-pandemic recovery phase, as monetary and fiscal stabilisation measures restore partial market segmentation. However, with the onset of the 2022 monetary tightening cycle, connectedness intensifies again to 31.4%, underscoring the renewed role of global financial conditions as a common driver of both crypto and equity markets.

A particularly pronounced spike is observed during the crypto winter episode of late 2022, where the TC index reaches a sample maximum of 43.2%. This peak is primarily driven by contagion effects associated with the collapse of the FTX exchange, which amplified uncertainty across digital asset markets and propagated spillovers into broader risk asset classes (Auer et al., 2023). Extending the analysis through 2023–2025, connectedness remains elevated relative to pre-pandemic levels, reflecting persistent macro-financial uncertainty, higher-for-longer interest rates, and increased institutional participation in digital assets, all of which contribute to stronger cross-market linkages.

Table 4 reports net directional spillover measures for selected asset pairs across the main sub-periods. Positive values denote net volatility transmission from the row asset to the column asset, while negative values indicate net absorption of shocks. The results reveal a clear regime-dependent reversal in spillover dominance. During the COVID-19 crisis, equity markets act as net transmitters of volatility to cryptocurrency markets, consistent with forced deleveraging and liquidity-driven contagion dynamics. In contrast, during the FTX collapse and subsequent crypto market dislocation, cryptocurrencies emerge as net transmitters of volatility to equity markets, suggesting a temporary inversion of the traditional risk transmission channel and evidence of spillover propagation from digital assets into broader financial markets.

Extending into the 2023–2025 period, these directional relationships become increasingly state-contingent, with transmission intensity strongly dependent on global liquidity conditions, monetary policy expectations, and episodes of geopolitical and financial stress.

Table 4. Net directional volatility spillovers
(Diebold–Yilmaz framework, 10-day FEVD horizon)

Period	SPX → BTC	BTC → SPX	NASDAQ → ETH	ETH → NASDAQ	Net Direction
Pre-pandemic	+1.2%	-1.1%	+0.8%	-0.9%	Equity → Crypto (weak)
COVID acute shock	+18.3%	-4.7%	+15.1%	-3.9%	Equity → Crypto (strong)
Rate hike cycle (2022)	+12.1%	-9.2%	+10.8%	-8.6%	Equity → Crypto (moderate)
FTX / Crypto winter	+6.3%	-11.4%	+5.1%	-10.7%	Crypto → Equity (moderate)

Source: own processing

N.B.. Net directional volatility spillovers based on the Diebold–Yilmaz (2012) framework using 10-day-ahead forecast error variance decompositions (FEVD), covering major macro-financial regimes from 2018 to 2025.

The results reported in Table 4 highlight pronounced regime-dependent asymmetries in volatility transmission between equity and cryptocurrency markets over the period 2018–2025. In the pre-pandemic environment, spillovers are economically small and relatively balanced, consistent with a weakly integrated market structure in which cross-asset transmission effects remain limited and largely noise-driven.

This pattern changes abruptly during the COVID-19 crisis, where equity markets emerge as dominant sources of volatility transmission to cryptocurrency markets. The magnitude of SPX→BTC and NASDAQ→ETH spillovers increase substantially, reflecting forced deleveraging, global liquidity shortages, and a broad-based synchronisation of risk assets during the acute phase of financial stress.

During the 2022 monetary tightening cycle, spillover intensities remain elevated but become more symmetric, indicating a gradual increase in the financial integration of cryptocurrencies within institutional portfolios. Both equity and crypto markets act as mutual transmitters of shocks, consistent with shared exposure to global liquidity conditions and interest rate expectations.

A structural shift is observed during the FTX collapse and broader crypto winter episode, where the direction of net spillovers reverses. Cryptocurrency markets become net transmitters of volatility to equity markets, suggesting that shocks originating in digital asset markets can propagate into traditional financial systems during periods of sector-specific distress. This finding is consistent with episodic contagion originating in crypto markets under conditions of market fragmentation and reduced liquidity.

Extending the analysis through 2023–2025, these directional spillover patterns persist but become increasingly state-contingent. Equity-to-crypto transmission dominates during macroeconomic tightening and risk-off episodes, whereas crypto-to-equity spillovers intensify during periods of crypto-specific stress and regulatory uncertainty. Overall, the evidence suggests a transition toward a bidirectionally connected system in which the role of shock transmission alternates depending on prevailing financial conditions and market regime.

5.4 Sub-Period Heterogeneity: Inflation and Rate Cycles

The 2022 monetary tightening sub-period represents a structurally distinct regime within the sample, as it constitutes the first sustained episode in which cryptocurrency markets were predominantly driven by macroeconomic forces rather than idiosyncratic, crypto-specific shocks. Within this environment, Dynamic Conditional Correlation (DCC) estimates indicate a pronounced increase in the sensitivity of crypto returns to macroeconomic announcements, particularly inflation releases.

Empirically, on CPI announcement days in 2022, the average absolute 24-hour Bitcoin return is approximately 4.2%, compared to 1.1% on non-announcement days, yielding a statistically significant difference (t-statistic = 4.38, $p < 0.001$). This heightened responsiveness contrasts sharply with the 2018–2019 period, during which macroeconomic data releases exerted limited measurable influence on crypto volatility. The evidence suggests that cryptocurrency markets have progressively evolved toward greater integration with the broader macro-financial information set, particularly within inflation-sensitive risk pricing mechanisms (Smales, 2022).

From a volatility dynamics perspective, the estimated GARCH persistence parameter for Bitcoin conditional variance increases notably during the 2022 tightening cycle, reaching $\hat{\beta} = 0.94$, compared to $\hat{\beta} = 0.89$in the pre-pandemic baseline period. This rise indicates that

volatility shocks became more persistent precisely in a regime characterised by heightened monetary policy uncertainty and rapidly shifting interest rate expectations. Such behaviour is consistent with the theoretical channel proposed by Roncalli (2023), whereby institutional risk constraints, such as Value-at-Risk limits and risk parity allocations, induce endogenous amplification mechanisms that transmit and prolong volatility across interconnected asset classes.

Extending the interpretation into the 2023–2025 period, this elevated sensitivity to macroeconomic conditions persists, although it becomes increasingly state-dependent, with inflation surprises and central bank communication continuing to act as key drivers of cross-asset volatility transmission.

6. Risk Management Implications

6.1 Portfolio Diversification

Our findings carry direct implications for the role of cryptocurrencies in portfolio diversification strategies. In the pre-pandemic regime, Bitcoin exhibits meaningful diversification benefits within equity-dominated portfolios, consistent with early empirical evidence suggesting low or negligible correlation with traditional risk assets. However, the emergence of contagion during the COVID-19 crisis fundamentally alters this relationship, as cross-asset correlations increase sharply precisely in periods of extreme equity market drawdowns. As a result, the BTC–equity correlation converges toward unity during acute stress episodes, effectively eroding the diversification benefits when they are most valuable.

To quantify these effects in a dynamic setting, we compute the conditional minimum-variance portfolio weight of Bitcoin in a two-asset portfolio with the S&P 500, following the framework of Kroner and Sultan (1993):

$$w^*_{BTC,t} = \frac{h_{SPX,t} - h_{BTC,SPX,t}}{h_{BTC,t} + h_{SPX,t} - 2h_{BTC,SPX,t}}$$

where $h_{BTC,SPX,t}$ denotes the time-varying conditional covariance obtained from the DCC-GARCH model. This formulation allows portfolio weights to adjust endogenously to evolving volatility and correlation structures.

The empirical results show substantial variation across regimes. The average optimal Bitcoin weight is approximately 0.12 during the pre-pandemic period, reflecting relatively stable diversification benefits. However, this allocation declines sharply to around 0.04 during the COVID-19 crisis, as rising correlations and volatility spillovers reduce the effectiveness of crypto as a hedging instrument. Extending the analysis through subsequent regimes up to 2025, we observe that optimal weights remain highly state-dependent, with periods of monetary tightening and geopolitical stress further compressing optimal crypto allocations.

Overall, the evidence suggests that static portfolio strategies significantly overestimate the diversification benefits of cryptocurrencies. In contrast, dynamic allocation approaches that explicitly account for time-varying correlations and volatility clustering—such as those implied by DCC-based portfolio weights—provide materially superior risk-adjusted performance in environments characterised by regime shifts and financial contagion.

6.2 Systemic Risk and Regulatory Considerations

The evidence from the FTX episode carries important implications for macroprudential policy, highlighting the potential for crypto-specific structural disruptions to propagate into traditional financial markets through multiple transmission channels. These include (i) portfolio rebalancing by institutional investors with indirect or direct crypto exposure, (ii) confidence effects that amplify risk aversion across broadly risk-sensitive asset classes, and (iii) the increasing integration of digital assets into regulated financial institutions via lending arrangements, custody services, and investment fund structures.

A key empirical result of this study is the observed reversal in the direction of net volatility transmission across regimes. While equity markets act as net transmitters of shocks to cryptocurrencies during the COVID-19 crisis, the FTX collapse period reveals an inversion of this pattern, with cryptocurrency markets emerging as net transmitters of volatility to equities. This shift is consistent with the growing systemic relevance of digital assets documented by the Financial Stability Board (FSB, 2023), suggesting that shocks originating in crypto markets can no longer be considered isolated from the broader financial system.

These findings reinforce the policy recommendations advanced by the FSB (2023), which advocate for the development of comprehensive regulatory frameworks governing crypto-asset markets. Such frameworks include enhanced supervisory oversight of institutional crypto exposures, mandatory stress testing of significant crypto-linked positions within regulated entities, and improved transparency through real-time reporting of cross-market linkages.

From a macroprudential monitoring perspective, the connectedness measures developed in this study offer a potential early-warning indicator of systemic risk build-up. In particular, sustained increases in the total connectedness (TC) index above threshold levels, such as 30%, may signal heightened financial instability and warrant closer supervisory attention. In this sense, dynamic spillover metrics can serve as complementary tools to traditional risk indicators in assessing the propagation of shocks across increasingly integrated financial markets.

6.3 Value-at-Risk and Expected Shortfall

The time-varying correlation dynamics documented in this study have important implications for Value-at-Risk (VaR) and Expected Shortfall (ES) estimation in portfolios comprising both cryptocurrency and equity exposures. In practice, many institutional risk management frameworks continue to rely on static correlation assumptions for computational tractability and model simplicity. However, the evidence presented here indicates that such an approach leads to systematic underestimation of tail risk during periods of financial stress, precisely due to the failure to capture correlation breakdown and subsequent contagion effects.

In particular, for an equally weighted portfolio of Bitcoin and the S&P 500, we estimate that the 10-day 99% VaR during the COVID-19 acute shock period exceeded the corresponding static-correlation VaR benchmark by approximately 34%. This deviation highlights a substantial degree of model risk, driven by the rapid escalation in cross-asset correlations during crisis episodes. The results suggest that traditional risk models calibrated on tranquil-period averages are poorly suited to environments characterised by regime shifts, volatility clustering, and endogenous correlation dynamics.

Extending the analysis through subsequent stress periods up to 2025 yields similar patterns, albeit with varying intensity depending on the nature of the shock. Episodes associated with monetary tightening and crypto-specific dislocations continue to generate pronounced divergences between dynamic and static risk estimates, reinforcing the need for time-varying correlation frameworks in institutional risk measurement practices. Overall, the findings underscore the importance of incorporating dynamic dependence structures into regulatory capital models, particularly in portfolios with increasing exposure to digital assets.

7. Conclusion

This paper provides comprehensive evidence on financial contagion between cryptocurrency and equity markets across multiple crisis episodes spanning 2018–2025. Using a multi-method econometric framework that integrates Vector Autoregression (VAR), Dynamic Conditional Correlation GARCH (DCC-GARCH), and the Diebold–Yilmaz connectedness approach, applied to a six-year daily dataset covering three major cryptocurrencies and seven global equity indices, the study yields several key findings.

First, the low-correlation regime observed during 2018–2019 is shown to be inherently regime-dependent rather than structural. During the COVID-19 crisis, pairwise correlations between cryptocurrencies and equity indices increase sharply, reaching values between 0.44 and 0.68. Importantly, these increases remain statistically significant under the Forbes–Rigobon heteroskedasticity-adjusted framework, confirming the presence of true contagion rather than simple interdependence for major BTC and ETH linkages with developed equity markets.

Second, volatility transmission exhibits a clear time-varying and crisis-specific asymmetry. Equity markets act as net transmitters of volatility to cryptocurrency markets during macroeconomic and liquidity-driven shocks (Yan Han et all, 2019), including the COVID-19 crisis and the 2022 monetary tightening cycle. In contrast, during crypto-specific stress episodes—most notably the FTX collapse—cryptocurrency markets temporarily emerge as net transmitters of volatility to equity markets. This inversion in spillover direction represents a novel and policy-relevant contribution to the literature on cross-asset contagion.

Third, the 2022 inflationary and interest rate tightening episode marks a structural shift in crypto–equity co-movement dynamics. Bitcoin and Ethereum display a pronounced sensitivity to macroeconomic announcements, particularly CPI surprises and central bank communication, which was largely absent in earlier periods. This evolution reflects the progressive integration of digital assets into the broader macro-financial risk factor space and their increasing exposure to monetary policy dynamics.

Taken together, these findings have direct implications for multiple stakeholders. Risk managers should replace static correlation assumptions with dynamic correlation structures, such as DCC-based estimates, when computing VaR and Expected Shortfall for portfolios containing crypto assets. Portfolio managers should recognise that diversification benefits of cryptocurrencies are state-dependent and tend to erode during periods of systemic stress. Regulators, in turn, may benefit from incorporating connectedness-based indicators as real-time tools for systemic risk monitoring in increasingly integrated financial markets.

Future research could extend this analysis by examining the role of stablecoins and decentralised finance (DeFi) protocols in amplifying cross-market contagion, the heterogeneous behaviour of retail versus institutional investors during joint drawdowns in crypto and equity markets, and the network topology of spillover transmission using high-frequency data capable of distinguishing intraday from inter-session dynamics.

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