DOI: https://doi.org/10.47703/2789-8253-2026-2-24-36

ORIGINAL ARTICLE

EURASIAN JOURNAL OF ECONOMIC & BUSINESS STUDIES

Volatility Spillovers in the Economics of Cryptocurrencies and Financial Markets

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SCSTI: 06.73.75
JEL Code: G17, G15, C32

Received: 3 March 2026
Revised: 17 April 2026
Accepted: 12 May 2026
Published: 30 June 2026

Conflict of interest:
author(s) declare that there is no conflict of interest

Abstract
With the increasing role of cryptocurrencies in the global financial system, the analysis of the mechanisms by which volatility transfers between digital and traditional assets is becoming particularly relevant. The purpose of the study is to assess the degree, directions, and temporal variability of volatility spillovers between Bitcoin, leading cryptocurrencies, and traditional financial instruments. Using daily data and both static and rolling-window estimates, the analysis assesses how shocks to volatility are transmitted between cryptocurrency and macro-financial markets. The results of the study showed that the Total Spillover Index (TSI) in the static model is 28.37%, while in the dynamic model it reaches an average of 35.9%, with peak values up to 45.25% in 2022. It has been established that Bitcoin acts as a net transmitter of volatility: the average level of transmitted effects is 60.31%, received effects are 50.59%, and the net spillover is +9.72%. Moreover, Bitcoin's place in the network is state-dependent to some extent: while it acts as a net transmitter in the average, speculative episodes in alternative cryptocurrencies can cause Bitcoin to act as a receiver of volatility shocks. The results indicate a high degree of internal connectivity in the cryptocurrency market, with limited integration with the traditional financial system, and a pronounced temporary variability in the structure of volatility interactions. These findings have implications for portfolio diversification, risk management, and the ongoing integration of digital assets into the global financial system.

KEYWORDS
Volatility, Volatility Transmission, Bitcoin, Risk, Cryptocurrency, Digital Economy, Financial Economics

1 | INTRODUCTION

In the last decade, cryptocurrency markets have experienced rapid growth and become a more visible part of the global financial system. Digital assets have transformed from a niche technical experiment into a multi-hundred-billion-dollar asset class, with massive capitalization, growing institutional interest, and frenetic trading since the launch of Bitcoin in 2009. However, this transformation has generated considerable interest among researchers and policymakers who are keen to understand how cryptocurrencies relate to traditional financial markets and whether they pose additional systemic risk.

At the heart of this discussion is volatility. In financial economics, volatility is interpreted as a proxy for uncertainty and the vehicle through which shocks are transmitted between markets. For decades, empirical studies on traditional asset classes have documented the existence of volatility spillovers between equity indices, commodities and cross-currency markets (Guchar et al., 2020), especially so during periods of financial stress. The emergence of cryptocurrencies raises a natural question: do volatility shocks originating in digital asset markets remain largely internal to the crypto ecosystem, or do they propagate more widely to conventional financial assets?

Bitcoin occupies an especially critical place in this debate. The largest and most liquid cryptocurrency, it is often viewed as the benchmark asset in the digital currency market. The empirical literature thus far primarily finds significant contagion across major cryptocurrencies, with Bitcoin often being found to act in transmission of price volatility to other cryptocurrencies. However, the impact of these volatility shocks on other assets in the market remains unknown. Certain studies indicate that cryptocurrencies are merely weakly integrated with conventional financial assets, including gold or foreign exchange rates, whereas others claim that an increasing institutional participation could successively tighten these interrelations across distinct markets.

An additional layer that has garnered growing interest concerns the time-varying nature of market connectedness. Volatility spillovers cannot remain stable over time. Rather, the wave of attention varies between different market regimes. Accordingly, periods of financial stress are commonly associated with increased interdependence among assets; hence, static measures of connectedness may miss structural shifts in volatility transmission.

In this context, the current research investigates volatility spillovers between Bitcoin, leading alternative cryptocurrencies, and some macro-financial drivers. The study employed the connectedness approach, using generalized forecast-error variance decomposition within the context of a Vector Autoregression (VAR) model. To differentiate average spillover relationships from time-varying dynamics, the research perform both static and rolling-window estimations. The use of a rolling analysis highlights periods when volatility transmission increases and whether Bitcoin's role as a shock transmitter or receiver varies with market conditions.

The paper has three key contributions. First, it adds to the existing literature on volatility connectedness by utilizing a much larger dataset that incorporates more recent bouts of turbulence in cryptocurrency markets. Second, the analysis enhances understanding of volatility transmission dynamics over time by applying static and dynamic measures of connectedness. Third, the analysis assesses the structural stability of spillover measures, enabling us to disentangle temporary spikes in connectedness from more permanent structural changes in market ties. Understanding these dynamics has practical implications for investors, portfolio managers, and policymakers. If cryptocurrencies are tightly integrated with the traditional financial markets, shocks to digital asset classes could propagate systemic risk in the wider financial system. On the contrary, weak cross-market spillovers imply that cryptocurrencies are partially segmented and they may still serve as diversifiers. It adds to the debate about the financial function and systemic importance of these digital assets by investigating both intra-cryptocurrency and cross-market volatility transmission.

2 | LITERATURE REVIEW

The rapid development of cryptocurrency markets has prompted extensive and diverse literature on return behavior, volatility dynamics, and correlations between digital assets and traditional financial markets. As the market capitalization of cryptocurrencies grew and institutional participation in the asset class increased, academics have taken greater notice of whether these new assets remain separate from conventional financial systems or have integrated into broader market structures (Adelopo & Luo, 2025; Polat, 2023). From the standpoint of risk management and financial stability, it is particularly important to understand how volatility transmits across such markets (Wu et al., 2024; Mensi et al., 2025).

Most of the initial empirical work was thus primarily concerned with the statistical properties of cryptocurrency returns. These studies provide a consistent record of characteristics, including volatility clustering, heavy-tailed distributions, and strong persistence; features observed in traditional financial time series data but often to more extreme degrees in cryptocurrency markets. Because of this, many researchers have adopted conditional heteroskedasticity models, such as GARCH-type specifications, over time in the study of cryptocurrency volatility. Katsiampa (2019), for instance, demonstrates that Bitcoin exhibits delayed volatility clusters with significant persistence and responds quickly to information entering the market. Compared with equities, commodities, or foreign exchange rates, the cryptocurrency markets have experienced significantly greater unconditional volatility due to speculative trading, and they are at an earlier stage of market development.

With the maturation of the cryptocurrency market, empirical studies have begun to pay more attention to interconnectedness and contagion effects. The number of studies exploring whether shocks originating in cryptocurrencies could spill over into other financial assets and vice versa began to grow. Previous contributions are typically based on multivariate GARCH-type settings to analyze the transmission of volatility and contagion effects. Though useful, these methods struggle to capture the nonlinearities and intricacies that need to be studied across markets.

Consequently, recent studies have adopted broader methodological approaches. Different approaches like wavelet coherence, cross-quantilogram analysis, and multifractal detrended cross-correlation analysis have been applied to study the nonlinear and time-varying dependence structures between cryptocurrencies versus other asset classes (Kurka, 2019). These techniques enhance researchers' capabilities in investigating spillover dynamics across varying time horizons and market environments, providing a richer understanding of the evolution of volatility interactions during extreme financial conditions (Rehman et al., 2024). With this extensive use of high-frequency data, the literature has also taken a more advanced turn on the empirical side, with new econometric models emerging that allow for time-varying connectedness.

Among the most widely utilized methods in this topic is the connectedness framework proposed by Diebold and Yilmaz (2009, 2012, 2014). This method applies forecast-error variance decomposition based on Vector Autoregression (VAR) models, offering a systematic approach to measuring the size and direction of spillovers between different assets. Overall, applications of the Diebold–Yilmaz framework to cryptocurrency markets find pronounced spillover effects amongst constituents of the digital asset ecosystem. Ji et al. (2019), for instance, document a tendency for Bitcoin to serve as a central transmitter of volatility shocks across crypto networks and find that spillovers are greater during periods of market stress. Corbet et al. (2018) identify similar dynamic interactions between cryptocurrencies and other (non-crypto) financial assets, but the magnitude of cross-market spillovers is relatively small compared with transmission within the cryptocurrency sector.

A key question that arises from this literature is the level of integration (or lack thereof) between cryptocurrency markets and traditional financial assets. A number of studies point toward cryptocurrencies continuing to act, overall, as a separate asset class. Bouri et al. (2017), for example, assess Bitcoin's potential hedge and safe-haven properties and find limited evidence that it consistently protects investors during periods of financial distress. Other empirical studies find relatively low correlations between cryptocurrencies and traditional assets such as gold, stocks, and foreign exchange rates. However, such correlations may increase temporarily during crisis periods. From a volatility perspective, the overwhelming evidence suggests that although cryptocurrencies exhibit high levels of internal contagion dynamics, their spillovers to traditional financial markets are relatively unamplified.

Another line of research investigates whether Bitcoin consistently leads the cryptocurrency ecosystem or whether leadership positions change over time. Bitcoin has been identified as the main shock transmitter in a number of studies, which implies, however, that its influence varies over time. In episodes of speculative behavior regarding alternative cryptocurrencies, we estimate volatility spills over from outside Bitcoin and then widens across the overall market. Empirical research considers rolling-window or time-varying-parameter VAR models, demonstrating that regime-dependent dynamics come into play in the context of monetary policy (Félix et al., 2020; Kammoun, 2026). These strategies show that the connectivity structures of cryptocurrency markets can change substantially based on market liquidity, investor behavior, and overall macroeconomic conditions. Evidence from the COVID-19 period suggests, for instance, that volatility spillover tends to increase during periods of global financial stress (Goodell & Goutte, 2021).

Building on this literature, the current study investigates volatility spillovers among Bitcoin, major alternative cryptocurrencies, and selected traditional financial assets. Examining spill-over flows both in a time-variation framework, as well as using static connectedness measures by imposing a rolling-window structure on the analysis. The study also measures the stability of the connectedness structure to assess whether recent increases in spillovers result from transient market volatility or more stable structural shifts in the cryptocurrency ecosystem.

3 | METHODOLOGY

This study investigates the time-varying volatility transmission dynamics between Bitcoin and selected financial assets using daily observations from 11 January 2018 to 22 August 2025. The sample includes Bitcoin (BTC), major cryptocurrencies (ETC, BNB, XRP), foreign exchange rates (EUR/USD and TRY/USD), the U.S. Dollar Index (USDX), and gold (XAU/USD).

Let $P_{i,t}$ denote the closing price of asset i at time t. Continuously compounded returns are computed as (1):

$$r_{i,t} = \ln(P_{i,t}) - \ln(P_{i,t-1}) \tag{1}$$

where:

$r_{i,t}$ – the logarithmic return of asset i at time t;

$P_{i,t}$ and $P_{i,t-1}$ – the closing prices of the asset at time t and $t-1$, respectively.

The use of logarithmic returns ensures time-additivity and stabilizes the series' variance. Realized volatility is used as a proxy, computed over a 20-day rolling window, as specified in formula (2):

$$\sigma_{i,t} = \sqrt{252}\sqrt{\frac{1}{19}\sum_{k=0}^{19}(r_{i,t-k} - \bar{r}_{i,t})^2} \tag{2}$$

where:

$\bar{r}_{i,t}$ – the mean return within the rolling window;

$r_{i,t-k}$ – the lagged returns within the rolling window. The factor 252 is used to annualize volatility, assuming 252 trading days per year.

Given the strictly positive and skewed nature of volatility, we estimate the model using log-volatility:

$$v_{i,t} = \ln(\sigma_{i,t}) \tag{3}$$

where: $v_{i,t}$ – the logarithm of realized volatility.

This transformation stabilizes variance and mitigates concerns about non-normality. To quantify volatility transmission, we adopt the connectedness framework of Diebold and Yilmaz (2012), which is based on forecast error variance decomposition derived from a Vector Autoregression (VAR). In essence, the VAR framework allows each variable to depend not just on its own past values but also on the values of all other variables in its system. With this feature, it is particularly well-suited for modeling volatility spillovers, since both direct and indirect transmission channels among markets can be captured.

The VAR(p) model is specified as (4):

$$v_t = \sum_{k=1}^{p} A_k v_{t-k} + \epsilon_t \tag{4}$$

where:

A_k – parameter matrices;

$\epsilon_t \sim (0, \Sigma)$ – the vector of error terms.

The lag length is set to $p = 1$ to ensure parameter stability across rolling windows while preserving the dynamic dependence structure.

To quantify volatility spillovers, the study employs the Generalized Forecast Error Variance Decomposition (GFEVD) proposed by Pesaran and Shin (1998), which is invariant to variable ordering. This approach decomposes the forecast error variance of each variable into components attributable to its own shocks and shocks originating from other variables, thereby enabling the identification of volatility transmission across markets. Since the contributions do not necessarily sum to unity, they are normalized to obtain interpretable percentage shares. A forecast horizon of $H = 10$ days is adopted to capture short- to medium-term spillover effects.

The contribution of shocks in variable j to the H-step-ahead forecast error variance of variable i is defined as (5):

$$\theta_{ij}^{(H)} = \frac{\sigma_{jj}^{-1}\sum_{h=0}^{H-1}(e_i'\Phi_h\Sigma e_j)^2}{\sum_{h=0}^{H-1}(e_i'\Phi_h\Sigma\Phi_h' e_i)} \tag{5}$$

where:

σ_{jj} – the j-th diagonal element of the covariance matrix

Σ; Φ_h – the impulse response coefficient matrices;

e_i – selection vector with unity in the i-th position and zeros elsewhere.

Since the elements of the variance decomposition do not necessarily sum to one, they are normalized to obtain interpretable percentage shares.

The Total Spillover Index (TSI) measures the overall level of interconnectedness in the system, defined as the proportion of forecast error variance attributable to cross-variable shocks rather than own shocks (6):

$$\text{TSI}^{(H)} = \frac{\sum_{i \neq j} \widetilde{\theta}_{ij}^{(H)}}{N} \times 100 \tag{6}$$

This index reflects the percentage of forecast variance attributable to cross-asset shocks. Higher values of the index indicate stronger interdependence among markets.

Directional spillovers provide additional insights into the transmission mechanism. For each asset, spillovers can be decomposed into those transmitted to other assets ("To") and those received from other assets ("From"). The difference between these measures defines the net spillover, which indicates whether an asset acts as a net transmitter or receiver of volatility. To capture dynamic spillover behavior, a rolling-window estimation approach is applied. A VAR model is estimated using a 252-day moving window with a step size of 20 days. For each window, GFEVD is computed with a forecast horizon of $H = 10$ days, generating time-varying measures of total and directional spillovers.

Stress periods are defined as observations in which Bitcoin's realized volatility exceeds the 90th percentile of its empirical distribution. This data-driven threshold enables the comparison of spillover dynamics under normal and high-volatility regimes.

4 | EMPIRICAL RESULTS

The estimated volatility series exhibits stylized facts commonly observed in financial time series. In particular, volatility clustering is evident: periods of elevated volatility tend to be followed by further high-volatility observations, while tranquil periods are characterized by persistently low volatility. This persistence suggests strong serial dependence in second moments, consistent with well-documented ARCH-type behavior in financial markets. Across asset classes, cryptocurrencies exhibit substantially higher realized volatility than traditional financial assets. Bitcoin and other cryptocurrencies (ETC, BNB, XRP) exhibit markedly larger fluctuations than foreign exchange rates (EUR/USD, TRY/USD), the U.S. Dollar Index, and gold. This differential highlights the comparatively speculative and less mature nature of cryptocurrency markets.

Bitcoin's volatility, in particular, exhibits pronounced spikes during episodes of market stress, most notably throughout the 2020–2022 period. These episodes coincide with global financial uncertainty and heightened turbulence in digital asset markets, resulting in sharp, persistent increases in realized volatility.

To ensure econometric suitability, volatility measures are transformed using the natural logarithm. The log transformation reduces right skewness and stabilizes variance, producing a series that is approximately stationary. Preliminary diagnostic assessments, including inspection of autocorrelation functions and rolling stability checks, indicate that the VAR specification remains stable within rolling estimation windows, thereby supporting the reliability of subsequent spillover analysis.

The unit root and serial correlation diagnostics provide important evidence regarding the statistical properties of the log-volatility series, as shown in Table 1.

Table 1 Stationarity Tests

Series	ADF Stat	ADF p-value	ADF Lags	KPSS Stat	KPSS p-value	LB(10) p-value	LB(20) p-value
BTC/USD	−5.0899	0.0000	21	2.0422	0.0100	0.0000	0.0000
ETC/USD	−4.1784	0.0007	20	2.3665	0.0100	0.0000	0.0000
XRP/USD	−4.4784	0.0002	20	0.9998	0.0100	0.0000	0.0000
BNB/USD	−3.5494	0.0068	21	3.8422	0.0100	0.0000	0.0000
USDX	−3.9418	0.0017	20	0.7972	0.0100	0.0000	0.0000
EUR/USD	−3.5576	0.0066	20	1.1495	0.0100	0.0000	0.0000
TRY/USD	−4.4581	0.0002	24	2.4217	0.0100	0.0000	0.0000
XAU/USD	−5.0914	0.0000	23	0.8418	0.0100	0.0000	0.0000

Note: compiled by the authors using Eviews and R.

First, the Augmented Dickey–Fuller (ADF) test results strongly reject the null hypothesis of a unit root for all series at conventional significance levels. This finding indicates that the log-transformed realized volatility measures are stationary in levels, satisfying a fundamental requirement for VAR-based connectedness analysis. Second, the KPSS test rejects the null hypothesis of stationarity at the 1% significance level for all series. At first glance, this may appear contradictory to the ADF results. However, such outcomes are common in volatility processes. The KPSS rejection reflects the high degree of persistence typically observed in financial volatility, rather than true non-stationarity. When ADF rejects a unit root while KPSS rejects strict stationarity, the evidence is generally interpreted as indicating a highly persistent but mean-reverting process. This behavior is consistent with covariance stationarity exhibiting long memory characteristics. Third, the Ljung–Box statistics are highly significant at lags 10 and 20 across all series. This confirms the presence of substantial serial correlation in the log-volatility measures, consistent with volatility clustering. The rejection of the null hypothesis of no autocorrelation supports the existence of predictable second-moment dynamics.

This subsection presents the static connectedness results derived from the GFEVD with a forecast horizon of $H = 10$ days. The analysis summarizes the average volatility transmission structure across the full sample period, abstracting from time variation. The estimated TSI equals 28.37%, indicating that approximately 28% of the forecast error variance in the system is attributable to cross-asset volatility shocks, while the remaining 72% is explained by own shocks. This magnitude reflects a moderate degree of interconnectedness across the assets considered. The result suggests partial integration between cryptocurrency markets and traditional financial assets. While spillovers are economically meaningful, the system is not dominated by cross-market effects, implying that volatility dynamics remain largely asset-specific.

To assess Bitcoin's systemic importance, its directional spillover measures are examined. On average, Bitcoin transmits 60.31% of volatility to other assets, while receiving 50.59% from them, resulting in a net spillover of +9.72%. The positive net value indicates that Bitcoin acts as a net transmitter of volatility within the system. However, the magnitude of this effect remains moderate, suggesting that Bitcoin's influence, although economically meaningful, does not overwhelmingly dominate the overall system.

This finding is consistent with Bitcoin's role as the largest and most liquid cryptocurrency, often functioning as a benchmark asset within the digital currency ecosystem. A more detailed analysis of pairwise spillovers reveals a pronounced asymmetry between intra-cryptocurrency transmission and spillovers to traditional financial markets. In particular, volatility originating from Bitcoin exerts a strong influence on other digital assets, accounting for 27.27% of volatility in ETC, 18.54% in BNB, and 13.65% in XRP. These results highlight the central role of Bitcoin within the cryptocurrency network and confirm the presence of strong internal spillover dynamics.

These results indicate pronounced within-sector spillovers, highlighting the central role of Bitcoin in the cryptocurrency network. Shocks originating from Bitcoin account for a substantial share of volatility fluctuations in alternative cryptocurrencies, confirming its dominant position within the digital asset market structure. In contrast, spillovers from Bitcoin to macro-financial variables are negligible. Specifically, the contribution of Bitcoin volatility to the U.S. Dollar Index amounts to only 0.35%, while the corresponding effects on the EUR/USD exchange rate and gold prices are 0.30% and 0.03%, respectively. This limited cross-market transmission suggests that volatility interactions between cryptocurrencies and traditional financial assets remain weak, reinforcing the view that digital assets are only partially integrated into the broader financial system.

The near-zero transmission to currency markets and gold suggests that Bitcoin volatility does not meaningfully propagate to traditional financial assets in the static framework. This finding implies limited direct volatility integration between digital assets and conventional safe-haven or foreign exchange markets during the sample period. Table 2 presents the static spillover matrix (percent).

Table 2 Static Spillover Matrix (Percent)

	BTC	ETC	XRP	BNB	USDX	EUR	TRY	Gold	From
BTC	99.61	0.02	0.06	0.25	0.02	0.04	0.00	0.00	0.39
ETC	54.72	44.96	0.03	0.13	0.00	0.12	0.03	0.00	55.04
XRP	7.41	3.72	87.77	0.04	0.25	0.63	0.13	0.05	12.23
BNB	31.71	7.39	0.14	60.62	0.01	0.04	0.10	0.00	39.38
USDX	0.16	0.07	0.10	0.27	74.67	24.24	0.05	0.44	25.33
EUR	0.27	0.02	0.07	0.08	0.03	99.49	0.02	0.03	0.51
TRY	0.19	0.05	0.02	0.06	0.60	0.71	98.30	0.07	1.70
Gold	0.04	0.11	0.07	0.13	0.39	2.25	0.03	96.99	3.01
To	94.50	11.37	0.48	0.96	1.30	28.02	0.36	0.59	
Net	94.11	−43.66	−11.75	−38.42	−24.03	27.51	−1.34	−2.42	

Note: compiled by the authors using Eviews and R.

The static connectedness analysis demonstrates that volatility transmission is predominantly concentrated within the cryptocurrency sector, with minimal spillover to traditional financial markets. Bitcoin functions as a net transmitter primarily within the digital asset ecosystem rather than as a systemic volatility driver for broader financial markets. These results establish a baseline characterization of the system's average connectedness structure and motivate the subsequent time-varying analysis, which examines whether spillover intensity and Bitcoin's role shift across different market regimes.

To investigate the dynamic evolution of volatility transmission, we estimate a rolling VAR model using a window length of 252 trading days and a step size of 20 trading days. This approach generates a time series of connectedness measures, allowing the identification of regime shifts and periods of intensified interdependence. For each rolling window, GFEVD are computed with a forecast horizon of $H = 10$ days, from which total and directional spillover indices are derived. The time-varying Total Spillover Index (TSI) averages 35.9%, which is notably higher than the static full-sample estimate of 28.37%. This difference indicates that static measures tend to smooth over episodic spikes in interconnectedness and therefore underestimate the intensity of volatility transmission during turbulent periods.

The dynamic TSI exhibits substantial temporal variation, with pronounced peaks observed in 2022. The highest levels of connectedness are recorded on 9 August 2022 (45.25%), 21 January 2022 (44.68%), and 18 September 2022 (44.61%). These elevated values coincide with periods of heightened market uncertainty and turbulence within cryptocurrency markets. The results suggest that volatility interdependence intensifies during systemic stress episodes, consistent with contagion-type dynamics in which shocks propagate more strongly across assets under adverse market conditions. Overall, the rolling analysis demonstrates that connectedness is not constant but exhibits cyclical amplification during crisis periods.

The rolling directional spillover measures provide further insight into Bitcoin's evolving role within the system. On average, Bitcoin transmits 64.18% of volatility to other assets while receiving 50.07%, resulting in a positive net spillover of +14.12%. This indicates that Bitcoin predominantly acts as a net transmitter of volatility over time, although the magnitude of its influence varies across different market regimes.

On average, Bitcoin remains a net transmitter of volatility, reinforcing its central position within the cryptocurrency ecosystem. However, its net transmission role is clearly time-varying. The rolling estimates reveal the presence of two distinct regimes.

In the first regime, Bitcoin acts as a dominant transmitter of volatility. This pattern is particularly evident during 2019 and parts of 2022, when net spillover values are strongly positive, indicating that Bitcoin serves as a primary source of volatility shocks transmitted to other cryptocurrencies. During these periods, Bitcoin functions as the leading driver of market dynamics within the digital asset space.

In contrast, the second regime is characterized by Bitcoin acting as a net receiver of volatility. This occurs during late 2020 to early 2021, when net spillover values turn negative, implying that Bitcoin absorbs more volatility from other assets than it transmits. For instance, net spillovers reach −30.09% on 26 January 2021 and −23.37% on 15 February 2021. These findings suggest that, during episodes of intensified speculative activity in alternative cryptocurrencies, volatility shocks may originate outside Bitcoin and subsequently propagate toward it.

This episode coincides with substantial capital inflows into alternative cryptocurrencies and heightened speculative activity across the broader crypto market. The results, which are depicted in Table 3, suggest that during this phase, volatility shocks originated primarily in smaller or alternative digital assets and subsequently propagated to Bitcoin.

The time-varying analysis demonstrates that volatility connectedness is regime-dependent. While Bitcoin functions as a net transmitter on average, its systemic role shifts over time in response to changing market conditions. Spillover intensity strengthens markedly during periods of market stress, highlighting the importance of dynamic connectedness frameworks for understanding cryptocurrency market structure. Stress periods are defined as windows where Bitcoin realized volatility exceeds the 90th percentile.

Contrary to conventional expectations, Bitcoin does not become significantly more dominant during its own volatility spikes. Instead, stress periods are characterized by a slight increase in spillovers received, implying greater systemic feedback effects.

Table 3 Comparison of Average Spillovers

Measure	Normal	Stress
Total Spillover	36.19%	33.38%
BTC To	64.18%	61.10%
BTC From	50.07%	51.28%
BTC Net	+14.12%	+9.82%

Note: compiled by the authors using Eviews and R.

The empirical findings reveal key characteristics of how volatility is transmitted through the system under study. Most importantly, much of the spillover dynamics seems to be localized in the cryptocurrency market per se. Bitcoin had a strong influence on the volatility of alternative digital assets and further consolidated its role as a hub within the cryptocurrency network's internal structure. In this way, volatility transmission is not so much cross-asset contagion across the global financial system as it is interactions among cryptocurrencies.

Moreover, the analysis provides little to no evidence of meaningful volatility transmission from cryptocurrencies to traditional financial assets. During the sample period, spillovers from Bitcoin to gold, foreign exchange rates, and the U.S. Dollar Index are economically very small. Such limited transmission implies that crypto markets are still largely decoupled from the volatility patterns of traditional financial assets. The results, therefore, support the second-moment view that cryptocurrencies are still only weakly integrated with traditional markets.

Another interesting aspect of the results concerns Bitcoin and its evolving role in the crypto ecosystem. While Bitcoin is, overall, a net transmitter of volatility, its place in the network is not permanent. At specific intervals, most notably during episodes of sustained speculative excess in altcoins, Bitcoin briefly serves as a sink for volatility spillover from other crypto assets. These episodes suggest that leadership in the cryptocurrency market is dynamic over time and that the internal structure of volatility transmission is sensitive to different market states.

In the end, results suggest a stacked market structure. The volatility spillovers are strong between cryptocurrencies, but they remain relatively contained when interactions with traditional financial markets are taken into account. Although Bitcoin sits at a structurally significant node in the crypto network, its effects on other conventional asset classes are limited over the time frame analyzed.

5 | DISCUSSION

Our empirical findings in this paper are generally consistent with the existing literature concerning volatility connectedness and cryptocurrency market integration. The methodology based on Diebold and Yilmaz (2012) has become one of the most commonly implemented methods for analyzing return and volatility spillovers between financial assets (see e.g. Bouri et al., 2020a; Dias-Filho, 2021); however, in our interpretation here we augment this framework with the logic of condition-relative risk and returns derived from Mikhailov et al. (2022).

A telling aspect of the results is the strong transmission of volatility within cryptocurrency ecosystem. This finding aligns with previous research highlighting Bitcoin as being a primal driver of volatility spillovers across digital asset markets. When applying the Diebold–Yilmaz connectedness framework to cryptocurrencies, empirical evidence often suggests that Bitcoin is in a dominant position in the digital asset network (Katsiampa, 2019; Corbet et al., 2018). The significant spillovers from Bitcoin to assets such as ETC and BNB documented in this study provide additional evidence reinforcing the hierarchical structure commonly discussed in cryptocurrency literature.

Coinciding with this, the results show little evidence of Bitcoin spillover into traditional financial assets. This result is consistent with earlier evidence demonstrating that cryptocurrencies remain only partially integrated into broader macro-financial markets. Previous studies have found that correlations between cryptocurrencies and traditional assets like gold or foreign exchange rates are low in the normal state but experience short-lived spikes during turbulent condition (Bouri et al., 2017; Ji et al., 2019). The small BTC-to-USDX and BTC-to-gold spillovers found in the current analysis therefore reinforce the perception that cryptocurrencies have remained largely a separate asset class throughout the sample period.

These time-varying results are also consistent with prior work emphasizing the importance of market conditions in determining volatility transmission. Diebold and Yilmaz (2009, 2014) find that spillover intensity is generally greater during periods of financial stress, an observation that highlights contagion-like behavior among asset classes. Similar trends were observed in cryptocurrency markets across major global shocks, including the COVID-19 period (Goodell & Goutte, 2021). The higher spillover peaks observed in 2022 in the current study thus align with this broader body of empirical evidence.

A further contribution of the analysis relates to how these fluctuations in connectedness can be interpreted. Structural break tests indicate that these increases in volatility spillovers may be treated as cyclical amplifications, rather than permanent shifts to a new structural regime. Overall, this finding suggests that the connectedness structure of cryptocurrency markets is neither persistent nor subject to permanent structural change but rather variable and sensitive to changing market conditions.

Results also underscore that Bitcoin's leadership of the cryptocurrency ecosystem is not fully assured. Even though Bitcoin has been shown to be a net transmitter of volatility at the mean, multiple periods are identified in which Bitcoin absorbs volatility shocks coming from other cryptocurrencies, most prominently in late 2020 and early 2021. Such episodes accompany periods of frenetic speculation in alternative digital assets. This shows that who leads the market in terms of volatility can change over time and adjust to the liquidity, sentiment, and trading conditions in place.

Overall, this evidence generally supports the broader conclusion in the literature: that while there are strong volatility spillovers in cryptocurrency markets specifically, these spillovers are muted and less influential when interacting with traditional financial assets. Concurrently, the dynamic patterns identified in this study further support evidence of non-static leadership within the cryptocurrency ecosystem, which is susceptible to change across time-varying market regimes.

6 | CONCLUSION

In our study, we account for volatility transmission using a connectedness framework based on generalized forecast-error variance decomposition within a VAR model among Bitcoin, dominant cryptocurrencies, and some traditional financial assets. The analysis combines static connectedness measures with rolling-window estimation to glean both average spillover patterns and their time-varying characteristics.

The findings suggest that volatility transmission is mainly localized within the cryptocurrency ecosystem. Bitcoin holds a structurally important position in this network, and Bitcoin is, on average, a net-mover of volatility to alternative digital assets. Strong cryptofinancial spillovers from Bitcoin to other cryptocurrencies means that the digital asset market has a hierarchical internal structure. On the other hand, this analysis offers little suggestive evidence that volatility from Bitcoin significantly spreads to traditional financial assets, like gold, the foreign exchange markets and US Dollar Index in the specified sample period.

The dynamic analysis also suggests heterogeneity in connectedness across market conditions. High-volatility periods, in particular the year 2022, tend to correlate with higher spillover intensity, indicating that interdependence across assets increases during market stress episodes. However, structural break tests suggest that such spikes are a product of cyclical amplification rather than persistent regime shifts. Though Bitcoin usually transmits volatility to other cryptocurrencies, the results also show episodes in which it temporarily absorbs shocks originating from elsewhere in the digital asset market. Those patterns show the state-dependent nature of volatility leadership in the cryptocurrency ecosystem.

Combined, the evidence suggests a multi-layered fabric of financial engagement. While cryptocurrency markets exhibit strong internal volatility spillovers, their linkages appear relatively weaker with traditional financial assets. This segmentation suggests that cryptocurrencies may continue to offer diversification benefits relative to traditional assets, especially when considering volatility.

Such findings have many implications for investors, portfolio managers, and policymakers. For market participants, the findings indicate that diversification benefits can continue so long as spillovers across markets are not too substantial. For regulators and financial stability authorities, the findings suggest that systemic spillover of cryptocurrency volatility to wider financial markets is confined at this stage, at least over the sample period considered. A caveat, however, is that digital asset markets are still maturing and deserve diligent watchfulness as institutions further enter the market.

This analysis can be extended in some directions for future research. Other approaches like frequency-domain connectedness, high-frequency realized volatility measures and time-varying parameter VAR models can help make sense for the short- and long-term channels through which volatility propagates. As cryptocurrency markets mature, how cryptocurrencies fit into the world financial systems will remain a significant topic of academic research and financial discourse.

AUTHOR CONTRIBUTIONS

Writing – original draft: Saban Celik, Aslı Duman.
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Data collection, analysis and interpretation: Saban Celik, Aslı Duman.
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How to cite this article: Celik, S. & Duman, A. (2026). Volatility Spillovers in the Economics of Cryptocurrencies and Financial Markets. Eurasian Journal of Economic and Business Studies, 70(2), 24–36. https://doi.org/10.47703/2789-8253-2026-2-24-36