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FTX's downfall and Binance's consolidation: The fragility of centralised digital finance

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ABSTRACT

This paper investigates the causes and the consequences of the FTX digital currency exchange's failure in November 2022. Analysing on-chain data, we report that FTX heavily relied on leveraging and misusing its native token, FTT, and we show how this behaviour exacerbated the company's fragile financial situation. To gain further insights into the downfall, we employ state-of-the-art network science instruments to model the evolutionary dependency structures of 199 cryptocurrencies on an hourly basis, and we investigate tick-by-tick public trades at the time of the events. We identify the collapse of the Terra-Luna ecosystem as the pivotal event that triggered a significant decrease in the exchange's liquidity. Results suggest that the crash was actively accelerated by Binance tweets causing a systemic reaction in the cryptocurrency market. Finally, identifying the actors who mostly benefited from the FTX's collapse and highlighting a generalised trend toward centralisation in the crypto space, we emphasise the importance of genuinely decentralised finance for a transparent, future digital economy.

"Never in my career have I seen such a complete failure of corporate controls and such a complete absence of trustworthy financial information as occurred here. From compromised systems integrity and faulty regulatory oversight abroad, to the concentration of control in the hands of a very small group of inexperienced, unsophisticated and potentially compromised individuals, this situation is unprecedented". John J. Ray III, Declaration in support of chapter 11 petitions and first day pleadings.

1. Introduction

In the past few years, the cryptocurrency market has experienced substantial growth, surpassing the three trillion dollar mark by the end of 2021 and still accounting for about a trillion in the present "winter" [1]. The interest in cryptocurrencies has been driven by heterogeneous factors and originated a relatively mature market with competing forces. The cryptocurrency market originally provided a platform for experimenting with new financial models characterised by the potential to be decentralised and free from authority's control. However, in the last few years, we are witnessing the growth of large crypto entities operating as classic financial actors (i.e. exchanges, banks, . . .) while being characterised by opaque financial conditions and poor governance. This development is a cause for concern, especially considering that

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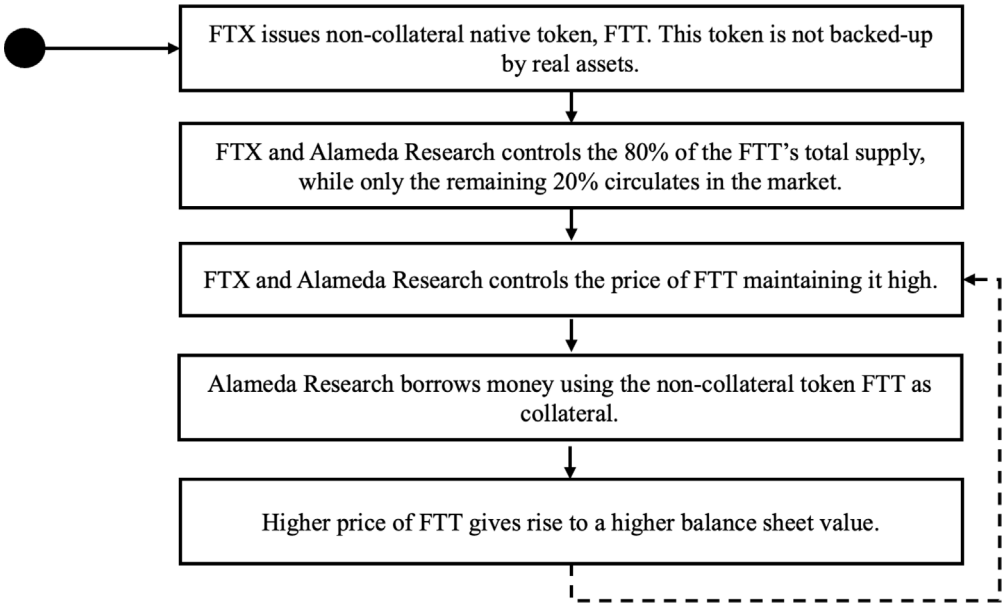

Fig. 1. Schematic depiction of the leverage mechanism used by FTX and Alameda Research.

such unregulated centralised entities have dominant positions in the market. This new scenario contradicts the principles of transparency, independence, and accountability originally envisioned for the crypto movement.

In May 2022, the Terra-Luna stablecoin collapsed, provoking a contagion across different crypto ecosystems with long-run effects. As described by Briola et al. [2], Terra-Luna was an algorithmic stablecoin whose underlying protocol relied on a two-coin system that was not backed by traditional collaterals. Its failure was presumably induced by a liquidity pool attack and eased by the inappropriate underlying blockchain framework. This collapse remarkably damaged the confidence in the crypto market, accelerating the onset of a "crypto winter". Users started massively withdrawing their funds from crypto institutions while investors recalled loans with cryptocurrencies as collateral. Consequently, summer 2022 was characterised by the bankruptcy of many prominent actors with excessive leverage, such as Three Arrows Capital (3AC), a Singapore-based cryptocurrency hedge fund [3], Voyager Digital, a cryptocurrency brokerage company [4], and Celsius, a cryptocurrency lending company [5].

Compared to the entities mentioned above, FTX, the third-largest digital currency exchange with USD 10 billion active trading volume and USD 32 billion valuation at the time of events [6,7], was able to hide its financial situation until 02 November 2022. On this day, CoinDesk reported that Alameda Research owned USD 6 billion FTX Tokens (FTT) in its balance sheet [8]. In other words, the balance sheet of the leading FTX trading firm mainly included the non-collateral native token created by FTX itself. This in-house token was costless for the issuer since it was not backed by any real asset. It is worth noting that native tokens are common in centralised digital currency exchanges such as Binance (Binance token — BNB), Huobi (Huobi token — HT), and Hxro (Hxro token — HXRO). They serve as utility tokens and offer customers various incentives, including reduced trading fees, among other non-financial perks. However, the case of FTX and its token FTT concealed a deeper underlying truth. Since its Initial Coin Offering (ICO) in 2019, most of FTTs (80% of the total supply) were held by FTX and Alameda Research [9]. In this scenario, both entities could have easily controlled the price of the non-collateral native token, FTT, to secure additional financing while increasing the value of their balance sheets. Their financial strategy relied on a leverage mechanism where a native token without inherent value was used as collateral to raise funds. Unfortunately, this vicious cycle (see Fig. 1) was fragile and highly exposed to external events affecting the price of FTT. As we show in this study, the Terra-Luna collapse represented such a shock. After that, both FTX and Alameda Research suffered from a credit crunch. They were initially able to avoid bankruptcy, given the misappropriation of clients' deposits, the sale of their reserves and the inflated value of FTT in their balance sheets. However, CoinDesk's report on the reliance of Alameda Research and FTX on their proprietary token unfolded the leverage mechanism used by the two companies. In response to this news, on 06 November 2022, Binance announced the liquidation of all the FTTs on its books, giving rise to a Twitter debate with FTX and Alameda Research which ended with the bankruptcy of FTX on 11 November 2022.

The rest of the paper is organised as follows: in Section 2, we present the FTX's downfall timeline providing quantitative insights based on three heterogeneous data sources (i.e. hourly closing price, on-chain data and public transaction data). In Section 3, we present state-of-the-art instruments from network science used to model evolutionary dependency structures among a set of 199 cryptocurrencies at the time of the events. In Section 4.1, we present obtained results

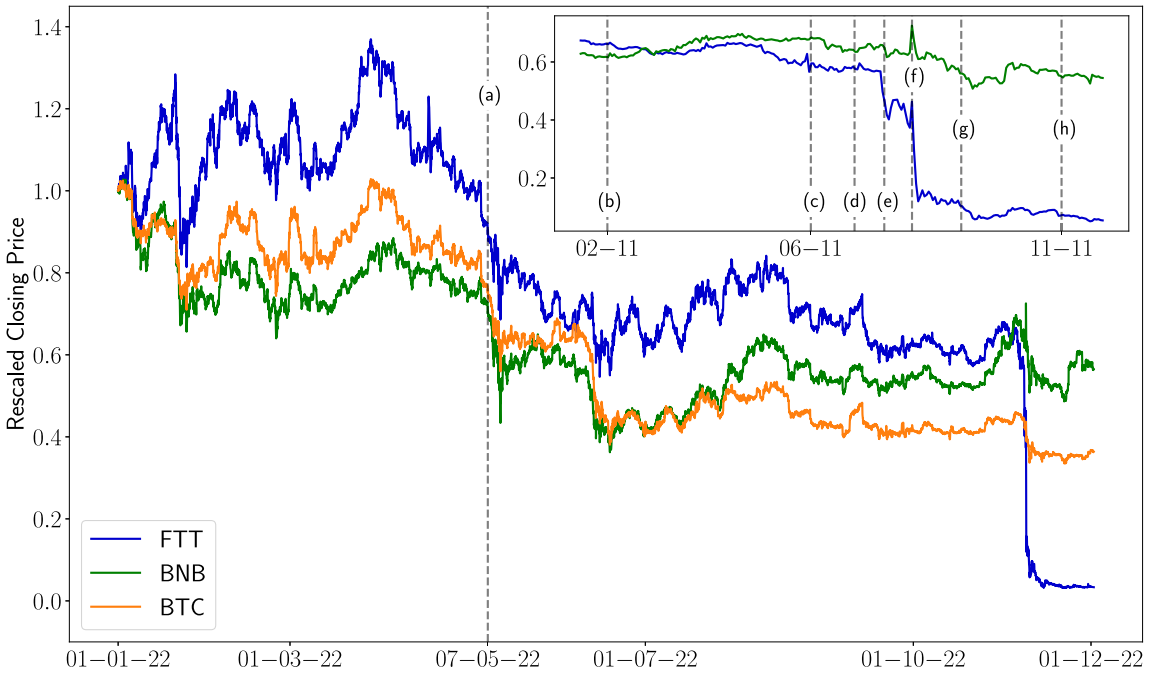

Fig. 2. Rescaled hourly closing prices for FTT, BNB and BTC from 01 January 2022 to 01 December 2022. The box on the upper right provides a focus on the period between 01 November 2022 to 01 December 2022. Events listed in Table 1 are plotted with dotted lines.

analysing the impact of the FTX collapse on the cryptocurrency market. In Section 4.2, we discuss the consequences of the crash, identifying the actors who mostly benefited from the FTX's collapse and highlighting a generalised trend toward centralisation in the crypto space. In Section 5, we discuss the meaning of our findings, highlighting the most alarming aspects of the events presented in the paper.

2. Data and quantitative nature of the events

2.1. Hourly data analysis

In this paper, we use hourly USD closing prices[1] for 199 cryptocurrencies (see Appendix for the full list) from 01 January 2022 to 01 December 2022. The dataset is directly obtained from Binance, the largest digital currency exchange in terms of traded volume [7], through the use of the CCXT Python package [10] (see Drożdż et al. [11] for a comprehensive statistical analysis on cryptocurrencies traded on Binance).[2,3]

Fig. 2 reports rescaled hourly closing prices for FTT, BNB and Bitcoin (BTC).[4] Dotted lines highlight the main events that led to the FTX's collapse (see also [9,14–17]). It is worth noting that, since 01 January 2022, FTT has demonstrated superior performance compared to BTC and BNB. As discussed in Section 1, such behaviour could result from a potential price manipulation of the crypto asset. However, after (a) Terra-Luna's collapse, we conjecture that FTX lost control over the FTT price due to its liquidity issues. On (b) 02 November 2022, 14:44 (GMT), CoinDesk reported that Alameda Research owned USD 6 billion FTTs in its balance sheet [8]. On (c) 06 November 2022, 15:47 (GMT), Binance CEO Changpeng "CZ" Zhao announced that any remaining FTT on the company's books would have been liquidated.

Immediately after, at 16:03 (GMT), the Alameda Research CEO, Caroline Ellison, reacted by tweeting that FTX would have bought FTTs from Binance at USD 22 each. Due to the huge concerns throughout the crypto space regarding the financial viability of FTX and Alameda Research, Bankman-Fried (i.e. FTX's CEO) tweeted on (d) 07 November 2022, 12:38

[1] In the original dataset sourced from Binance, closing prices are expressed in BUSD. We compute USD prices by using the time-corresponding BUSD/USD exchange rate.

[2] The findings by Drożdż et al. [11] indicate that the return distributions, volatility clustering effects, and temporal multifractal correlations of the most prominent cryptocurrencies closely resemble those observed in well-established financial markets. However, smaller cryptocurrencies still exhibit some inefficiencies in this sense.

[3] As reported by Alexander and Dakos [12] and Vidal-Tomás [13], using traded data from liquid exchanges guarantees the reliability of results.

[4] FTT and BNB are chosen based on their role in the events analysed in the current paper, while BTC is chosen as a proxy for cryptocurrency market's behaviour.

Table 1
Timeline of the events that led to the FTX's bankruptcy in November 2022.

Date	Reference	Event
07-05-2022 22:00	(a)	Terra-Luna collapsed. First day that Terra (USDT) lost the peg to USD.
02-11-2022 14:44	(b)	CoinDesk reported that the value of Alameda Research heavily relied on the FTX's in-house tokens, FTT. Specifically, Alameda Research owned USD 14.6 billion of assets and USD 6 billion are FTT.
06-11-2022 15:47	(c)	Changpeng "CZ" Zhao (i.e. Binance CEO) announced that his company would have liquidated any remaining FTT on Binance books. In response to this announcement, at 16:03 (GMT), Caroline Ellison (i.e. Alameda Research CEO), tweeted that FTX would have bought all the FTT tokens from Binance at a value of USD 22 each.
07-11-2022 12:38	(d)	Due to the huge concerns throughout the crypto space regarding the financial viability of FTX and Alameda Research, Bankman-Fried tweeted "*A competitor is trying to go after us with false rumours. FTX is fine. Assets are fine*".
08-11-2022 02:48	(e)	A massive selling pressure on FTT is detected. It could have been related to the liquidation of Alameda Research loans.
08-11-2022 16:03	(f)	Binance announced the existence of a non-binding letter of intent to purchase FTX.
09-11-2022 15:32	(g)	CoinDesk anticipated Binance's intention to decline any kind of deal. The news was officially confirmed at 20:50 (GMT).
11-11-2022 15:23	(h)	FTX and its 130 related companies, announced that they commenced voluntary proceedings under chapter 11 of the United Stated bankruptcy code.

(GMT), "*A competitor is trying to go after us with false rumours. FTX is fine. Assets are fine.*". As we show in Section 2.3, on (e) 08 November 2022, from 02:47 (GMT) to 02:48 (GMT), there was a sudden increase in selling pressure equal to 1.3 million BUSD, which resulted in the first decrease in FTT price. In line with Khoo et al. [9], we conjecture that creditors recalled Alameda Research loans with FTT as collateral. Since Alameda Research could not have repaid loans, Sam Bankman-Fried was forced to ask Binance to step in and acquire the Firm. Consequently, on (f) 08 November 2022, 16:03 (GMT), Binance announced a non-binding letter of intent to purchase FTX. On (g) 09 November 2022, 15:32 (GMT), CoinDesk anticipated Binance's intention to decline any deal. Binance confirmed the leak at 20:50 (GMT) of the same day as a result of the corporate due diligence. Finally, on (h) 11 November 2022, 15:23 (GMT), FTX, and 130 associate companies, announced that they would have commenced voluntary proceedings under chapter 11 of the United States bankruptcy code. Table 1 reports a detailed timeline of the events.

2.2. On-chain data analysis

To quantitatively prove the relevance of Terra-Luna's collapse on the FTX's bankruptcy, we use high-quality on-chain data from Glassnode [18]. After the failure of the algorithmic stablecoin, both FTX and Alameda Research suffered from a credit crunch caused by the decrease in FTT's price and the increased difficulty in obtaining credit from lenders. Indeed, bankruptcies characterising summer 2022 (i.e. 3AC, Voyager Digital and Celsius) fomented the market's uncertainty, decreasing the lending volume and causing a generalised down-market. As a consequence, since May 2022, FTX and Alameda Research were no longer able to control FTT's price, and the leverage mechanism described in Fig. 1 was abruptly interrupted. The Wall Street Journal reports that the CEO of Alameda Research informed her employees that the Firm used FTX clients' funds to pay back creditor's loans that were being recalled due to the credit crunch triggered by Terra-Luna collapse [19]. The apology letter sent on November 2022 by Sam Bankman-Fried to his employees further confirms the crucial role of Terra-Luna's failure in FTX bankruptcy: "*I believe that the events that led to the breakdown this month* [November 2022] *included a crash in markets this spring* [Terra-Luna] *that led to a roughly 50% reduction in the value of collateral*" [20].

In order to validate our events' reconstruction, we report in Fig. 3 the rescaled total amount of reserves (in BTC and Ethereum) owned by FTX and Binance from 01 January 2022 to 01 December 2022. FTX, differently from its main competitor (i.e. Binance), started to sell its reserves slightly after the Terra-Luna collapse in May 2022 to overcome the credit crunch. Based on these findings, in Fig. 4, we extend Fig. 1 by incorporating a new branch that depicts the circumstances that disrupted the vicious cycle involving FTX and the consequences observed since May 2022.

2.3. Transaction data analysis

To gain further insights on the FTX's bankruptcy, we analyse FTT's public trades occurred on the Binance digital currency exchange at the time of the events. Also in this case, the dataset is directly obtained from Binance digital currency exchange using the CCXT Python package [10]. Unlike hourly closing prices, transaction data are expressed in Binance USD (BUSD), the exchange's native stablecoin.

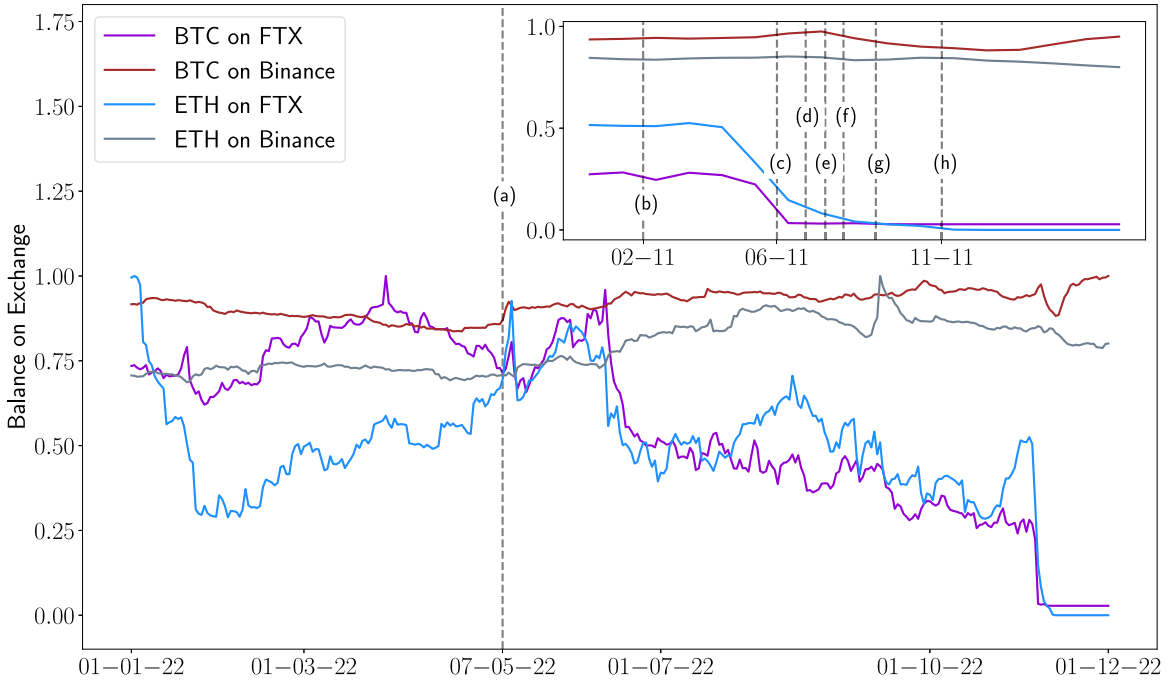

Fig. 3. Rescaled total amount of Bitcoins and Ethereum Coins held on FTX and Binance addresses from 01 January 2022 to 01 December 2022. The box on the upper right provides a focus on the period between 01 November 2022 to 01 December 2022. Events listed in Table 1 are plotted with dotted lines.
Source: Data are retrieved from Glassnode [18].

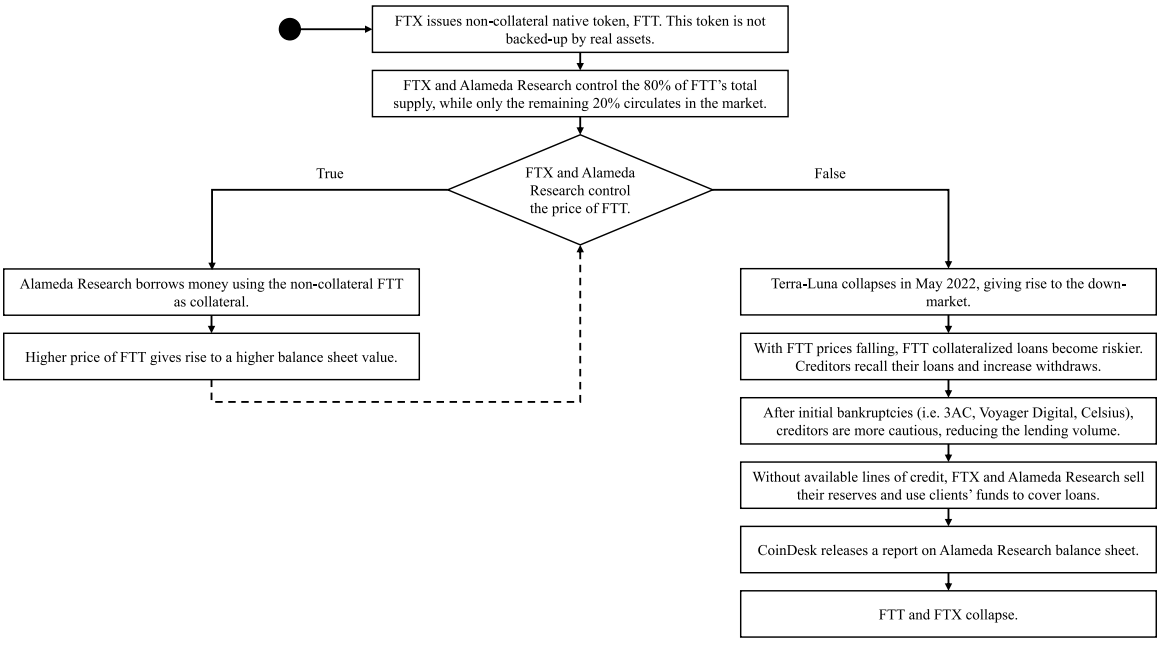

Fig. 4. Schematic depiction of the mechanism that led to the FTX's collapse.

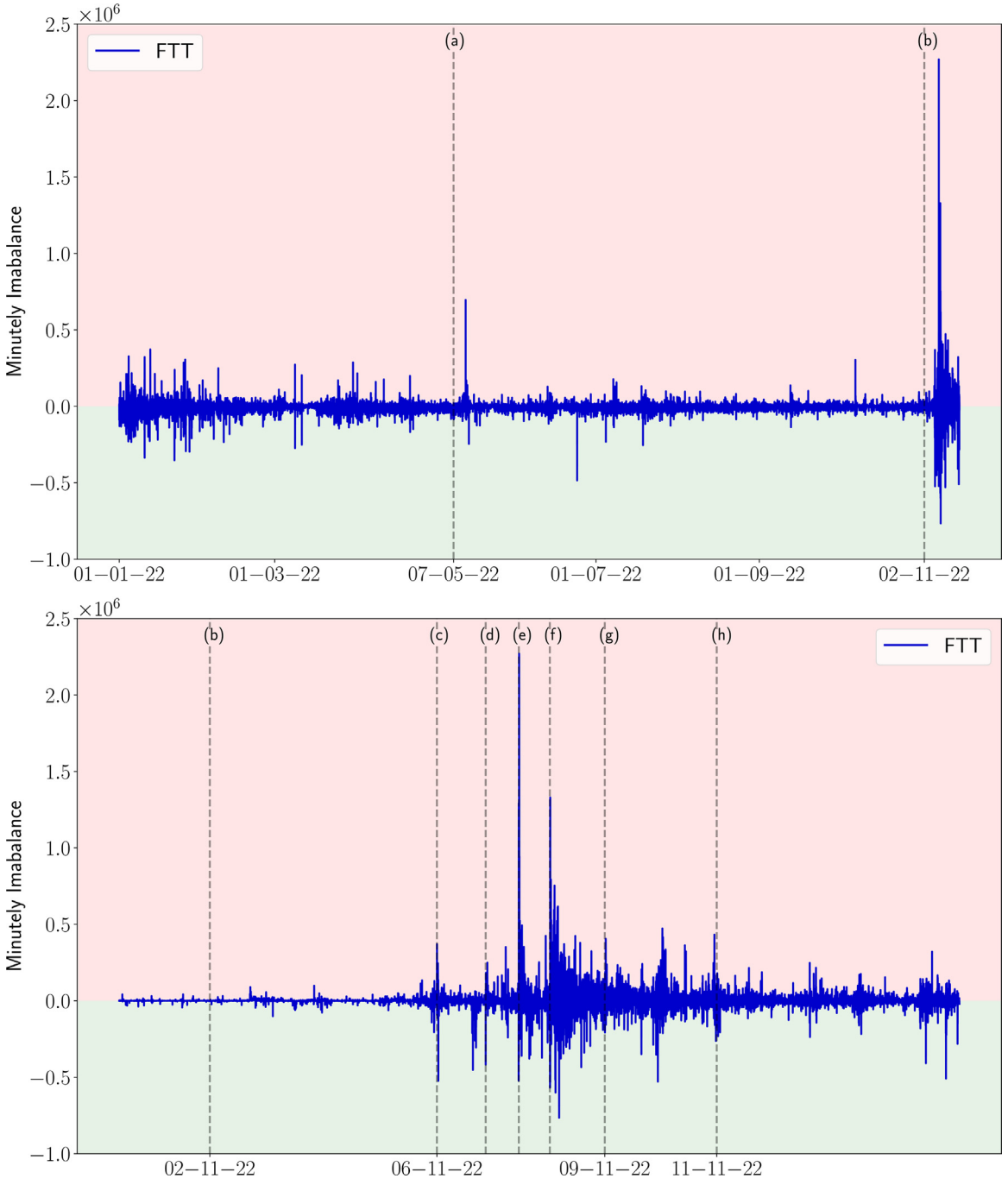

Fig. 5. Minutely imbalance for FTT on the Binance digital currency exchange. Positive values (red colour area) and negative values (green colour area) denote selling and buying pressure, respectively. The first figure covers the period from 01 January 2022 to 01 December 2022. The second figure provides a focus on the period between 01 November 2022 to 01 December 2022. Events listed in Table 1 are plotted with dotted lines.

Fig. 5 reports minutely imbalances, where positive values (red area in the plot) indicate a selling pressure, while negative ones (green area in the plot) indicate a buying pressure.[5] Our analysis reveals that, prior to November 2022,

[5] The calculation of the imbalance is based on the methodology described in Briola et al. [2]. The procedure involves separating data into buy and sell trades, computing the transaction costs by multiplying the volume of each transaction by its execution price, aggregating the transaction costs by minute, and subtracting the total of buy transactions costs from the total of sell transactions costs to obtain imbalances.

the highest selling pressure in FTT occurred on 12 May 2022 with a value of BUSD 695,690 as a direct consequence of the Terra-Luna's failure. This finding enforces our statement about the crucial role of the Terra-Luna's collapse in FTX's bankruptcy, as no other significant event appears to have influenced the market, including the Russia-Ukraine conflict [21] and the implementation of contractionary monetary policies [22]. In Fig. 5, we further observe that, in November 2022, market dynamics were affected by the Twitter debate involving FTX, Alameda Research and Binance. CoinDesk's report alone (b) had a limited impact on the market. In contrast, the first significant shock is observed on (c) 06 November 2022 at 15:47 (GMT), when the Binance CEO announced the intention to liquidate FTT reserves, leading to a rise in selling pressure at 15:49 (GMT), amounting to BUSD 369,420. In light of the high buying pressure at 16:23 (GMT) (i.e. BUSD 523,730), we postulate that Binance elicited a counter-reaction from FTX. Despite the efforts by the FTX's CEO to restore investors' trust (d), FTT experienced a significant selling pressure equal to BUSD 1.3 million on (e) 08 November 2022, at 02:48 (GMT), when it was traded at BUSD 21.83. The most significant selling pressure (i.e. BUSD 2.56 million) is detected at 02:56 (GMT) of the same day when FTT had already dropped to BUSD 19.6.[6] In agreement with Khoo et al. [9], a plausible explanation could be that Alameda Research had loans to be liquidated when the price of FTT would have fallen below BUSD 21.8. Hence, we cannot exclude that this abnormal selling pressure could have been generated by FTX itself trying to repay loans collateralized by FTT. In this scenario, having already used the majority of clients' funds and most of the reserves to front the credit crunch triggered by the Terra-Luna's collapse (see Section 2.2), FTX did not have alternative sources of liquidity. Despite its origin, this event led to the technical collapse of FTX, as observed on (f) 08 November 2022. Sam Bankman-Fried asked Binance to acquire the FTX group, further spreading panic among investors and leading to a significant drop in the FTT price (see Fig. 2). On (g) 09 November 2022, Binance declined to acquire FTX, generating additional selling pressure. On (h) 11 November 2022, the bankruptcy of FTX was announced with minimal impact, as investors had already taken into account the collapse, and the price was BUSD 2.79.

3. Methodology

3.1. Network analysis: Triangulated Maximally Filtered Graph (TMFG)

To describe the impact of FTX's collapse on the market's dynamics, we analyse the evolution of a set of 199 cryptocurrencies' dependency structures during the crash on an hourly basis. As shown in Briola et al. [2], we use the Pearson correlation coefficient to model linear relationships among the assets. It is worth noting that during periods of stress in the underlying system, pure correlations may exhibit heightened sensitivity. An exponential time-weighting structure that assigns a larger weight to the latest observations and lower weights to older observations can mitigate this effect. The existing literature shows that weighted correlations are smoother and more resilient to market turbulence than unweighted ones (see, e.g. [23]). Additionally, weighted correlations are more effective in distinguishing genuine correlations from spurious ones. Following the definition in Pozzi et al. [24], we define the Pearson correlation coefficient weighted with exponential smoothing as follows:

$$\rho^{w}_{i,j} = \frac{\sum_{t=1}^{\Delta t} w_t (y^i_t - \bar{y}^w_i)(y^j_t - \bar{y}^w_j)}{\sqrt{\sum_{t=1}^{\Delta t} w_t (y^i_t - \bar{y}^w_i)^2}\sqrt{\sum_{t=1}^{\Delta t} w_t (y^j_t - \bar{y}^w_j)^2}}. \tag{1}$$

where $w_t = w_0 e^{\frac{t-\Delta t}{\theta}}, \forall t \in \{1, 2, \ldots, \Delta t\} \wedge \theta > 0$ represents an exponentially smoothed weight structure such that $\sum_{t=1}^{\Delta t} w_t = 1$ and $\bar{y}^w_k = \sum_{t=1}^{\Delta t} w_t y^k_t$. Δt corresponds to rolling windows made of 24 h with steps of 1 h each, and θ is set to 0.1.[7] Based on Eq. (1), we use the Triangulated Maximally Filtered Graph (TMFG) [25,26] to model dependencies among cryptocurrencies. The TMFG belongs to the family of Information Filtering Networks [27–31] and is an effective tool to represent and model dependency structures among variables characterising complex systems. Its building procedure guarantees to optimise specific global properties (e.g. the likelihood) of the system under analysis, imposing, at the same time, two topological constraints: being a planar and chordal graph. A graph is said to be planar if it can be embedded in a sphere without edges crossing. A graph is said to be chordal if all cycles made of four or more vertices have a chord, reducing the cycle to a set of triangles. A chord is defined as an edge that is not part of the cycle but connects two vertices of the cycle itself [26]. The advantage of chordal graphs is that they fulfil the independence assumptions of Markov (i.e., bidirectional or undirected relations) and Bayesian (i.e., directional relations) networks [32,33]. The TMFG is characterised by $3n - 6$ edges (where n is the number of variables in the system) and is composed of three- and four-nodes cliques (i.e. complete subgraphs). Compared to its two main alternatives (i.e. the Minimum Spanning Tree [27] and the Planar Maximally Filtered Graph [31]), the TMFG presents two main advantages: (i) it can be used to generate sparse probabilistic models as a form of topological regularisation [34] and (ii) it is computationally efficient. In this study, cryptocurrencies are represented as nodes, and the edges between them are determined by exponentially smoothed weight correlations (see Eq. (1)). The time-dependent influence of each cryptocurrency is measured through the Eigenvector Centrality [35]. Intuitively, a cryptocurrency has a higher Eigenvector centrality as long as it is connected to other relevant cryptocurrencies, which are also characterised by a high Eigenvector centrality.

[6] After Caroline Ellis announced that Alameda Research would have purchased all of Binance's FTT holdings for USD 22 per token, FTT traded between BUSD 21.83 (i.e. USD 21.85) and BUSD 22 (i.e. USD 22.01) for a couple of hours, suggesting that USD 22 was not a psychological barrier for investors.

[7] The results are consistent for different values of θ.

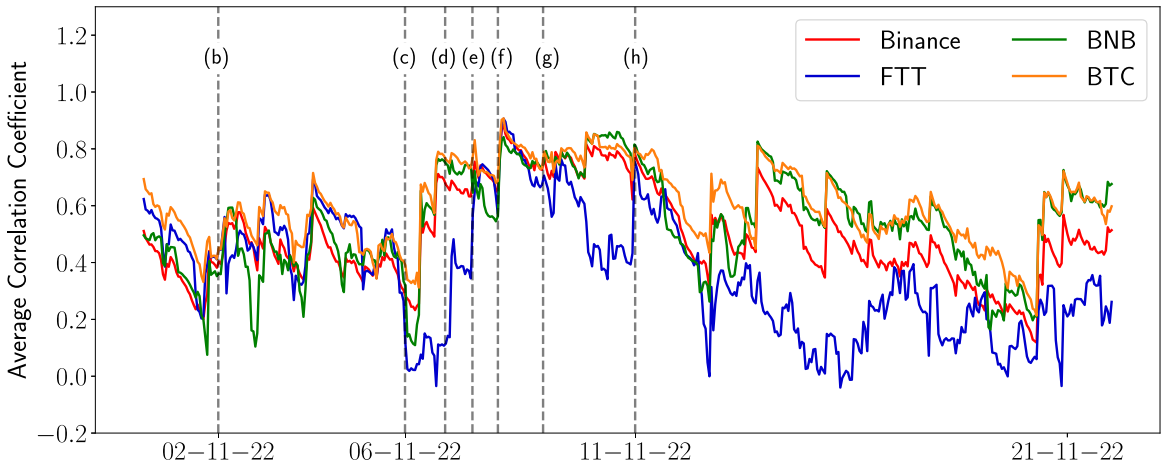

Fig. 6. Exponentially smoothed weighted correlations for FTT, BNB, BTC and Binance digital currency exchange, using 24 h rolling windows with steps of 1 h each. Binance (red line) denotes the average correlation of all the 199 cryptocurrencies, while FTT (blue line), BNB (green line) and BTC (orange line) represent their average correlation with the rest of the system. The figure covers the period from 01 November 2022 to 01 December 2022. Events listed in Table 1 are plotted with dotted lines.

3.2. Buy and hold returns

We use buy-and-hold returns (BHR) to analyse the financial performance of the cryptocurrencies in our dataset (see [36–39]). In the current work, BHR is defined as the relative difference between prices on 01 December 2022 and 01 January 2022. This simple computation allows to quantify the investors' trust in different projects in the crypto space. More specifically, the investors' confidence in a particular project is highlighted by a high cryptocurrency performance relative to the overall market.

4. Results

4.1. Ftx's collapse: Correlations and network analysis

Fig. 6 reports exponentially smoothed average correlation coefficients for FTT, BNB, BTC, and the Binance digital currency exchange.[8] In line with findings in Section 2.3, results indicate that the CoinDesk report did not significantly impact the market's dynamics. The first notable event is observed in (c) when the Binance CEO announced the intention to liquidate all the FTT reserves held by his company. The announcement gave rise to the complete disconnection of FTT from the market (Binance), with an average correlation coefficient close to 0. This finding is coherent with results provided by Conlon et al. [17], who observed the first significant negative FTT's response on 06 November 2022. Afterwards, we identify a continuous increase in market correlations since the whole market reacted to the flow of FTT-related news (i.e. (d), (e) and (f)). The maximum correlation is observed on (f) 08 November 2022, at 19:00 (GMT), shortly after Binance announced a non-binding letter of intent to acquire FTX.

The maximum market correlation coincides with the highest hourly selling pressure in FTT, with BUSD 6.29 million in (net) sales (see Fig. 7), which shows the systemic effect of the FTX's collapse on the market. The trend persisted until the official FTX's bankruptcy (h) when the market correlation decreased remarkably. FTT was then "excluded" from the crypto system.

To enhance our understanding of the system's collective dynamics during the FTX's downfall, we examine assets' centralities within the TMFG. Fig. 8 illustrates the temporal evolution of the Eigenvector Centrality for FTT, BNB, and BTC, computed on non-overlapping rolling windows of 24 hours. We highlight two interesting findings. First, the impact of CoinDesk's report (b) on the FTT Eigenvector Centrality is worth noting. Despite a lack of significant effects on prices (see Fig. 2) and market correlations (see Fig. 6), we observe a decline in Eigenvector Centrality (see Fig. 8) in correspondence of this event. This suggests that following the report's publication on 02 November 2022, FTX and Alameda Research may have ceased their speculative operations with FTT.

Second, Fig. 8 sheds additional light on the potential misuse of FTT. As a utility token, it should have been utilised by FTX to offer incentives to users, such as reduced trading fees or the ability to pay for goods and services.[9] This token was, therefore, not intended to be mainly used for speculative purposes. In other words, FTT and native tokens should

[8] The Binance digital currency exchange represents the average correlation of all the 199 cryptocurrencies available in the study.

[9] See [40] for an overview of the usage of BNB, a utility token similar to FTT.

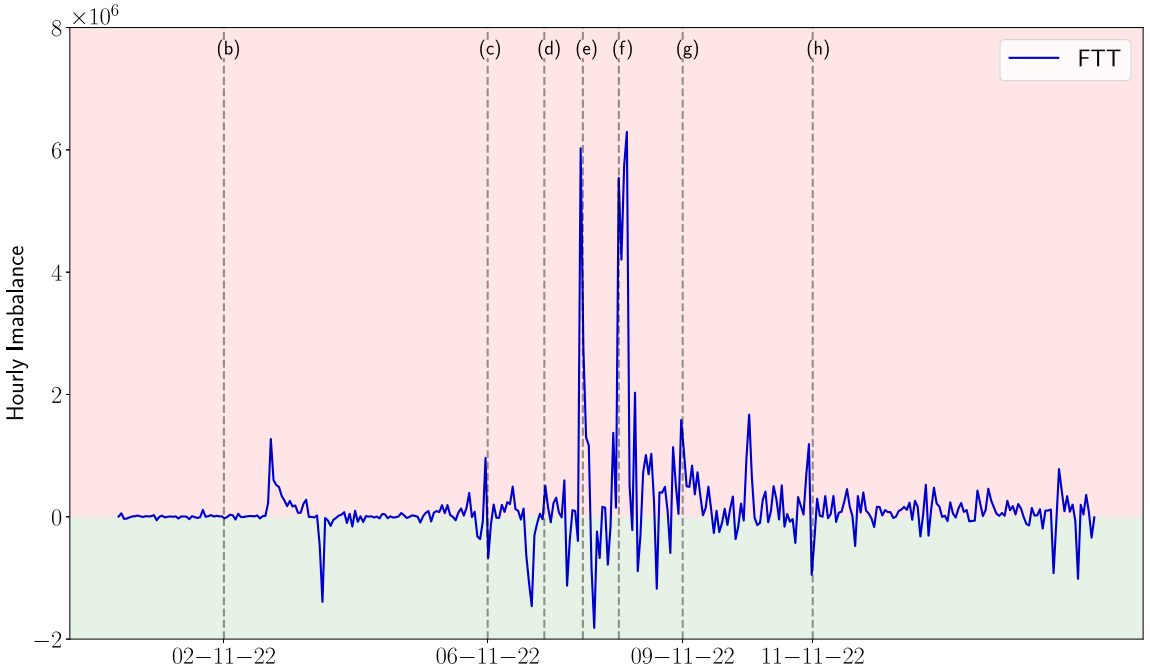

Fig. 7. Hourly imbalance for FTT on the Binance digital currency exchange. Positive values (red colour area) and negative values (green colour area) denote selling and buying pressure, respectively. The figure covers the period from 01 November 2022 to 01 December 2022. Events listed in Table 1 are plotted with dotted lines.

be characterised by a low market correlation and degree of centrality by nature. This phenomenon was firstly analysed by Briola and Aste [41], who found that centralised exchange tokens (e.g., BNB, HT, and HXRO) are characterised by lower market correlation (and lower centrality) compared to digital currencies (e.g., BTC and Litecoin) or smart contract tokens (e.g., ETH and Tron). In that paper, the authors also found a suspicious result, apparently without a clear explanation: FTT was characterised by a high degree of centrality, similar to the one of more speculative cryptocurrencies such as BTC and Litecoin. Given that the authors utilised data from the FTX digital currency exchange, they hypothesised that this result could have been explained by "*an overestimation of the role played by the exchange-specific token, FTT*". As depicted in Fig. 8, FTT exhibits a high degree of centrality also in the Binance digital currency exchange, with peaks even higher than ones of BTC and BNB. In light of what described in the current research work, we can assert, with sufficient confidence, that this behaviour was due to the misuse of FTT as a speculative currency. Specifically, users could only use the 20% of the total supply as a utility token. In contrast, 80% of the supply was used for speculative purposes by Alameda Research's and FTX's managers to take advantage of the upward market and drive up FTT's price. In other words, given the unbalanced FTT supply distribution, FTX's managers could have inflated the token's price during up-market periods as long as credit lines were available. This misuse was reflected in a higher correlation and centrality of FTT. On the contrary, during its ICO, BNB was better distributed among heterogeneous actors, including the foundation team (40%), angel investors (10%), and the general public (50%) [42]. This distribution guaranteed a fair valuation of BNB and correct use as a utility token by Binance's users, giving rise to a lower degree of centrality, as observed by Briola and Aste [41].

4.2. Binance: the raise of centralised digital finance

Despite the tremendous effects on the trust on the crypto movement, the failure of FTX in November 2022 was beneficial for the exchange's immediate competitor: Binance. In Table 2, we report the ten cryptocurrencies with the worst and best performance in terms of BHR from 01 January 2022 to 01 December 2022. The median BHR for the sample is −79%, with 25th and 75th percentiles of −69% and −87%, respectively. Despite the Ukraine–Russia conflict [21], Terra-Luna's collapse [2] and contractive monetary policies [22], BNB is among the best performing assets, with a BHR of −43.5%. This result demonstrates the investors' confidence in Binance and the consolidation of the cryptocurrency market around this Firm. Moreover, as a consequence of the FTX's failure, Binance reported a 30% increase in trading activity [43], further emphasising its growing dominance in the crypto space since 2022.[10] This point is also supported by the number of daily

[10] Binance exchange has experienced a consistent growth in trading activity since 2022. This surge in activity can be attributed to various factors, including the implementation of promotions and features by the platform. For instance, Binance introduced the elimination of trading fees for all 13 BTC spot trading pairs, as well as the BUSD zero maker fee promotion. These initiatives contributed to the growing popularity and engagement of traders on the platform.

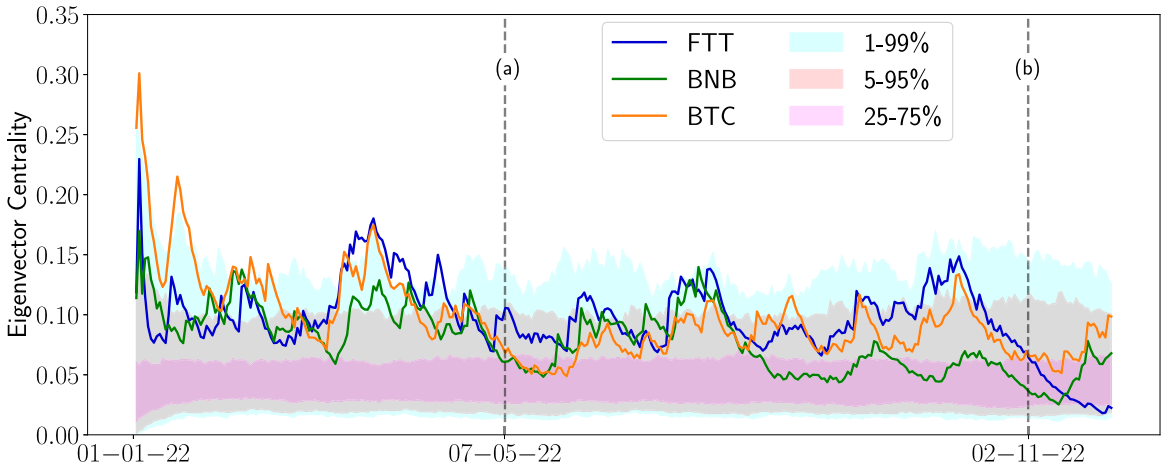

Fig. 8. Non-overlapping eigenvector centrality for FTT, BNB and BTC using a 24 h rolling window. Colour areas show the distribution of the eigenvector centrality for the rest of cryptocurrencies considering 1%–99%, 5%–95%, and 25%–75% percentiles. The figure covers the period from 01 January 2022 to 01 December 2022. The figure covers the period from 01 January 2022 to 01 December 2022. Triggering events for the Terra-Luna' and FTX's collapse are plotted with dotted lines.

Table 2
Buy and hold (BHR) returns from 01 January 2022 to 01 December 2022. First row reports cryptocurrencies showing the most negative returns, while the second row reports cryptocurrencies showing the most positive returns.

Crypto (−)	SPELL	RAY	FTT	ILV	MOVR	JASMY	MIR	PERP	GALA	HNT
BHR	−0.974	−0.971	−0.967	−0.959	−0.956	−0.947	−0.947	−0.945	−0.945	−0.941
Crypto (+)	CHZ	BNB	ETC	UNFI	DOGE	XMR	QNT	TRX	LAZIO	TWT
BHR	−0.442	−0.435	−0.428	−0.426	−0.408	−0.382	−0.323	−0.287	0.068	2.123

active users in the blockchain infrastructure, on 01 December 2022, since BNB chain was the leader with 1,497,102 daily active users, followed by Ethereum (313,110), Polygon (361,252), PancakeSwap (146,097) and Solana (107,943) [44].

The growing dominance of Binance can be further assessed by considering the top two crypto assets performers in 2022, LAZIO and TWT. On the one hand, LAZIO appears to have a financial advantage in its niche (see, e.g. [45]) due to the presence on Binance digital currency exchange. This advantage is further bolstered by Binance's sponsorship of S.S. Lazio football club, which prominently displays the Binance brand on the team's jerseys [46]. On the other hand, TWT is the native token of Trust Wallet, a self-custodian cryptocurrency wallet founded by Viktor Radchenko in November 2017 and acquired by Binance in July 2018. Interestingly, on 13 November 2022, Binance CEO tweeted about the advantages of self-custodianship and the role of Trust Wallet in this regard, leading to a 47% increase in the value of TWT [47].

In line with this findings, we also highlight Binance's relevance in the stablecoin market with the presence of BUSD. As shown in Fig. 9, on 01 December 2022, BUSD represented approximately the 50% of the entire stablecoins' supply on digital currency exchanges. Similarly, Fig. 10 shows how BUSD increased its value by 54% since 01 January 2022, while its main centralised competitors (i.e. USDT and USDC) registered comparatively worse market performances (i.e. −17% and 1%, respectively). Interestingly, the decentralised option, DAI, was the most affected by the Terra-Luna's collapse, with a decrease in market cap equal to −42%. This result could highlight a potential shift in users' sentiment, with the centralised option preferred over the decentralised one. This would be in line with what is stated in Duan and Urquhart [48], where the authors observe that "*BUSD is found as the most stable stablecoin with the fastest correction speed*", while DAI is the least stable.[11]

5. Conclusion

This paper investigates the causes and effects of the FTX's failure in November 2022. Our contribution to the existing literature is threefold. First, we use three different data sources (i.e. hourly closing prices, on-chain data and transaction data) to quantitatively analyse the events at different granularities. Second, we study the evolution of dependency structures among 199 cryptocurrencies and capture the phases of the market's reaction to the ongoing downfall. We

[11] BUSD is a Binance branded stablecoin, issued by Paxos Trust company. Paxos is a regulated institution supervised by the New York Department of Financial Services (NYDFS). On 13 February 2023, NYDFS ordered Paxos Trust to stop the issuance of BUSD, since the United States Securities and Exchange Commission alleged that BUSD is an unregistered security [49]. Binance informed that they "*will make product adjustments accordingly*" [50].

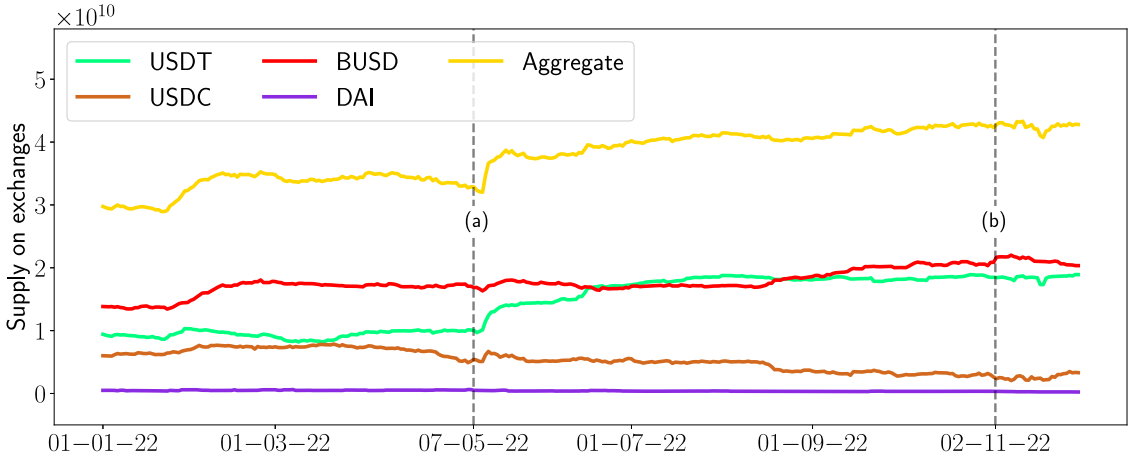

Fig. 9. Supply held on exchanges' reserves of the top four stablecoins (i.e. USDT, USDC, BUSD and DAI). The figure covers the period from 01 January 2022 to 01 December 2022. Triggering events for the Terra-Luna' and FTX's collapse are plotted with dotted lines.
Source: Data are retrieved from Glassnode [18].

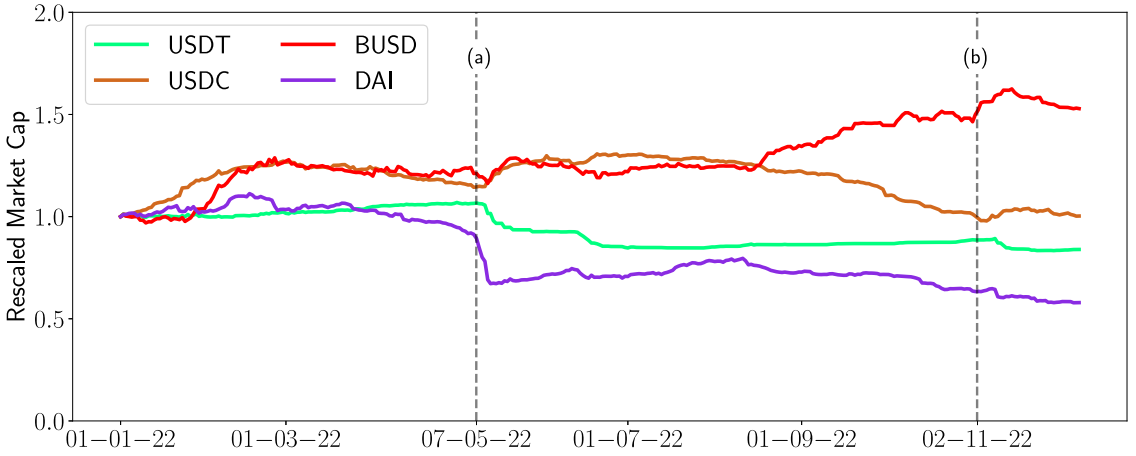

Fig. 10. Rescaled market capitalisation of the top four stablecoins (i.e. USDT, USDC, BUSD and DAI). The figure covers the period from 01 January 2022 to 01 December 2022. Triggering events for the Terra-Luna' and FTX's collapse are plotted with dotted lines.
Source: Data are retrieved from Defillama [51].

show that the absence of adequate prudential regulation and the lack of transparency could have allowed FTX to build a leverage mechanism characterised by (i) the issuance of non-collateralised native tokens (FTT), (ii) control over the majority of FTTs, and (iii) unlimited loan requests using FTT as collateral despite its lack of inherent value. We also show that the decline of FTX was triggered by Terra-Luna's crash, which resulted in a decrease in FTT's price and a sudden reduction of credit availability. Despite the attempts to hide the compromised financial situation by selling digital reserves and misappropriating customers' funds to pay loans, the reliance of FTX and Alameda Research on FTT was finally reported by CoinDesk, raising a Twitter debate on the stability of the Firm. We identify the Binance announcement to sell FTT reserves as the catalyst for FTX's collapse. At the same time, the systemic impact of the downfall on the cryptocurrency market was evident only after the attempt to sell the company. As a third contribution, we analyse the effects of the FTX's collapse on the process which is driving the crypto movement toward centralisation. Specifically, we demonstrate that the consolidation of Binance's leading role in the crypto space in response to the FTX's downfall recalls the urgency to protect users preventing the creation of opaque monopolies. In 2022, Binance's volume market share increased from 48.7%, in the first quarter, to 66.7%, in the last quarter [52]. When Bitcoin was created in 2008, Satoshi Nakamoto [53] stated that "*what is needed is an electronic payment system based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party*". After 15 years, the cryptocurrency industry appears to be moving toward centralisation, with third-party entities serving as the primary means for exchanging cryptocurrencies. Despite not being created by central banks, cryptocurrencies are now predominantly managed by unregulated private companies acting as traditional financial institutions (e.g. paying interests

for deposits, providing landings and releasing debit cards). These centralised and unregulated entities cannot be considered part of the new digital economy since they are a transposition of the existing regulated financial institutions inside the crypto space. Decentralised Finance (DeFi) should be the obvious candidate to support the future digital economy, given that it naturally provides users on-chain transparency, self-custody, governance, and fair access to financial products. Consequently, DeFi could avoid the governance issues represented by FTX, whose managers were able to raise USD 2 billion from 80 investors [54], misuse users' funds, and create an articulate corpus of 130 side companies without any supervision. Unfortunately, as underlined by Fu et al. [6] and Aramonte et al. [55], given its security risks and excessive concentration of decision power in the hands of large coin-holders, DeFi cannot yet be considered a mature solution.

CRediT authorship contribution statement

David Vidal-Tomás: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing. **Antonio Briola:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing. **Tomaso Aste:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing – review & editing.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

The authors do not have permission to share data.

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Appendix

List of the 199 cryptocurrencies analysed in the current paper. For each asset, the symbol, the name, the category (if available) and the corresponding sector (if available) according to the taxonomy proposed by [56] is reported.

Symbol	Name	Category	Sector
AAVE	Aave	Financial	Lending
ADA	Cardano	Infrastructure	Smart Contract Platforms
ADX	Adex	Media and Entertainment	Advertising
AERGO	Aergo	Infrastructure	Enterprise and BaaS
ALCX	Alchemix	Financial	Lending
ALGO	Algorand	Infrastructure	Smart Contract Platforms
ALICE	Alice	Media and Entertainment	Gaming
ALPACA	Alpaca Finance	–	–
ALPHA	Alpha Finance	Financial	Asset Management
AMP	Amp	Financial	Payment Platforms
ANT	Aragon Network	Infrastructure	Misc
AR	Arweave	Services	File Storage
ARPA	Arpa	–	–
ATOM	Cosmos	Infrastructure	Smart Contract Platforms
AUDIO	Audius	Media and Entertainment	Content Creation and Distribution
AUTO	Cube	Services	AI
AVA	Travala.com	Payments	Payment Platforms
AVAX	Avalanche	Infrastructure	Smart Contract Platforms
AXS	Axie Infinity	Media and Entertainment	Gaming
BADGER	Badger DAO	Financial	Decentralised Exchanges
BAKE	BakerySwap	–	–
BAL	Balancer	Financial	Decentralised Exchanges

BAND	Band Protocol	Infrastructure	Data Management
BAR	FC Barcelona Fan Token	–	–
BAT	Basic Attention Token	Media and Entertainment	Advertising
BCH	Bitcoin Cash	Payments	Currencies
BEL	Bella	Financial	Asset Management
BICO	Biconomy	–	–
BIFI	Beefy.Finance	–	–
BNB	BNB	Financial	Smart Contract Platforms
BNT	Bancor	Financial	Decentralised Exchanges
BOND	BarnBridge	Financial	Derivatives
BTC	Bitcoin	Payments	Currencies
BTCST	Bitcoin Standard Hashrate Token	–	–
BURGER	Burger Swap	–	–
CAKE	PancakeSwap	–	–
CELO	Celo	Infrastructure	Smart Contract Platforms
CELR	Celer Network	Infrastructure	Scaling
CFX	Conflux Network	Infrastructure	Smart Contract Platforms
CHR	Chromia	Infrastructure	Application Development
CHZ	Chiliz	Media and Entertainment	Payment Platforms
CKB	Nervos Network	Infrastructure	Smart Contract Platforms
COCOS	Cocos-BCX	–	–
COTI	Coti	Infrastructure	Application Development
CRV	Curve	Financial	Decentralised Exchanges
CTK	CertiK	Infrastructure	Smart Contract Platforms
CTSI	Cartesi	Infrastructure	Smart Contract Platforms
CTXC	Cortex	Services	AI
CVX	Convex Finance	–	–
DASH	Dash	Payments	Currencies
DTA	DATA	Media and Entertainment	Advertising
DENT	Dent	Services	Data Management
DEXE	DeXe	–	–
DF	dForce	–	–
DGB	DigiByte	Payments	Currencies
DIA	DIA	Infrastructure	Data Management
DODO	DODO	Financial	Decentralised Exchanges
DOGE	Dogecoin	Payments	Currencies
DOT	Polkadot	Infrastructure	Smart Contract Platforms
EGLD	MultiversX	Infrastructure	Smart Contract Platforms
ELF	aelf	Services	Shared Compute
ENJ	Enjin Coin	Media and Entertainment	Gaming
ENS	Ethereum Name Service	Infrastructure	Identity
EOS	EOS	Infrastructure	Smart Contract Platforms
ERN	Ethernity Chain	Media and Entertainment	Collectibles
ETC	Ethereum Classic	Infrastructure	Smart Contract Platforms
ETH	Ethereum	Infrastructure	Smart Contract Platforms
FARM	Harvest Finance	Financial	Asset Management
FET	Fetch.ai	Infrastructure	Artificial Intelligence
FIDA	Bonfida	–	–
FIL	Filecoin	Infrastructure	File Storage
FIO	FIO Protocol	Payments	Interoperability
FLOW	Flow	Infrastructure	Smart Contract Platforms
FORTH	Ampleforth Governance Token	Payments	Currencies
FRONT	Frontier	Infrastructure	Asset Management
FTM	Fantom	Infrastructure	Smart Contract Platforms
FTT	FTX Token	Financial	Centralised Exchanges
FXS	Frax Share	Financial	Stablecoins
GALA	Gala	Media and Entertainment	Gaming
GHST	Aavegotchi	Media and Entertainment	Gaming
GRT	The Graph	Infrastructure	Data Management

HBAR	Hedera Hashgraph	Infrastructure	Smart Contract Platforms
HIVE	Hive	Media and Entertainment	Content Creation and Distribution
HNT	Helium	Infrastructure	IoT
HOT	Holo	Infrastructure	Application Development
ICP	Internet Computer	Infrastructure	Smart Contract Platforms
ICX	ICON	Infrastructure	Smart Contract Platforms
IDEX	IDEX	Financial	Decentralised Exchanges
ILV	Illuvium	Media and Entertainment	Gaming
INJ	Injective Protocol	Financial	Derivatives
IOST	IOST	Infrastructure	Smart Contract Platforms
IOTX	IoTeX	Infrastructure	IoT
IQ	Everipedia	–	–
JASMY	Jasmy	–	–
JOE	Trader Joe	Financial	Decentralised Exchanges
JST	JUST	Financial	Decentralised Exchanges
KLAY	Klaytn	Infrastructure	Smart Contract Platforms
KNC	KyberNetwork	–	–
KP3R	Keep3rV1	–	–
KSM	Kusama	Infrastructure	Smart Contract Platforms
LAZIO	Lazio Fan Token	–	–
LINA	Linear	–	–
LINK	Chainlink	Services	Data Management
LIT	Litentry	–	–
LPT	Livepeer	Infrastructure	Shared Compute
LRC	Loopring	Financial	Decentralised Exchanges
LSK	Lisk	Infrastructure	Application Development
LTC	Litecoin	Payments	Currencies
LTO	LTO Network	Infrastructure	Enterprise and BaaS
MASK	Mask Network	Services	Data Management
MATIC	Polygon	Infrastructure	Scaling
MBOX	Mobox	–	–
MC	Merit Circle	Financial	Gaming
MDX	MDX	Financial	Decentralised Exchanges
MINA	Mina	Infrastructure	Smart Contract Platforms
MIR	Mirror Protocol	Financial	Derivatives
MKR	Maker	Financial	Lending
MLN	Enzyme Finance	Financial	Asset Management
MOVR	Moonriver	Infrastructure	Smart Contract Platforms
MTL	Metal	Payments	Payment Platforms
NEAR	NEAR Protocol	Infrastructure	Smart Contract Platforms
NEO	NEO	Infrastructure	Smart Contract Platforms
NMR	Numeraire	Financial	Asset Management
NULS	NULS	Infrastructure	Enterprise and BaaS
OCEAN	Ocean Protocol	Services	Data Management
OGN	Origin Protocol	–	–
OM	MANTRA DAO	Financial	Lending
OMG	OMG Network	Infrastructure	Scaling
ONE	Harmony	–	–
ONT	Ontology	Infrastructure	Smart Contract Platforms
ORN	Orion Protocol	Financial	Decentralised Exchanges
OXT	Orchid	Services	Data Management
PEOPLE	ConstitutionDAO	–	–
PERP	Perpetual Protocol	Financial	Derivatives
PHA	Phala.Network	–	–
PLA	PLA	Payments	Gaming
POLS	Polkastarter	Financial	Crowdfunding
POND	Marlin	Infrastructure	Smart Contract Platforms
POWR	Power Ledger	Services	Energy
PROM	Prometeus	–	–

PSG	Paris Saint-Germain Fan Token	–	–
PYR	Vulcan Forged	Media and Entertainment	Gaming
QNT	Quant Network	Infrastructure	Interoperability
QTUM	Qtum	Infrastructure	Smart Contract Platforms
RAD	Radicle	–	–
RARE	SuperRare	–	–
RAY	Raydium	Financial	Decentralised Exchanges
REEF	Reef	–	–
REN	Ren	Financial	Interoperability
REQ	Request Network	Financial	Payment Platforms
RNDR	Render Token	Services	Shared compute
ROSE	Oasis Network	–	–
RSR	Reserve Rights	Financial	Asset Management
RUNE	THORChain	–	–
RVN	Ravencoin	Payments	Currencies
SAND	The Sandbox	Media and Entertainment	Gaming
SC	Siacoin	Services	File Storage
SCRT	Secret Network	Infrastructure	Smart Contract Platforms
SHIB	Shiba Inu	Payments	None
SKL	SKALE Network	Infrastructure	Scaling
SNX	Synthetix	Financial	Derivatives
SOL	Solana	Infrastructure	Smart Contract Platforms
SPELL	Spell Token	Financial	Lending
SRM	Serum	Financial	Decentralised Exchanges
STMX	StormX	Payments	Rewards
STPT	Standard Tokenization Protocol	–	–
STRAX	Stratis	–	–
STX	Stacks	Infrastructure	Smart Contract Platforms
SUN	SUN	–	–
SUPER	SuperFarm	–	–
SUSHI	SushiSwap	Financial	Decentralised Exchanges
SXP	Swipe	Financial	Payment Platforms
SYS	Syscoin	Infrastructure	Scaling
THETA	Theta Network	Media and Entertainment	Content Creation and Distribution
TOMO	TomoChain	Infrastructure	Smart Contract Platforms
TRB	Tellor	Infrastructure	Data Management
TRIBE	TRIBE	–	–
TRX	TRON	Infrastructure	Smart Contract Platforms
TWT	Trust Wallet Token	Financial	Payment Platforms
UFT	UniLend	Financial	Lending
UNFI	Unifi Protocol DAO	Financial	Interoperability
UNI	Uniswap	Financial	Decentralised Exchanges
UTK	UTRUST	Payments	Payment Platforms
VET	VeChain	Infrastructure	Smart Contract Platforms
WAVES	Waves	Infrastructure	Smart Contract Platforms
WAXP	WAX	Media and Entertainment	Collectibles
WIN	WINkLink	–	–
WING	Wing Finance	Financial	Lending
WRX	WazirX	Financial	Centralised Exchanges
XEC	eCash	Payments	Currencies
XLM	Stellar	Payments	Currencies
XMR	Monero	Payments	Currencies
XTZ	Tezos	Infrastructure	Smart Contract Platforms
XVG	Verge	Payments	Currencies
XVS	VENUS	Financial	Lending
YFI	yearn.finance	Financial	Asset Management
ZEC	Zcash	Payments	Currencies
ZIL	Zilliqa	Infrastructure	Smart Contract Platforms
ZRX	0x	Financial	Decentralised Exchanges

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