A Shortfall in Investor Expectations of Leveraged Tokens

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Abstract

Leveraged tokens (LVTs) are emerging crypto-assets primarily issued by centralized exchanges. The concept is borrowed from leveraged ETFs (LETFs) in traditional financial markets, which offer higher gains (and higher losses) relative to price movements in the underlying asset. Leverage is commonly used by short-term traders to amplify returns from daily market shifts. However, LVTs have been implemented differently from LETFs by exchanges in the crypto market, with variations across platforms. We examine the mechanics and constituent components of LVTs, demonstrating that the lack of a standard has resulted in deficiencies and unexpected technical and economic outcomes. To identify existing problems, we analyze more than 1,600 leveraged tokens from 10 issuers. Our analysis reveals that 99.9% of LVTs are centralized, with 80% lacking blockchain interaction, leading to transparency issues. Total supply information is difficult to access for 53% of them, and 41% appear inadequately backed at launch. Additionally, 97% of LVTs are vulnerable to front-running during well-known events, and they deviate from their stated leverage ratios more than LETFs, partly due to inconsistent re-leveraging processes and higher management fees. This work provides a framework for crypto investors, blockchain developers, and data analysts to gain a deep understanding of leveraged tokens and their impact on market dynamics, liquidity, and price movements. It also offers insights for crypto exchanges and auditors into the internal functionalities and financial performance of LVTs under varying market conditions.

2012 ACM Subject Classification Security and privacy

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1 Introduction

A typical Exchange-Traded Fund (ETF) is a weighted basket of stocks from firms with a common characteristic (e.g., they all operate in a specific sector or have a high market capitalization). The issuer splits the basket into shares, which are bought and sold on exchanges just like individual stocks [32].

▶ **Example 1.** One of the most widely traded ETFs is the *SPDR S&P500 ETF*, with the ticker symbol *SPY*. It is issued by SSGA[1] and holds a basket of stocks from nearly 500 publicly traded companies that are included in the S&P500[2] index. The S&P500 index has globally served as a gauge for the performance of the U.S. stock market as a whole, due to its depth and diversity. Since SPY tracks the S&P500 index, investors can gain broad exposure and diversify their investment risk across the stock performance of 500 companies in 11 sectors without the logistics or starting capital required to buy shares in all these companies.

Leveraged ETFs (LETFs) were introduced in 2006 and are ETFs designed to amplify the daily performance of the underlying basket (more on leverage in Section 3.1).[3] Inverse LETFs aim to achieve a return that is a multiple of the inverse of the underlying asset's daily performance [25, 11, 42]. Many investors alternatively refer to LETFs and inverse LETFs as "Bullish" and "Bearish" LETFs, respectively, reflecting their short-term sentiment on future price movements.

▶ **Example 2.** *Direxion Daily S&P500 Bull 3x ETF (SPXL)* is a 3x (three times) LETF that seeks to deliver triple the daily performance of the S&P500. It magnifies each 1% gain in the S&P500 index into a 3% gain and loses 3% for every 1% drop in the index. *Direxion Daily S&P500 Bear 3x ETF (SPXS)* delivers triple the opposite daily performance of the S&P500 index. If the S&P500 index depreciates by 1%, SPXS gains 3%, and vice versa [52, 30].

A Leveraged Token (LVT) in the cryptocurrency and crypto-asset ("crypto") market can be compared to a Leveraged ETF (LETF) in the traditional financial market. Similar to LETFs, LVTs use leveraged products available in the crypto market to outperform the underlying asset's return on a daily basis. While the majority of LETFs are actively managed funds[4], LVTs employ one of three management models: (i) centralized, (ii) decentralized, and (iii) hybrid. Centralized LVTs are primarily managed by crypto exchanges and can be purchased on the spot market or directly from the exchange (*cf.* Appendix A.5 of the full version [40] on investing in LVTs). Decentralized LVTs operate on-chain and can be traded by interacting directly with the smart contract. Hybrid LVTs are essentially decentralized LVTs that are traded on centralized crypto exchanges. Users trade on centralized exchanges for their user-friendly interfaces, continuous-time order books (rather than automated market makers, which are the only trading mechanism efficient enough to run on-chain), and increased liquidity due to aggregated buy and sell orders.[5] However, this model introduces certain disadvantages resulting from the combination of centralized and decentralized systems (*e.g.* functional complexities, security concerns, custodial risks, *etc.*).

▶ **Example 3.** An issuer may offer BTC3L/BTC3S as a pair of LVTs tracking Bitcoin (BTC) as the underlying asset. A Bitcoin futures contract (BTC-Perp[6]) can be used as the leveraged product to outperform Bitcoin in the short term. The number three in the LVT name

[1] State Street Bank and Trust Company (SSGA) is one of the three dominant companies in the ETF market, with a 14.01% market share, following BlackRock and Vanguard, which have 33.64% and 29.16%, respectively [46].
[2] The S&P 500 index comprises 500 of the top publicly traded companies in the U.S. It was launched in 1957 by the credit rating agency Standard and Poor's [26].
[3] The underlying asset can be stocks, market indexes (e.g., S&P 500, NASDAQ-100, etc.), commodities (e.g., gold, oil, corn, etc.), or any asset with a price.
[4] In actively managed funds, investment managers actively buy and sell assets with the goal of outperforming a specified benchmark index, resulting in higher management fees.
[5] The more liquid an asset is, the easier and more efficient it is to convert back into cash. Less liquid assets take more time and may incur higher costs [24].
[6] A type of Bitcoin futures contract without a defined expiration date (known as a "perpetual" contract).

Table 1 *Left table:* Number of issued leveraged tokens per year, average per year, and number of unique underlying assets, which we collected manually from different sources. An underlying asset might be used to create multiple tokens with different leverage levels. *Right table:* Characteristics of issued LVTs by different issuers. Only 20% of tokens have been created on the blockchain. 99.9% of LVTs use derivatives as the leveraged product, which is offered by the same issuer (Internal for Pionex as of Jan 2023). Except for *Index Coop*, the rest of the issuers use off-chain fund management systems. Rebalancing triggers for *Index Coop* are still off-chain.

	Number of LVTs per year							
Issuer	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**	**Average**	**Underlying Assets**
MEXC		162	116	102	76	456	114	217
AscendEX				228	112	340	170	94
Gate.io		116	96	54	8	274	69	123
Pionex		60	102	36	2	200	50	76
FTX	102	27				129	65	43
KuCoin			50	6	38	94	31	45
Binance		38	2			40	20	20
ByDFi				16	24	40	20	20
ByBit				34		34	34	17
Index Coop			2			2	2	2
Total	**102**	**403**	**368**	**476**	**260**	**1609**	**322**	**654**

<table>
<tr><th colspan="4">Characteristics of LVTs</th></tr>
<tr><th>Fund Source</th><th>Blockchain Rep.</th><th>Fund Management Algorithm</th><th>Leveraged Product</th></tr>
<tr><td rowspan="3">Internal</td><td rowspan="4">No</td><td rowspan="9">Off-Chain</td><td rowspan="9">Futures</td></tr>
<tr></tr>
<tr></tr>
<tr><td>Internal / External</td></tr>
<tr><td rowspan="5">Internal</td><td>Yes</td></tr>
<tr><td rowspan="4">No</td></tr>
<tr></tr>
<tr></tr>
<tr></tr>
<tr><td>External</td><td>Yes</td><td>On-Chain / Off-Chain</td><td>Debt</td></tr>
</table>

represents the multiplier (triple-leveraged), while L/S stands for going long/short on the market.[7] BTC3L gains 3% when the price of Bitcoin rises by 1%, and loses 3% for every 1% price drop. Conversely, when Bitcoin drops by 1%, BTC3S gains 3%, and loses 3% for every 1% price rise.

Since 2019, more than 1,600 LVTs have been issued by various crypto exchanges. The FTX exchange introduced the original concept by issuing 102 tokens on the blockchain.[8] Trading volumes exceeded $1 million per day [15]. This upward trend has continued, with other exchanges issuing approximately 32 new LVTs per month on average from January 2020 to November 2023 (see Table 1).

Motivation for studying LVTs

- *LVT attractiveness for investors:* Investment in LETFs nearly doubled in 2022 compared to 2021 [48], demonstrating an appetite for low-risk leverage, which is satisfied in the crypto market by LVTs. LVTs reduce liquidation risks compared to derivatives and margin trading. However, other characteristics (e.g., volatility drag) must be understood to avoid unexpected value destruction. These risks are not unique to LVTs; they also exist in LETFs.[9] (See the full version [40], Appendix A.5, and comparative Table 6 for more details on why investors are attracted to this type of token.)
- *LVT distinctive dynamics:* Section 2 offers a cohesive framework for understanding key aspects of LVTs, such as their underlying dynamics, peculiarities in product design, effects on crypto markets, and investor suitability. Leveraged products can impact market dynamics, especially in highly volatile markets [44]. More technical details are provided in Section 3, which can be useful for those involved in the design and implementation of LVTs to understand how these tokens affect liquidity and price movements, potentially influencing the robustness and reliability of trading algorithms.

[7] Going long refers to buying an asset with the expectation that its value will increase, allowing it to be sold for a profit later. Conversely, going short refers to profiting from a decline in the asset's value [27].
[8] The ERC-20 standard is the most prominent standard for fungible tokens on the Ethereum blockchain. These tokens can represent financial assets such as LVTs and can be exchanged between users.
[9] In 2018, Credit Suisse had to close an LETF ETN after its price plunged 90% in one day. In another example, WisdomTree had to close its 3x oil products in March 2020 after their value was wiped out [48].

- *Regulatory implications:* LVTs introduce new risks for market regulation, investor protection, and financial stability. Our work contributes to broader discussions on how to effectively regulate emerging financial technologies like LVTs. Additionally, since LVTs are often held by commercial firms requiring audited financial statements [17], auditors should understand how LVTs function, their risks, and how they perform under different market conditions.

Contributions of this paper

In this work, we study more than 1,600 leveraged tokens from 10 issuers, examining various aspects such as underlying assets, interaction with the blockchain, types of leveraged products, and fund management algorithms. We dedicate part of the paper to carefully explaining LVT mechanics and constituent components to help the reader understand the functionality of leveraged funds, rebalancing mechanisms, and smart contracts. We then address six research questions about LVTs:

- RQ 1: What information is visible to traders of an LVT?
- RQ 2: To what extent are LVTs locked to the offering exchange?
- RQ 3: Are the LVTs offered today adequately backed?
- RQ 4: What are the possibilities of front-running in LVTs?
- RQ 5: How well do LVTs track their asserted leverage ratios?
- RQ 6: Are LVT fees in-line with traditional LETFs?

Methodology of measurements and dataset

To extract the list of issuers, we identified the top 100 crypto exchanges based on 24-hour trading volume, as reported by crypto comparison websites.[10] Then, by visiting each provider's website, we manually checked whether LVTs were offered. We supplemented this with searches on Google[11], online forums and blogs[12], and crypto news sites[13]. The combined list should be comprehensive as of 2023 and includes LVTs from various types of exchanges (both large and small, centralized and decentralized), covering different asset classes.

The majority of LVTs exhibited common elements that allowed for formal representation in Section 2. We reviewed each LVT's documentation to understand its functionality [22, 3, 16, 38, 39, 29, 5, 7, 6, 14], enabling us to identify their components as discussed in Section 3. Outliers that did not fit into the typical LVT model due to unique structural features were not excluded (e.g., Hybrid LVTs by FTX). Instead, the model was generalized to include these 6% of outliers. We have described the parts of the model that were extended for this category (e.g., the smart contract component for decentralized LVTs).

In Section 4, the functionality of tokens is evaluated by answering six research questions. To address these, we collected data from both the token issuers and historical data available through various exchanges and financial databases. Issuer documentation provided crucial details on the structure, mechanics, and intended use of LVTs. Historical data were gathered from reputable financial data providers[14], including price histories, trading volumes, issuance dates, and other relevant metrics. Additionally, we cross-referenced data from multiple sources

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[10] Websites: `coinecko.com`, `coinmarketcap.com`, `cryptocompare.com`, and `coinranking.com`.
[11] Search terms: leveraged tokens, leveraged ETFs cryptocurrency, leveraged crypto assets, crypto leverage trading platforms, crypto leverage trading token issuers, etc.
[12] Crypto blogs and forums such as `reddit.com` (e.g., /cryptocurrency or /binance subreddits).
[13] News sources: `coindesk.com` and `cointelegraph.com`.
[14] Data sources: `tradingview.com`, `cryptodatadownload.com`, `etherscan.io`, and `finance.yahoo.com`.

to validate the accuracy and consistency of our dataset. It is worth mentioning that the analyzed data from sources (e.g., `tradingview.com`) are aggregated directly from the source exchanges, ensuring the information is accurate and up-to-date. The direct connection to exchanges means that the data reflect real-time market conditions and historical performance accurately. Moreover, these data sources are widely used and trusted within the financial and cryptocurrency communities, providing tools and data to a large number of traders, analysts, and researchers, underscoring their credibility.

Related work

To our knowledge, this is the first academic paper on LVTs; however, our work overlaps with studies on LETFs, which have established the following research findings:

- The effect of compounded returns intensifies with longer holding periods, causing LETFs to struggle to maintain their stated leverage over time. As a result, long-term performance is not linearly related to the return of the underlying asset [50, 34, 23, 12, 9].
- LETFs can underperform over longer periods without efficient rebalancing. Researchers state that frequent rebalancing during periods of high volatility is necessary to maintain leveraged exposure to the tracking index. They conclude that reducing rebalancing frequency can significantly decrease tracking errors [9, 8, 18].
- The impact of LETFs on market volatility and liquidity shows that their daily rebalancing can increase volatility and trading volume near the market close, potentially distorting the market price of LETFs and creating additional inefficiencies [12, 23, 9, 49, 41, 44].
- Investors often do not fully understand the mechanisms, risks, and proper uses of LETFs, which require tolerating increased risk. Consequently, LETFs are suitable only for experienced and skilled investors who comprehend the complexities and hazards of trading with them [9, 18, 31].

2 Price and Return Dynamics

As daily returns is embedded in the design of LVTs, a k-leveraged LVT should generally earn k times of the daily return of the underlying. The amplification ratio, known as leverage (k), can be fixed or dynamic. A proportional change in the underlying price is k-times the proportional change in LVT price. In the short-term, LVT return is consistent with k, but beyond a single day, the return is highly path dependent, making LVTs unsuitable for buy-and-hold strategies. This is an issue that is ignored by most retail investors, leading to unexpected loss of capital. In the following, the price and return dynamics of LVTs have been discussed, aiding analysis and simulation of such issues.

2.1 LVT Price Dynamics

LVTs are intentionally designed with leverage as a core component of their architecture. They are aimed at outperforming the return of the underlying benchmark on a daily basis.[15] Let P_{t_n} represent the LVT price at calendar time t_n, expressed as:

$$P_{t_n} = P_{t_{n-1}} \left(1 + k\frac{\Delta S_{t_n}}{S_{t_{n-1}}}\right) \qquad n \in [1, 365), t \geq 0, k \in [-5, -0.5] \cup [0.5, 5] \tag{1}$$

[15] Returns will be slightly lower after deducting fund management fees, accounting for market volatility, interest paid on borrowing, and other associated expenses.

S_{t_n} is the underlying price at time t_n, indexed by n, where n denotes the days of the year. The frequency of n does not have to be daily; it can be redefined in hours or minutes without any loss of generality. However, since daily returns are embedded in the LVT product design, n is effectively daily. P_{t_n} represents the price of the LVT at the close of trading day n. $S_{t_{n-1}}$ and $P_{t_{n-1}}$ are the initial prices of the underlying asset and LVT, respectively, at the beginning of trading day n (or at the end of trading day $n-1$). ΔS_{t_n} is the amount of change in the underlying price relative to the initial price. The constant variable k is the LVT multiplier (leverage), which can be defined as either a fixed or dynamic value, depending on the issuer. LVTs with fixed leverage can take values from the set $\{-5, -3, -2, -1, -0.5, 0.5, 2, 3, 5\}$, while dynamic leverage fluctuates within the range $[-4.0, -1.25] \cup [1.25, 4.0]$.

The multiplier k further divides LVTs into three main functional groups: (i) Long LVTs, where $k \in \{2, 3, 5\} \cup [1.25, 4.0]$. The value of a long LVT rises k times faster than the underlying asset and is profitable in rising markets; (ii) Short LVTs, where $k \in \{-5, -3, -2, -1\} \cup [-4.0, -1.25]$. The value of a short LVT rises $|k|$ times faster than the underlying asset and is profitable in falling markets. This type of LVT is also used to hedge[16] positions or as a substitute for short-selling the underlying asset; (iii) Low-risk LVTs, where $k \in \{-0.5, 0.5\}$. Low-risk LVTs can be used to reduce the impact of adverse market movements without the full risks associated with higher leverage factors. Every 1% change in the underlying leads to a 0.5% change in the price of a low-risk LVT (*i.e.* less profit with less risk). Equation (1) indicates a linear relationship between the LVT price and the underlying price from time t_{n-1} to t_n. It can be shown algebraically that:

$$P_{t_n} = P_{t_{n-1}} + kP_{t_{n-1}} \left(\frac{\Delta S_{t_n}}{S_{t_{n-1}}} \right) \Rightarrow \frac{\Delta P_{t_n}}{P_{t_{n-1}}} = k \left(\frac{\Delta S_{t_n}}{S_{t_{n-1}}} \right) \tag{2}$$

When n and $n-1$ are close enough to each other in equation (2), the proportional change in the LVT price relative to its initial price equates to the proportional change in the underlying price relative to its initial value. Equation (2) then becomes:

$$\frac{dP_t}{P_t} = k \frac{dS_t}{S_t} \tag{3}$$

If there is not enough initial capital for the fund, the issuer may borrow $(k-1)P_t$ from external financial sources at an interest rate of $r \geq 0$. Considering f as the expense ratio of the fund, equation (3) can be completed as:

$$\frac{dP_t}{P_t} = k \frac{dS_t}{S_t} - \big((k-1)r + f\big)dt \tag{4}$$

As will become clear later in Section 2.2, equation (4) does not represent the return of an LVT; rather, it only shows the LVT price change relative to the underlying for discrete time intervals. Discrete time is commonly used in financial modeling, where prices are calculated at specific intervals, such as daily, hourly, or minutely. Therefore, equation (1) can be used, for example, to calculate the LVT price change on trading day 2 compared to day 1. The price of an LVT at any arbitrary interval can also be modeled in continuous time, as detailed in Appendix A.12 of the full version [40]. However, for the modeling of LVTs in this work, discrete time is more appropriate, reducing unnecessary complications.

[16] Hedging is a common practice to reduce the risk of adverse price movements in another position. For example, opening a \$100K long Bitcoin position and hedging it by buying a \$20K 2x short Bitcoin LVT. If the long position experiences a 5% price drop, the net loss is partially offset by gains from the hedge position, resulting in a net loss of $(2 \times 5\% \times \$20K) - (5\% \times \$100K) = \$2K - \$5K = -\$3K$, which is less than the $-\$5K$ loss without hedging.

2.2 LVT Return Dynamics

The return of LVTs cannot simply be considered as k times the return of the underlying asset. Let $R_{t_{(n-1)\to n}}$ represent the return of the underlying asset (in percentage) at price S from time t_{n-1} to t_n:

$$R_{t_{(n-1)\to n}} = \frac{\Delta S_{t_n}}{S_{t_{n-1}}} \quad n \geq 1, t \geq 0, t_0 = 0 \tag{5}$$

Considering the relationship between the price of LVT and the underlying in (3), the return of the LVT from time t_{n-1} to t_n can be expressed as $G_{t_{(n-1)\to n}} = 1 + kR_{t_{(n-1)\to n}}$. Since daily return is embedded in the design of LVTs, the frequency of n here is daily. In the short run (a trading day), where the underlying volatility is almost constant, the change in the LVT price relative to the underlying can be assumed to be equivalent to k-times the return. However, in the long run (several trading days or weeks), LVT return may be significantly lower or higher than the underlying due to the compounding effect, as given by:

$$G_{t_{0\to n}} = (1 + kR_{t_{0\to 1}})(1 + kR_{t_{1\to 2}}) \cdots (1 + kR_{t_{(n-1)\to n}}) = \prod_{n=1}^{N} (1 + kR_{t_{(n-1)\to n}}) \tag{6}$$

The longer-term return of LVTs is impacted by the carried-over k multiplier on each trading day, which magnifies both profit and loss due to the compounding effect. Even though the intention behind long and short LVTs is to move in opposing directions on a daily basis, it is common for both types to generate negative cumulative returns when held over an extended period (see example 30 in Appendix A.5 of the full version [40] on the compounding effect).

Takeaways: Daily returns are embedded in the design of LVTs. Generally, a k-leveraged LVT should earn k times the daily return of the underlying asset. The amplification ratio, known as leverage (k), can be fixed or dynamic. Leverage divides LVTs into three functional groups: Long, Short, and Low-risk. A proportional change in the underlying price results in a k-times proportional change in the LVT price. In the short term, LVT returns align with k, but beyond a single day, the return becomes highly path-dependent, making LVTs unsuitable for buy-and-hold strategies. This is an issue ignored by most retail investors, leading to unexpected capital losses.

3 Leveraged Token Mechanics

LVTs are tokenized representations of a leveraged fund whose value is derived from the value of a leveraged product. Leveraged products are essential components of LVTs, allowing issuers to form a leveraged fund and offer it as centralized or decentralized tokens. 99.9% of LVT issuers use crypto futures as the leveraged product. To properly reflect the value of the fund through circulating LVTs, the notional value of all tokens must match the fund's notional value. As the price of the leveraged product changes over the trading day, the leverage of the fund gradually diverges from the promised ratio. The *fund management algorithm* resets this deviation by buying or selling the leveraged product on a daily basis. It also implements the logic of the LVT and defines how it should function in different market conditions. If an LVT is designed to be fully on-chain and decentralized, the smart contract provides the functionality of the *fund management algorithm* as well, by extending common features of the ERC-20 standard. The constituent components of LVTs vary depending on the issuer. According to issuer documentation, the general components of a typical LVT are illustrated in Figure 1, followed by a brief explanation of the functionality of each component.

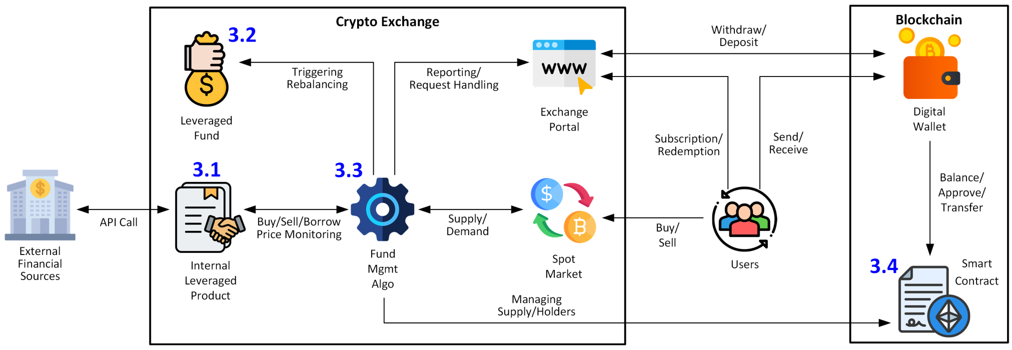

Figure 1 The constituent components of LVTs, according to the issuer's documentation, have been implemented internally by some issuers, resulting in missing blockchain components.

3.1 Leveraged product

LETFs use leverage to open positions worth more than the required capital. In LVTs, leveraged cannot appear out of nowhere. In the absence of Total Return Swaps (TRS) in the crypto market (more on TRS and financial leverage in Appendix A.1 of the full version [40]), other mechanisms for achieving leverage are (i) opening positions in the crypto derivatives market, which provides up to 200x leverage, and (ii) borrowing capital from external sources, generating up to 10x leverage. LVT issuers typically do not use high factors, offering tokens with up to 5x leverage. This allows to choose either derivatives or debt as the leveraged product. 99.9% of issued LVTs use futures (a type of derivative), and only *Index Coop* uses the debt market to finance investments.[17] The desired outcome for them is to generate future returns that outweigh the cost of borrowing. Other issuers that use derivatives aim to minimize dependency on other exchanges for buying and selling futures. They often offer the corresponding futures trading in their own portfolio to facilitate LVT management and reduce the cost of transactions between exchanges (compare the *Leveraged Product* and *Fund Source* columns in Table 1). For example, every issuer that launched BTC Long/Short tokens offers BTC-Perp futures as the underlying. Internal leveraged products facilitate LVT operations, such as adjusting fund positions, monitoring underlying price fluctuations, and triggering fund rebalancing.

3.2 Leveraged fund

It is a fund that derives its *notional value* from a basket of leveraged products.[18] The leveraged products provide leveraged exposure, upon which the value of the issued tokens is based. Let V_{t_n} represent the price of the k-times leveraged product V on trading day n, tracking the underlying asset S. The price of V_{t_n} differs from S as it carries k-times exposure. A leveraged fund L with a notional value of L_{t_n} can be formed by purchasing a basket of V, given by:

$$L_{t_n} = kV_{t_n}B_{t_n}\big(1 + (\rho_{t_n} + \phi_{t_n})\big) \quad t \geq 0, 0\% \leq \rho_{t_n} + \phi_{t_n} \leq 0.5\%, \rho_{t_0} = 0, \phi_{t_0} = 0 \tag{7}$$

[17] *Index Coop* uses money market protocols on Ethereum (e.g., Compound protocol) that offer permissionless borrowing and lending capabilities [13].

[18] The notional value represents the total value of a financial instrument or contract at its full face value (i.e., controlled money by the financial instrument). The notional value is not typically exchanged between counterparties; instead, it serves as a reference point for calculating payments or obligations [21].

Where B_{t_n} is the number of V units forming the fund at the rebalancing time t_n. ρ_{t_n} and ϕ_{t_n} represent management and futures funding fees, respectively. ρ_{t_n} is always negative, as the issuer deducts associated expenses from the fund's value. ϕ_{t_n} can be positive or negative, depending on the *futures funding fee* payments (more in Section 4.4.3). The sum of ρ_{t_n} and ϕ_{t_n} (i.e., the total daily fee) varies per LVT issuer and ranges from 0.01 to 0.5 percent daily. Note that the change in the price of the leveraged product (V_{t_n}) is proportional to the underlying price (S_{t_n}), but does not vary based on the k multiplier. More precisely, $V_{t_n} = V_{t_{n-1}}(1 + R_{t_{(n-1)\to n}})$. In equation (7), L_{t_n} represents the financial value controlled by the leveraged fund L, which originates from the leveraged product V. The change in the price of V is proportional to S, but the value of L changes with respect to the k factor. In simple terms, V represents the price of the leveraged product, while L represents the amount of money that can be controlled using V.

▶ **Example 4.** An issuer may arrange an *Ether long double-leveraged fund* by purchasing 4 *Ether-Perp long 2x futures* at \$1.5K (V_{t_0}). The 2x leverage of Ether-Perp allows the issuer to pay half of the Ether price, which is assumed to be \$3K (S_{t_0}). With zero fees in (7) at t_0 ($\rho_{t_0} + \phi_{t_0} = 0$), a leveraged fund L worth $2 \times \$1.5K \times 4 = \$12K$ can initially be formed (L_{t_0}). A 10% change in the price of Ether affects the price of futures by the same 10%, bringing it to \$1.65K (V_{t_n}). However, the notional value of the fund (L_{t_n}) changes according to $k = 2$, reaching $2 \times \$1.65K \times 4 = \$13.2K$. This demonstrates the effect of k on L compared to V.

LVTs are issued with a certain initial supply that can be adjusted through the *Subscription* and *Redemption* process (more on this process in Appendix A.5 of the full version [40]). For added or removed tokens, the issuer offsets the notional value of the fund with the notional value of the tokens by buying or selling the corresponding amount of the leveraged product. Let N_{t_n} represent the total supply of a k-leveraged LVT at time t_n. The notional value of the issued LVTs (A_{t_n}) can be expressed as:

$$A_{t_n} = kN_{t_n}P_{t_n} \tag{8}$$

Equating (7) and (8) gives the total number of tokens (N_{t_n}) that should exist at the price of P_{t_n} at time t_n. Mathematically, this can be expressed as: $kN_{t_n}P_{t_n} = kV_{t_n}B_{t_n} \Rightarrow N_{t_n} = \frac{V_{t_n}B_{t_n}}{P_{t_n}}, \quad t \geq 0, P_{t_0} \geq 1$.

▶ **Example 5.** Assume $P_{t_0} = \$10$ as the initial offering price of ETH2L in the previous example 4. P_{t_0} is typically set by the issuer at either \$1 or \$10 per token.[19] The initial supply of ETH2L at \$10 per token is:

$$N_{t_0} = \frac{V_{t_n}B_{t_n}}{P_{t_n}} = \frac{\$1.5K \times 4}{\$10} = 600$$

The notional value of all 600 tokens ($A_{t_0} = 2 \times 600 \times \$10 = \$12K$) is consistent with the notional value of the leveraged fund ($L_{t_0} = 2 \times \$1.5K \times 4 = \$12K$). Investors purchase a portion of this fund in the form of LVT, allowing them to generate twice the profit compared to the underlying Ether-Perp. Essentially, the value of the ETH2L token is derived from the *Ether long 2x leveraged fund*, which in turn is derived from the 4 positions in the *Ether-Perp long 2x futures*.

[19] Taken from the initial public offering (IPO) price of a SPAC (Special Purpose Acquisition Company), which is typically set at a nominal \$10 per unit. Unlike a traditional IPO, the SPAC IPO price is not based on the valuation of an existing business but rather on future income expectations.

3.3 Fund management algorithm

As the price of the leveraged product (V_{t_n}) fluctuates over time, the notional value of the leveraged fund (L_{t_n}) changes, causing the leverage ratio of the LVT to deviate from the stated leverage. Let $\tilde{k_{t_n}}$ represent the realized leverage ratio that the notional value of the tokens (A_{t_n}) represents at time t_n, expressed as $\tilde{k_{t_n}} = \frac{L_{t_n}}{N_{t_n} P_{t_n}}$.

▶ **Example 6.** Referring to the first trading day of ETH2L in examples 4 and 5, in which the price of Ether (S_{t_0}) increases by 10%, the notional value of the fund (L_{t_n}) changes to $2 \times \$1.65K \times 4 = \$13.2K$. The 2x leverage of the LVT increases its price by 20%, rising to \$12 (P_{t_n}) from the initial \$10 (P_{t_0}). Since the LVT supply remains constant at 600 tokens, the leverage ratio of the fund drops from 2x to 1.8x. ($\tilde{k_{t_n}} = \frac{L_{t_n}}{N_{t_n} P_{t_n}} = \frac{\$13.2K}{600 \times \$12} = 1.8\overline{3}$).

The analysis above suggests that with the change in the price of the underlying (S_{t_n}) and subsequently the price of the leveraged product (V_{t_n}), the notional value of the leveraged fund (L_{t_n}) changes, and the realized leverage ratio of LVTs ($\tilde{k_{t_n}}$) becomes higher or lower than the stated leverage k. Mathematically, if $\mathbb{E}[\tilde{k_{t_n}}]$ represents the expected change in $\tilde{k_{t_n}}$ in relation to the underlying price change (S_{t_n}), applying equations (1) gives us:

$$\mathbb{E}[\tilde{k_{t_n}}] = \frac{kV_{t_n} B_{t_n}(1 + R_{t_{(n-1)\to n}})}{kN_{t_n} P_{t_n}} = \frac{V_{t_n} B_{t_n}(1 + R_{t_{(n-1)\to n}})}{N_{t_n} P_{t_{n-1}}(1 + kR_{t_{(n-1)\to n}})} \quad (9)$$

As the number of tokens (N_{t_n}) remains constant while the price of the underlying changes at a rate of $(1 + R_{t_{(n-1)\to n}})$, the denominator of (9) changes k-times faster (or slower) than the numerator, resulting in positive or negative leverage skewness. This highlights the need to re-leverage the fund on a daily basis, a process managed by the *fund management*.[20]

Fund management is an off-chain algorithm (or on-chain for decentralized tokens) that dynamically adjusts the fund to maintain the leverage at the expected ratio. When the token's leverage increases, it sells some of the fund's positions to reduce the leverage and return it to the expected level (*cf.* Full version [40] appendix A.7 for rebalancing details). The majority of algorithms are off-chain with no interaction with the blockchain. The only on-chain instance is implemented by *Index Coop* [13]. In addition to correcting the leverage, the algorithm interacts with other components to adjust supply, update balances, monitor the price of the underlying, and deduct daily fees.

3.4 On-chain contracts

For decentralized LVTs, a smart contract represents the leveraged fund on the blockchain. It is typically implemented as an ERC-20 token [20, 2, 43], allowing users to exchange LVTs on the blockchain without issuer intervention. As indicated in the *Blockchain Representation* column of Table 1, 80% of issuers have not created LVTs on the blockchain. As a result, this component is missing from Figure 1. The absence of a smart contract leads to several deficiencies, which are discussed in the next section.

Takeaways: An LVT is a tokenized representation of a leveraged fund, whose value is derived from the value of a leveraged product. 99.9% of LVT issuers use crypto futures as the leveraged product. As the price of the leveraged product fluctuates over a trading day, the leverage of the fund gradually diverges from the promised ratio. The *fund management algorithm* resets this deviation by buying or selling the leveraged product on a daily basis.

[20] Also referred to as *fund management agent*, *fund management party*, or *certified fund manager*.

4 Research Questions

Due to the lack of a common standard in LVTs for defining the rebalancing process, data transparency, implementation standards, etc., these tokens are issued with varying features at the discretion of the issuer. We examine the characteristics of issued tokens per issuer and discuss the respective deficiencies as research questions RQ1 to RQ6.

4.1 RQ1: What information is visible to traders of an LVT?

Among the 10 LVT issuers, only *FTX* and *Index Coop* have created tokens on the Ethereum blockchain. FTX's management model was hybrid (*i.e.* tradable decentralized tokens on a centralized exchange), while only *Index Coop*'s tokens are fully decentralized. The remaining 8 exchanges prefer to implement LVTs centrally and entirely internal.

▶ **Example 7.** Binance leveraged tokens (BLVTs) are one of the centralized LVTs that are entirely accessible within Binance's ecosystem. They can be exclusively traded on Binance's spot market with no possibility of withdrawal. BLVTs are not even published on Binance's own blockchain (BNB Smart Chain) and are created more like a pseudo-crypto.[21]

4.1.1 Transparency in total supply

Total supply is used to calculate the Net Asset Value (NAV) of LVTs as a representation of the market's fair value. Due to imbalances in supply and demand, the market price of LVTs may deviate from the NAV, trading at a premium or discount. In the long run, LVT prices converge to the NAV due to a mechanism similar to arbitrage in traditional markets. Orders placed far from the NAV price lose or gain value over time (*cf.* Full version [40] appendix A.13 on the general arbitrage mechanism). In the short run, however, investors use the NAV as a reference price when buying or selling, especially in bulk. The NAV of LVTs can be calculated by equating (7) and (8), with the current token supply N_{t_n}:

$$kN_{t_n}P_{t_n} = kV_{t_n}B_{t_n} \Rightarrow P_{t_n} = \frac{V_{t_n}B_{t_n}}{N_{t_n}} \quad t \geq 0, N_{t_0} \geq 1 \tag{10}$$

▶ **Example 8.** In the previous examples (4) to (6), when the Ether price increases by 10% on day 2, the market price of ETH2L trades at \$12 (after a $2 \times 10\% = 20\%$ increase), while its NAV price is $(\$1.65K \times 4)/600 = \$11$. ETH2L is, in fact, overvalued, and traders should wait for either (i) the arbitrage mechanism to play out and bring the LVT price down, or (ii) the next rebalancing schedule, which will match the fund's value with the notional value of the tokens.

For LVTs hosted on the blockchain, total supply is public and can be retrieved for NAV calculations. However, for centralized LVTs, investors must refer to the exchange's website. The total supply of tokens on some exchanges, such as AscendEX, Pionex, Gate.io, and ByDFi, does not appear to be public, making it difficult to verify the real value of LVTs (*i.e.* 53% of all tokens). LVTs are *open-end funds* with a theoretically unlimited token supply.[22] Issuers can increase the supply based on market liquidity and demand for the

[21] A cryptocurrency that is not sufficiently decentralized [1].

[22] Open-end funds can issue an unlimited number of shares. The fund sponsor sells shares directly to investors and redeems them as well. The NAV per share of an open-end fund is calculated daily by dividing the total value of the fund (minus liabilities) by the total number of shares outstanding [10].

token. Transparency in the number of issued tokens builds trust and reduces the risk of investment. Moreover, it addresses audit questions such as, Has the fund's value changed proportionately after increasing or decreasing the supply of LVTs? How much were the fund's value deviations in the previous audit period, and were they within the acceptable range?

4.1.2 Transparency in transactions

Transactions on the blockchain show the flow of tokens and the movement of the fund. This enables investors to analyze transactions and ensure the expected functionality of LVTs.

▶ **Example 9.** We reviewed all *Mint* and *Burn* transactions of ETCBULL (FTX 3x Long Ethereum Classic) on the blockchain.[23] The analysis suggests that a total of 51,640,895 tokens were issued, and 24,207 were destroyed (*i.e.* 51,616,688 circulating tokens). The trend of issuing tokens has taken on exponential velocity since April 2022. A total of 783,022 tokens were issued during the 960-day period between October 2019 and May 2022, while 50,857,873 tokens were issued over just 184 days from April to October 2022. In other words, 98.5% of all tokens were issued in just 6 months. Checking the recipient address indicates FTX's possible sub-wallet as the receiver. This sudden change in token supply warrants further investigation, especially given FTX's collapse shortly afterward. A possible explanation for this anomaly is presented in Appendix A.11 of the full version [40].

This is just an example indicating the importance of transparency in LVT transactions. Transactions of centralized tokens are not public and only available to the issuer. Statistically, transactions of 80% of LVTs cannot be analyzed as we did in the above case.

4.1.3 Transparency in token holders

Holders of tokens created on the blockchain are public, allowing investors to check them as a measure of the token's liquidity. A small number of market participants reduces the token's liquidity and can make it more challenging to execute large orders. It may also lead to a wider bid-ask spread, increasing the cost of executing trades. Investors generally prefer assets with higher liquidity, narrower bid-ask spreads, and more market participants.

▶ **Example 10.** 90% of XRPBULL (FTX 3x Long Ripple) tokens are distributed among four holders.[24] In another example, three accounts own 94% of all issued FTX 3x Long Cardano (ADABULL) tokens.[25]

Holding a large number of tokens by a limited number of accounts can noticeably elevate investment risk. One holder may decide to sell a significant number of tokens at any moment, potentially resulting in a notable price drop within a short period of time, leading to significant losses for smaller holders. Since most issuers do not publish the list and respective ownership percentages of centralized LVTs, the participants of 80% of LVTs remain uncertain.

4.1.4 Inability to audit

Conducting audits ensures the security, functionality, and compliance of LVTs as claimed by the issuer. Unlike centralized LVTs, the code of tokens created on the blockchain is public,

[23] ETCBULL transactions on the Ethereum blockchain filtered for issued and deposited tokens to FTX's own address: `https://bit.ly/3MwHVqv`.
[24] List of XRPBULL holders: `https://bit.ly/3MQurrc`.
[25] List of ADABULL holders: `https://bit.ly/3MUxPRZ`.

allowing auditors to identify vulnerabilities and associated risks. The security of these 20% decentralized LVTs can be evaluated by reviewing the code against industry best practices such as SWC [45]. Moreover, external audits are essential for LVTs to ensure they function as intended, such as verifying the output of methods when transferring tokens or updating balances. Auditors may also provide recommendations to improve the security, functionality, and compliance of LVTs. For centralized LVTs, the code is not public, requiring cooperation and willingness of the issuer to conduct a thorough review and quality assessment. Sharing the code and the results of an independent audit would improve transparency and help build trust between token holders and issuers.

Takeaways: In some centralized LVTs, investors do not have access to crucial information such as total supply, transactions, and holders. Total supply is a necessary parameter for calculating the fair value of tokens and is also used by auditors to evaluate the consistency and efficiency of LVTs. Transparency in transactions enables investors, auditors, and anyone involved in the LVT ecosystem to analyze token flow, detect suspicious activities, enhance security, ensure compliance, and verify token functionality. The number of holders for centrally issued tokens is unknown, leading to a much higher investment risk compared to decentralized counterparts.

4.2 RQ2: To what extent are LVTs locked to the offering exchange?

4.2.1 Interoperability with dapps and DeFi

In 2019, the total value locked in Decentralized Finance (DeFi) was approximately 700 million USD. As of April 2022, it stands at around 150 billion USD, representing more than 200% growth in less than three years [51]. Hosted LVTs on the blockchain (which usually comply with one of the fungible[26] token standards) facilitate interaction with DeFi systems, unlocking potential interoperability opportunities.

▶ **Example 11.** FTX was able to employ blockchain interoperability to share its ETHBULL (3x Long Ethereum) with other exchanges such as Poloniex, Indodax, Bittrex, and Gate.io.[27] These exchanges owned 20%, 4%, 3%, and 2% of ETHBULL, respectively, and offered it on their platforms due to the possibility of interaction with DeFi.

In contrast, centrally issued LVTs cannot interact with other platforms and operate in isolation, preventing LVTs from moving across different platforms and systems. Decentralized LVTs, on the other hand, foster connectivity and enable users to access a wide range of services and functionalities without being confined to a single exchange.

4.2.2 Inability to custody

At first glance, the custody issue seems common to all assets on centralized exchanges. However, BTC buyers can transfer it to their personal wallets, while centralized LVTs remain locked within the exchange. Holders do not own the actual tokens but are simply betting on price movements. Some explain this custodial issue by viewing LVTs as “token contracts”, though this term is not widely recognized nor aligns with the functionality of crypto derivatives. LVTs are essentially tokenized forms of derivative exposures.

[26] Fungible (interchangeable) token standards are widely used by decentralized applications (dApps) to interact with other applications. ERC-20 is the dominant standard, followed by ERC-777 and ERC-1155.
[27] List of ETHBULL holders: `https://bit.ly/3MSZX7P`.

▶ **Example 12.** BTCUP and BTCDOWN are issued by Binance and track Bitcoin as the underlying asset. Unlike Bitcoin holders, owners of these tokens cannot withdraw or transfer them to their own digital wallets. In contrast, similar Bitcoin leveraged tokens were created by FTX on the Ethereum blockchain (known as BULL and BEAR tokens). Holders of these tokens still had the opportunity to exchange them on decentralized exchanges, such as Uniswap[28], shortly after FTX's bankruptcy. Holders could recover 80% of the token value on the first day of the bankruptcy, 50% on the second day, and up to 20% on the third day.

Takeaways: The inability to self-custody centralized LVTs raises greater concerns compared to decentralized counterparts, potentially increasing the investment risk in these crypto-assets. Another important advantage of tokens created on the blockchain is their interoperability with other dApps, crypto exchanges, and the DeFi ecosystem in general. LVTs that interact with DeFi offer the opportunity to participate in a more open and transparent financial system that operates without the need for intermediaries.

4.3 RQ3: Are the LVTs offered today adequately backed?

The simplest definition of an LVT is a tokenized leveraged fund. According to the documentation of LVT issuers, 99.9% of leveraged funds derive their value from a basket of positions in the futures market [3, 22, 5, 6, 7, 39, 16, 29, 38]. The issuer must either (i) offer futures trading in their portfolio, or (ii) open futures positions on other crypto exchanges and manage them systematically through APIs as the underlying asset fluctuates.[29] The question we raise, due to the lack of external audits, is to what extent LVT issuers have properly prepared futures contracts before launching LVTs. Have users invested in tokens that are properly backed, or are they simply trusting the issuer and potentially investing in tokens with no real value?

4.3.1 Missing futures product

Some issuers have launched LVTs without offering the corresponding futures products. While we cannot rule out the possibility that they hold the necessary futures positions on other exchanges, this raises concerns that these LVTs might not be adequately backed.

▶ **Example 13.** AscendEX uses its own futures products and does not rely on futures products from other exchanges. However, they issued 3x/5x Long/Short Monero (XMR3L/S and XMR5L/S) without offering XMR perpetual contracts initially. To our knowledge, no XMR futures products were available on the market from any exchange to be used as leveraged products at the time of the launch of these XMR tokens.

The above example is one of 390 issued tokens lacking a corresponding futures product (see column B of Table 2). Based on available historical data and information from the issuer's website, 24% of LVTs did not have the necessary futures product offered by the same issuer and instead relied on futures from other exchanges.

[28] DEX transactions of FTX 3X Long Bitcoin Token (BULL) and FTX 3X Short Bitcoin Token (BEAR) on the Ethereum blockchain: `https://bit.ly/3pOh3uz`, `https://bit.ly/41Dal81`.

[29] Among 10 LVT issuers, Pionex used the *Binance Broker API* for its *Futures Arbitrage Bot*, but it has been terminated since June 2021 [37]. After reviewing Pionex's documentation [38], it remains unclear whether *Binance Futures* is still used as the leveraged product for LVTs. However, Pionex launched its own futures product in January 2023. If they no longer use *Binance Futures* and rely solely on their own futures product, it appears that 148 LVTs did not have corresponding futures contracts at the time of launch (e.g., ETC3L/S, ZRX2L/S, XLM3L/S).

Table 2 *Left table:* Number of issued LVTs with delayed or missing futures products, analyzed using historical data and undisclosed information. To our knowledge, 41% of the issued LVTs did not have sufficient financial backing at the time of launch. *Right table:* Rebalancing and fee deduction schedules, which we collected manually from the issuers' websites. Regardless of leverage type, rebalancing is performed daily at different times. Additionally, Threshold-Based (TBR) or Out of Range (OOR) rebalancing methods are used to trigger interim rebalancing. Fund expenses are also deducted at various times with variable percentages.

Issuer	Delayed Futures Launch	Missing Futures Product	Total Delayed or Missing	Total Launched LVTs	% of unbacked LVTs
	(A)	(B)	(C)	(D)	(E)
AscendEX	36	214	250	340	74%
Pionex	0	148	148	200	74%
MEXC	176	12	188	456	71%
ByDFi	16	0	16	40	40%
FTX	18	0	18	129	14%
Gate.io	18	16	34	274	12%
Binance	0	0	0	40	0%
ByBit	0	0	0	34	0%
KuCoin	0	0	0	94	0%
Index Coop	0	0	0	2	0%
Total	**264**	**390**	**654**	**1609**	**41%**

<table>
<tr><th rowspan="2">Leverage</th><th colspan="2">Rebalancing Schedule</th><th colspan="2">Fee deduction</th></tr>
<tr><th>Regular Daily</th><th>Interim</th><th>Daily Schedule</th><th>Expense Ration</th></tr>
<tr><td>(a)</td><td>(b)</td><td>(c)</td><td>(d)</td><td>(e)</td></tr>
<tr><td>Fixed</td><td>02:30 UTC</td><td>10% TBR / OOR</td><td>00:00 UTC</td><td>0.500%</td></tr>
<tr><td>Fixed / Variable</td><td>00:00 UTC+8</td><td>10% TBR</td><td rowspan="3">00:00 UTC+8</td><td>0.030%</td></tr>
<tr><td rowspan="4">Fixed</td><td>00:00 UTC</td><td rowspan="2">15% TBR</td><td>0.100%</td></tr>
<tr><td>08:00 UTC+8</td><td>0.030%</td></tr>
<tr><td>02:00 UTC</td><td>10% TBR</td><td>00:00 UTC</td><td>0.030%</td></tr>
<tr><td>00:00 UTC-4</td><td rowspan="3">10% TBR / OOR</td><td>00:00 UTC+8</td><td>0.300%</td></tr>
<tr><td rowspan="2">Variable</td><td>N/A</td><td rowspan="2">00:00 UTC</td><td>0.010%</td></tr>
<tr><td>00:00 UTC</td><td>0.005%</td></tr>
<tr><td>Fixed / Variable</td><td>08:00 UTC+8</td><td>14% TBR</td><td>23:45 UTC+8</td><td>0.045%</td></tr>
<tr><td>Fixed</td><td>00:00 UTC</td><td>20% TBR</td><td>00:00 UTC</td><td>0.023%</td></tr>
</table>

4.3.2 Delayed futures product

Missing futures products are not the only issue with centralized LVTs. For 264 tokens, the corresponding futures product was only offered after the issuance of the tokens (see column A of Table 2). In other words, at the time of the launch of 17% of LVTs, the required futures may not have existed. According to the LVT documentation on issuers' websites, these issuers did not disclose using futures from other crypto exchanges. Internal futures trading was introduced later, after the token was launched.

▶ **Example 14.** MEXC issued 3x Long/Short Cardano (ADA3L/S) in February 2020, while ADA-Perp was only launched in July 2020, resulting in a 154-day delay. They did not disclose using futures from other exchanges, indicating the fund might have been operating without financial backing during this period.

According to available information, on average, 41% of LVTs have missing or delayed futures products (see column E of Table 2). The main financial issue with LVTs is the lack of transparency in the fund management system. Centralized LVTs function like a black box to investors and are fully managed by the issuer. Even for tokens with proper futures backing (e.g., Binance, ByBit, and KuCoin), investors can rely solely on numeric assertions made on the issuer's website.

Takeaways: The value of LVTs is derived from a leveraged fund, which itself is based on the value of futures. In the absence of futures at the time of offering, investors may have purchased LVTs that lacked proper financial backing. An analysis of available historical data on the issuer's website shows that, on average, 2 out of every 5 issued LVTs did not appear to have proper financial backing at the time of launch. Although the exchange may have addressed this issue over time, the required futures contracts were missing at the time of issuance. Without external audits, investors can rely solely on the exchange's claims and assume that LVTs are financially backed as promised.

4.4 RQ4: What are the possibilities of front-running in LVTs?

Front-running is an illegal practice in the equity market where non-public information is used to purchase shares of a company before the price moves [19, 53, 4]. For instance, FINRA[30] announced a \$700K fine against *Citadel Securities*[31] in 2020 for front-running activities between 2012 and 2014 [35]. In the design of LVTs, certain well-known events can be exploited by traders to benefit from anticipated price movements. They can engage in similar front-running practices that may impact the price of the underlying asset and the token itself. We review these events and explore possible front-running scenarios as follows.

4.4.1 Event I: Impending fund rebalancing

Rebalancing is the process of maintaining the desired leverage ratio of funds over time. To keep the leverage at the stated ratio, issuers perform periodic rebalancing. This can be triggered at predefined intervals (e.g., every day, every 8 hours, or every n blocks), or upon meeting certain conditions (e.g., after exceeding a specific threshold). All LVT issuers perform regular daily rebalancing and trigger interim rebalancing in volatile markets (see columns B and C of Table 2). They may trigger rebalancing when the underlying asset's price fluctuates by more than $X\%$, or when the leverage passes a threshold. The *fund management algorithm* governs the rebalancing process, adjusting futures positions and restoring the leverage ratio to the target level (*cf.* Full version [40] appendix A.7 for details on the rebalancing process).

The number of contracts that must be bought or sold to restore the leverage is predictable, making front-running possible. Let ΔB_{t_n} represent the number of required futures contracts to rebalance the fund at time t_n. ΔB_{t_n} can be easily calculated by considering the return of the underlying asset from time t_{n-1} to t_n ($R_{t_{(n-1)\to n}}$). The number of required futures contracts to restore the fund leverage can be calculated by subtracting the notional value of the tokens (equation 8) from the notional value of the fund (equation 7):

$$\Delta B_{t_n} = (1 + kR_{t_{(n-1)\to n}})kN_{t_{n-1}}P_{t_{n-1}} - (1 + R_{t_{(n-1)\to n}})kV_{t_{n-1}}B_{t_{n-1}} - (\rho_{t_n} + \phi_{t_n})L_{t_n} + \epsilon_{t_n}$$

This equation is quadratic and can be simplified as $ax^2 - bx - c$ for long tokens, and $-ax^2 + bx - c$ for short tokens. When the underlying return is positive ($R_{t_{(n-1)\to n}} > 0$), ΔB_{t_n} is always positive ($a > 0$), and when the return of the underlying is negative, ΔB_{t_n} is negative as well ($a < 0$). In simpler terms, for long LVTs, futures exposure must be increased when the underlying price is rising, and decreased when the underlying price is falling (see *Fund Basket Delta* in Tables 12 and 13 of appendix A.7 in the full version [40]).

There is also a fund expenses term $(\rho_{t_n} + \phi_{t_n})L_{t_n}$, which is usually deducted from the fund's value to cover operating expenses. However, this term can turn positive when the received funding fees (ϕ_{t_n}) exceed the fund expenses (ρ_{t_n}). ϵ_{t_n} represents a disturbance term that captures the effects of news or shocks in the underlying. Since rebalancing is a predictable event, by buying or selling ΔB_{t_n} of the leveraged product, other traders can front-run the trade, potentially impacting the price of the token or even the underlying asset.

▶ **Example 15.** Consider the following sequence in which Alice calculates ΔB_{t_n} to potentially front-run the rebalancing trade:

1. Alice checks the issuer's website for the upcoming rebalancing of BTC5L (5x Long Bitcoin). She notices the next daily rebalancing is scheduled for 00:00 UTC.
2. Alice calculates the number of contracts that will be bought or sold by the issuer to maintain the 5x target leverage of BTC5L.

[30] The Financial Industry Regulatory Authority (FINRA) is a government-authorized organization that oversees U.S. equity markets by regulating member brokerage firms and exchange markets.
[31] Citadel Securities is the largest designated market maker on the New York Stock Exchange (NYSE).

3. Alice front-runs the rebalancing trade by placing an order just before 00:00 UTC (ahead of the rebalancing trade). If she anticipates that the algorithm will buy Bitcoin futures, she may buy Bitcoin futures expecting increased demand, driving up the price, and giving her the opportunity to sell futures at higher prices. Conversely, if BTC5L will be selling the fund's positions, leading to increased supply, she may sell Bitcoin futures.

Front-running in the above example may not only manipulate the price of Bitcoin futures but also inflate the price of BTC5L. Consider the following scenarios (A) and (B), with corresponding calculations in Table 8 of appendix A.5 in the full version [40].

- Alice calculates the *Basket Delta* of BTC5L prior to the rebalancing schedule and realizes that the algorithm will purchase 594.21 new contracts at $33,000 (Scenario A in Table 8 of appendix A.5 in the full version [40]). Assuming this purchase increases the price of Bitcoin futures by 1%, she can buy contracts just before the rebalancing trade at $33,000 and sell them afterward at $33,330. A 1% increase in the underlying price inflates the token price to $15.05. This provides Alice an additional opportunity to buy the token for $15 before the rebalancing and sell it at a higher price afterward.
- The effect of Alice's strategy in the previous scenario may be amplified if many traders engage in front-running. The increased demand may raise the price of Bitcoin futures even before the rebalancing trade. If the influx of other traders pushes Bitcoin futures up by 1%, and the rebalancing trade further increases the price by another 1%, this secondary effect could also inflate the token price further and create more price distortion (Scenario B in Table 8 of appendix A.5 in the full version [40]).

4.4.2 Event II: Management fee deduction

Similar to LETFs, daily fees and expenses are deducted from the leveraged fund to cover associated costs (*cf.* Full version [40] appendix A.8 on incurred costs). The fee rate and daily schedule vary by issuer (see columns D and E of Table 2). Management fees are deducted at specific times, allowing adversaries to exploit this known event, potentially coinciding with rebalancing. The simultaneous occurrence of events I and II can intensify the front-running effect during the rebalancing process.

▶ **Example 16.** Consider the same sequence as the previous example, where Alice calculates the *Basket Delta* of BTC5L at the same time as the management fee deduction. The issuer's withdrawal of $99,000 (Management fee row in Table 8 of appendix A.5 in the full version [40]) reduces the fund's value. To compensate, $99,000/$33,000 = 3 additional contracts need to be purchased. The coincidence of these two events causes the rebalancing algorithm to slightly increase demand by purchasing 597.21 contracts instead of 594.21.

4.4.3 Event III: Futures funding fee exchanges

Funding fee is a mechanism in Perps to converge the price of contracts with the price of the underlying crypto. It is calculated based on the notional value of the futures position and is exchanged between short and long traders who keep their positions open. Shorts pay longs when the funding rate is negative, and longs pay shorts when the rate is positive (*cf.* Full version [40] appendix A.9 for details on funding fee dynamics). The intervals for *Funding fee exchange* are public and displayed on the issuer's website, typically occurring every 8 hours at 00:00 UTC, 08:00 UTC, and 16:00 UTC. Since the fund is composed of futures, it either pays or receives funding fees at these times. This predictably increases or decreases the value of the leveraged fund, which can be exploited to amplify the effects of front-running.

The impact of front-running can be exacerbated when events I, II, and III occur simultaneously. Such concurrency may force the algorithm to buy or sell more contracts than would be required for fund rebalancing alone (*i.e.* $\Delta\tilde{B_{t_n}} = \sum_{n=1}^{3} \Delta B_{t_n}$).

▶ **Example 17.** As calculated in the *Basket Delta* row of Table 8 in appendix A.5 of the full version [40], in the first rebalancing cycle, an additional 2.70 futures contracts are required to cover the 0.3% daily management fee deduction and 0.03% daily funding fee exchange. This means that 2.7 more contracts will be added if events II and III coincide with event I. The impact on basket delta can be even more significant as the value of the fund increases in a volatile market (see *Fee Basket Size* row in Table 12 of appendix A.5 in the full version [40] on rebalancing in volatile markets).

To mitigate front-running in LVTs, issuers should avoid rebalancing the fund on predetermined schedules. Techniques such as intraday or randomized rebalancing, or algorithmic trading, can help reduce the visibility of rebalancing trades.[32] Only Binance avoids regular daily rebalancing, instead triggering it when the underlying price fluctuates more than 10% or when leverage falls outside the range of $[-4.0, -1.25] \cup [1.25, 4.0]$. This means 97% of current LVTs perform fund rebalancing at specific intervals, increasing the likelihood of daily front-running (see column B of Table 2).

Takeaways: The possibility of front-running in LVTs arises from the predictability of impending fund rebalancing, management fee deductions, and futures funding fee exchanges. Adversaries can exploit the temporary changes in supply and demand initiated by the fund. This effect may be intensified if all three events occur simultaneously or if there is large-scale participation by multiple traders. Front-running has also been a concern in LETFs, though it is mitigated by the continuous oversight of regulatory bodies such as the SEC and FINRA.

4.5 RQ5: How well do LVTs track their asserted leverage ratios?

The leverage ratio of LVTs is determined by the issuer and can be either variable (dynamic) or fixed. If an LVT uses the *Underlying+Leverage+Long/Short* naming convention, the leverage is most likely fixed. The *Underlying+Up/Down* format is used for LVTs with variable leverage.

▶ **Example 18.** KuCoin has issued ETH3L as a 3x long token tracking Ether as the underlying. Binance similarly offers ETHUP and ETHDOWN tokens with a target leverage in the range of [1.25, 4] and [-4, -1.25], respectively.

Very high leverage factors such as ±10x or ±15x are not common in currently issued LVTs, as the majority of them provide ±3x leverage (see Figure 3a in Appendix A.4 of the full version [40]). Low leverage is aimed at minimizing losses and extending the liquidation point during periods of high volatility. Highly leveraged LVTs lose value in the same proportion as the underlying asset and may not be attractive to investors. Crypto exchanges advertise LVTs as an investment vehicle providing leveraged exposure to crypto-assets with minimal liquidation risk. However, LVTs with high leverage factors defeat this promise.

[32] Iceberg orders, which are large orders broken into smaller lots, are a sophisticated trading algorithm used to execute rebalancing trades in smaller, more discrete chunks over time.

4.5.1 Inconsistency of fixed leverage

Approximately 16% of LVTs are issued with variable leverage, fluctuating in the range of $[-4.0, -1.25] \cup [1.25, 4.0]$. Additionally, 9%, 59%, and 11% of LVTs have fixed 2x, 3x, and 5x leverage ratios, respectively. As shown in Table 10 of Appendix A.6 in the full version [40], LVTs with fixed leverage may not always provide exactly the promoted leverage. One aspect of risk involves leverage deviation (also called tracking error). Furthermore, some issuers do not rebalance the fund in the same way.

► **Example 19.** MEXC and KuCoin adjust the leverage of only the tokens that have lost value. Consider a volatile market where Bitcoin loses 10% in a day. These issuers adjust only the leverage of BTC3S, while the leverage of BTC3L remains unchanged, as it gained value [22, 28]. For example, if the price of Bitcoin is $30K and the fund holds 600 contracts, the fund's initial value is $18M. Assuming 600K issued tokens at an initial offering price of $10, the target leverage is 3x (*i.e.* $k = (600 \times \$30K)/(600K \times \$10) = 3$). A 10% increase in Bitcoin's price changes the leverage of BTC3L and BTC3S to 2.53x and 4.71x, respectively. However, these exchanges correct the leverage of BTC3S to prevent further capital loss in case of more price decline. As a result, this rebalancing process undervalues the BTC3L fund (*i.e.* inflates the value of BTC3L). Instead of only rebalancing the losing side, both BTC3L and BTC3S positions should be adjusted simultaneously to bring the leverage back to 3x as advertised by the issuer.

We compared the leverage deviation of Bitcoin LVTs with LETFs over the course of a year. Analysis details are provided in Appendix A.6 and Table 10 of the full version [40]. As can be seen, LVTs exhibit higher leverage deviations than similar products in the equity market. This issue becomes more apparent when comparing the standard deviation of returns in the equity and crypto markets. Leverage deviation leads to underperformance or overperformance of tokens, causing investors to experience returns that deviate from the intended amplification effect of LVTs. This is particularly important in light of previous research on LETF returns, which shows that LETFs, on average, do not negatively impact investor short-term returns [33]. Results indicate that the daily return distribution using real-world historical data is significantly more leptokurtic than the normal distribution. However, in LVTs, returns tend to have a wider or flatter shape (platykurtic) due to higher leverage deviation.

4.5.2 Disadvantages of variable leverage

LVTs with variable leverage aim to: (i) minimize the impact of volatility drag (*cf.* Full version [40] Appendix A.10), and (ii) reduce the possibility of front-running (as discussed in Section 4.4). LVTs are advertised as an investment vehicle that amplifies returns relative to a certain multiplier, although this factor changes constantly in tokens with variable leverage. This introduces an additional risk dimension, requiring regular monitoring and adjustment of positions as the leverage fluctuates. Additionally, these types of tokens rebalance on an as-needed basis with no predetermined schedules. Rebalancing can therefore be triggered by (i) a sudden fluctuation in the underlying price (such as more than 15%), (ii) exceeding the expected leverage range (such as above 4x or below 1.25x for long LVTs), and (iii) handling subscription or redemption requests, which change the total supply. One disadvantage of this type of rebalancing is that funds can remain undervalued or overvalued for extended periods.

► **Example 20.** The rebalancing events of BTCUP (a Long Bitcoin LVT by Binance) over the past 3 years are listed in Table 14 of Appendix A.6 in the full version [40]. A rebalancing event occurred on 03-Jan-2023, 204 days after the previous one on 13-Jun-2022. During those 204 days, no rebalancing event was triggered because the changes in Bitcoin's price did not exceed the 10% threshold limit, and the fund's leverage fluctuated within the expected range of 1.25x to 4x. During this period, the fund's value was much lower (or higher) than the amount required to support the value of issued tokens, but no rebalancing occurred. Undervalued funds may benefit the issuer, while investors hold inflated tokens.

Another disadvantage of dynamic leverage is the imbalance in rebalancing triggers. Some issuers initiate the rebalancing process at different ranges for long and short tokens.

▶ **Example 21.** Pionex triggers rebalancing when the leverage of long tokens exceeds the range of $[2.2, 4.0]$, while this range is $[1.8, 4.8]$ for short tokens [36]. This inconsistency increases the complexity of position management, leading to unfavorable outcomes for investors.

LVTs with variable leverage may reduce the probability of front-running but also reduce token transparency and increase the complexity of managing positions. In the absence of a specific standard for the rebalancing of dynamic leverage, each issuer implements its own algorithm, which is not necessarily consistent with others. This causes confusion for investors when switching from one exchange to another, as they may expect similar performance.

Takeaways: As the price of the underlying asset fluctuates, the value of the fund and the presented leverage change at different rates. The price of the token might be at a premium or discount, not reflecting the actual value of the fund. All LVT issuers reconcile the total value of the tokens and the fund through a daily rebalancing schedule. However, the way this process is implemented differs by issuer, leading to deviations from the target leverage. Rebalancing in both types of tokens—those with fixed and dynamic leverage—has its shortcomings. Referring to LETFs, where almost 100% of traditional LETFs adhere to a fixed leverage strategy [47], suggests that fixed leverage may be more appropriate for LVTs as well. However, there is still a need to reduce the current high leverage deviation compared to LETFs, which can be achieved by modifying the relevant algorithms.

4.6 RQ6: Are LVT fees in-line with traditional LETFs?

Issuers of LETFs/LVTs charge daily fees to cover the associated costs of operating the fund (*cf.* Full version [40] Appendix A.8 on associated expenses). In recent years, fees have generally come down, with the average annual Management Expense Ratio (MER) for traditional ETFs and LETFs being 0.45% and 0.95%, respectively. We reviewed the daily fees of all LVTs and summarized the results in Table 3. Depending on the issuer, the annual MER for LVTs varies from 1.83% to 36.5%. Comparatively, the standard deviation of MER in LETFs and LVTs is 0.38% and 34.21%, respectively. This signifies that fees are less predictable and more volatile in LVTs than in LETFs (up to 90 times), impacting the overall expense ratio and net returns. Additionally, high fees often indicate a developing market with a lack of a broad base of issuers. This could be a risk indicator for investors, who typically expect lower fees due to increased competition and improved market maturity.

Takeaways: High daily fees in LVTs act as a continuous drag on performance, eroding returns, leading to underperformance, and making them less attractive. Daily costs in LVTs should be lower than in LETFs, given that futures transactions are internal and there is much less regulatory overhead. Furthermore, higher fees serve as a risk indicator for developing markets with limited competition and inefficient cost management.

Table 3 Comparison of the daily expense ratio in the equity and crypto markets. Each day, the daily fee is deducted from the price of ETFs/LETFs/LVTs, which negatively impacts the ROI. Therefore, investing in assets with lower daily rates (green rows) is less risky with higher return.

Market	Symbol	Issuer	Underlying Index/Asset	Leverage	Annual Expense Ratio	Daily Expense Ratio
Equity	IVV	BlackRock	S&P500	+1x	0.0300%	0.000119%
	VOO	Vanguard	S&P500	+1x	0.0300%	0.000119%
	SPY	SSGA	S&P500	+1x	0.0945%	0.000375%
	QQQ	Invesco	NASDAQ-100	+1x	0.2000%	0.000794%
	TQQQ	ProShares	NASDAQ-100	+3x	0.8600%	0.003413%
	SH	ProShares	S&P500	-1x	0.8800%	0.003492%
	SSO	ProShares	S&P500	+2x	0.8900%	0.003532%
	SDS	ProShares	S&P500	-2x	0.9000%	0.003571%
	SPXU	ProShares	S&P500	-3x	0.9000%	0.003571%
	UPRO	ProShares	S&P500	+3x	0.9100%	0.003611%
	PSQ	ProShares	NASDAQ-100	-1x	0.9500%	0.003770%
	QLD	ProShares	NASDAQ-100	+2x	0.9500%	0.003770%
	QID	ProShares	NASDAQ-100	-2x	0.9500%	0.003770%
	SQQQ	ProShares	NASDAQ-100	-3x	0.9500%	0.003770%
	SPXL	Direxion	S&P500	+2x	1.0000%	0.003968%
	SPXS	Direxion	S&P500	-2x	1.0800%	0.004286%

Market	Symbol	Issuer	Underlying Index/Asset	Leverage	Annual Expense Ratio	Daily Expense Ratio
Crypto	BTC3L	ByBit	Bitcoin	+2x to +4x	1.8250%	0.005000%
	BTC3S	ByBit	Bitcoin	-2x to -4x	1.8250%	0.005000%
	BTCUP	Binance	Bitcoin	+1.25 to +4x	3.6500%	0.010000%
	BTCDOWN	Binance	Bitcoin	-1.25 to -4x	3.6500%	0.010000%
	BTC3L	Pionex	Bitcoin	+2.2x to +4x	10.9500%	0.030000%
	BTC3S	Pionex	Bitcoin	-2.2x to -4x	10.9500%	0.030000%
	BTC3L	ByDFi	Bitcoin	+3x	10.9500%	0.030000%
	BTC3S	ByDFi	Bitcoin	-3x	10.9500%	0.030000%
	BTC3L	KuCoin	Bitcoin	+3x	16.4250%	0.045000%
	BTC3S	KuCoin	Bitcoin	-3x	16.4250%	0.045000%
	BTC3L	MEXC	Bitcoin	+3x	36.5000%	0.100000%
	BTC3S	MEXC	Bitcoin	-3x	36.5000%	0.100000%
	BTC3L	Gate.io	Bitcoin	+3x	36.5000%	0.100000%
	BTC3S	Gate.io	Bitcoin	-3x	36.5000%	0.100000%
	BTC3L	AscendEX	Bitcoin	+3x	109.5000%	0.300000%
	BTC3S	AscendEX	Bitcoin	-3x	109.5000%	0.300000%

5 Concluding remarks

Like leveraged ETFs, the primary goal of LVTs is to simplify investing in leveraged positions by reducing the complexities of managing such positions and limiting the risk of liquidation. During our study period, we identified numerous issues with LVTs, including a lack of transparency, custody by the issuing exchange, and possible inadequate backing. 99.9% of LVTs are implemented as centralized products, accessible only within the exchange's ecosystem. 80% of them have no interaction with the blockchain, leading to a lack of transparency in total supply, transactions, and holders.

We examined these issues along with several financial and security concerns. The total supply of 53% of LVTs is not published by the issuers, making it difficult for investors to calculate the NAV and trade LVTs at a fair market price. Additionally, 41% of LVTs may be issued with inadequate financial backing at launch, as the required futures contracts were either issued late or may not have existed at the time of the initial offering. 97% of LVTs carry the risk of front-running during well-known events, where adversaries can potentially exploit rebalancing trades. LVTs exhibit greater leverage deviation from the stated ratio compared to LETFs, due to inconsistent fund management in tokens with fixed leverage or inefficiencies in the rebalancing algorithm in LVTs with dynamic leverage.

LVTs generally have higher management fees compared to LETFs, which impacts the fund's ability to achieve its expected return. LVTs tend to underperform over extended periods (monthly or weekly) due to the compounding effect, making them unsuitable as a long-term investment vehicle.

All our findings point to the same conclusion: investors expecting simple leveraged positions that "just work" are likely to be disappointed by leveraged tokens. LVTs require careful consideration of their unique characteristics, making them more suitable for experienced traders.

Future works

Increased scrutiny from regulators and mandatory audits are potential avenues to ensure that LVTs are adequately backed. Moving LVTs on-chain could improve transparency regarding supply, transactions, and holders, while enabling self-custody. Front-running mitigation should be explored through randomized rebalancing or stealth trading (e.g., iceberg orders). LVT algorithms should be adjusted to reduce deviations from stated leverage. These measures aim to better align LVTs with investor expectations.

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