A Quantitative Analysis of Perpetual Futures Funding Rates: Mechanics, Prediction Models, and Decentralized Arbitrage Execution

I. Strategic Overview: Funding Rates as Market Predictors and Arbitrage Vectors

A. The Structural Dominance of Crypto Perpetual Futures

Perpetual futures contracts have fundamentally restructured the cryptocurrency derivatives landscape, establishing themselves as the primary engine driving market liquidity and price discovery. These contracts permit continuous exposure to the underlying asset's price movements without the constraints of a mandatory expiration date.[1] This zero-expiry feature, pioneered by exchanges in 2016, eliminated the need for traders to periodically roll over contracts, a complexity inherent in traditional futures markets.[1]

The resulting high volume has elevated perpetuals to critical financial infrastructure. On centralized exchanges (CEXs), perpetuals currently account for a substantial majority of derivative activity, exceeding 70% of total volume on major platforms.[1] This dominance is mirrored in decentralized finance (DeFi), where the perpetual decentralized exchange (DEX) market has seen volumes explode, propelled by incentives and a migration away from centralized venues. Data suggests that perpetuals accounted for over 56% of total DEX volume in 2025.[3] The core design challenge introduced by the lack of an expiration date—maintaining alignment between the contract price and the underlying Index Price—is solved by the introduction of the funding mechanism, which is a periodic fee exchanged between market participants.[4]

B. Funding Rate Deviation as a Leading Indicator of Systemic Risk

The funding rate is more than a simple cost-of-carry metric; it is a vital metric that generates new streams of data—alongside Open Interest (OI) and liquidation flows—that are crucial for gauging market sentiment and systemic risk.[2] Analysis demonstrates that funding rates act as a **leading indicator of market risk** rather than merely reflecting past price action.[6]

When funding rates exhibit aggressive spiking behavior, it indicates a severe market imbalance where one side of the contract, typically the long or short position, is "aggressively stacked" with excessive leverage.[6] This extreme basis deviation suggests that the market's inherent price alignment mechanisms are struggling to cope with overwhelming speculative pressure. Historically, such conditions often precede "violent corrections" in the underlying asset's price, primarily driven by cascading forced liquidations.[6] The relationship between high leverage and liquidation can be mathematically modeled as a "stopping time problem" [7], reinforcing the notion that funding rate spikes are direct evidence of market fragility.

The function of arbitrage is to ensure price stability, yet when the funding rate becomes extremely high, it indicates that the natural mechanism of price convergence is inadequate to clear the market imbalance due to limitations in capacity, execution speed, or cost constraints faced by arbitrageurs. This inability of the arbitrage system to instantly close the futures-spot gap reveals the market's underlying vulnerability, confirming the necessity of treating extreme funding rates as a definitive risk signal rather than just a fleeting profit opportunity.[6]

Furthermore, the operational structure of perpetual futures, while innovative, has historically attracted significant speculative activity due to the availability of high leverage (up to 125x).[1] This environment of increased volatility and risk of cascading failures has prompted exchanges to implement stronger Know Your Customer (KYC) requirements and advocate for fixed, transparent fee structures.[8] The need for exchanges to actively manage these operational parameters suggests an evolving regulatory risk landscape, which necessitates continuous monitoring by quantitative professionals who rely on these markets.

II. Definitive Mechanics and Theory of Perpetual Funding Rates

A. The Mechanism of Price Alignment and Peer-to-Peer Payments

The perpetual funding mechanism is a required, periodic payment exchanged between traders holding opposite positions, designed to keep the perpetual contract price tethered to an external index reference, typically the underlying spot price.[4] The payment is purely peer-to-peer; the exchange does not collect any fees on the transfer itself.[9]

The directionality of the payment depends on the contract's current premium or discount relative to the index price:

1. **Positive Funding Rate:** Occurs when the perpetual contract trades at a premium (above) the spot Index Price. In this scenario, traders holding long positions must pay a fee to those holding short positions.[10] This payment incentivizes traders to take the opposite side (short the contract and buy the spot asset), thereby driving the contract price down and back toward the spot price.[10]
2. **Negative Funding Rate:** Occurs when the perpetual contract trades at a discount (below) the spot Index Price. Short position holders pay a fee to long position holders.[10] This incentivizes new traders to take long positions, pushing the contract price up toward

alignment.[10]

B. The Standardized Funding Rate Calculation

While implementation details vary, the general funding rate formula is typically a composite of two primary components, the Premium Index and the Interest Rate.[14]

$$\text{Funding Rate} = \text{Premium Index} + \text{Interest Rate}$$

The **Premium Index** represents the basis difference between the contract's Mark Price and the Index Price (or spot market equivalent).[11] The **Interest Rate** is a fixed component, often set low (e.g., 0.01%), which represents the baseline cost of borrowing or lending the underlying asset.[9]

The actual payment exchanged between parties is based on the position's notional value. The calculation for the payment at the end of the interval is defined as:

$$\text{Payment} = \text{Position Size} \times \text{Oracle Price} \times \text{Funding Rate} \quad [9]$$

A critical design consideration in decentralized protocols, such as Hyperliquid, is the specification that the funding payment notional is determined using the **Spot Oracle Price** (the external Index Price), rather than the potentially volatile Mark Price of the perpetual contract.[9] This design choice is fundamental to insulating the arbitrage mechanism from transient market manipulations or flash crashes that might temporarily skew the derivative's internal price. By pegging the payment to a stable, externally referenced price, the protocol ensures the viability and reliability of the cash-and-carry hedge, confirming the protocol's prioritization of stability over short-term volatility influence.

C. Technical Nuance: Annualization and Limits

For accurate analysis and strategy comparison across various venues, funding rates must be standardized. Because exchanges utilize differing payment intervals (which can range from hourly to 8-hourly) [8], the calculated rate needs to be annualized for comparability. The standard formula for this conversion is:

$$\text{Annualized Rate} = \text{Rate} \times \frac{1 \text{ year}}{\text{period in years}} \quad [13]$$

It is important to note that funding payments are applied to the value of the long or short position and do not change that position's value in a compounding manner. This means that funding rates are **not compounded** [13], simplifying the calculation of expected carry costs for long-term arbitrage positions to a simple linear summation of expected payments. This non-compounding nature makes the yield of the cash-and-carry trade easier to model and less sensitive to high-frequency rate fluctuations than traditional interest rate structures found in finance.

Exchanges also implement volatility caps and floors to restrict the range of the funding rate, preventing immediate and potentially catastrophic price divergence. Examples include limits based on maintenance margin rates [16] or predefined percentage caps, such as Hyperliquid's 4% per hour cap.[9]

III. Deconstructive Analysis of Leading DEX Funding Mechanisms (Case Cases)

The efficiency of perpetual futures funding rate arbitrage is highly dependent on the underlying infrastructure and the precise calculation mechanics employed by individual exchanges, particularly within the competitive decentralized market.

A. Hyperliquid's L1 Architecture and Calculation (HL Case Study)

Hyperliquid differentiates itself through its underlying technology. It operates on HyperCore, a bespoke Layer 1 blockchain optimized for ultra-low latency and high-throughput order book trading, capable of processing up to 200,000 orders per second.[17] This performance, achieved through the HyperBFT consensus algorithm, makes Hyperliquid a direct competitor to centralized exchange infrastructure, vital for successful High-Frequency Trading (HFT) arbitrage.[17]

The protocol's funding rate calculation is transparent and utilizes a rigorous clamping function to maintain stability:

1. Premium Calculation: The premium is calculated using the Impact Bid Price, which incorporates market depth:

   $$\text{Premium} = \frac{\text{Impact Bid Price} - \text{Spot Price}}{\text{Spot Price}} \quad [9]$$
2. Clamped Difference: This step introduces stability by limiting sharp deviations between the fixed Interest Rate (e.g., 0.01%) and the calculated Premium Rate:

   $$\text{Clamped Difference} = \min(\max(\text{Interest Rate} - \text{Premium Rate}, -0.05\%), 0.05\%) \quad [9]$$
3. Final Funding Rate:

   $$\text{Funding Rate} = \text{Premium Rate} + \text{Clamped Difference} \quad [9]$$

The calculation employs the **Impact Bid Price**, which integrates the **Impact Notional** parameter specified in the contract.[9] This mechanism ensures that the funding rate is responsive to market movements requiring significant capital flow to resolve, rather than being triggered by superficial, thin quotes at the top of the order book.

The explicit and relatively narrow clamping range (0.05% hourly) is a deliberate design choice. Rather than instantly adjusting the rate to an extreme basis deviation, this clamp limits the speed of convergence when the contract price significantly diverges from spot.[9] For quantitative traders, this restriction provides a predictable duration for high-conviction carry trade opportunities. A narrow clamp guarantees that if a 1% premium exists, the funding rate will likely remain high for several hours, making the profit profile of the ensuing arbitrage trade stable over a multi-period horizon and less dependent on sub-millisecond execution speeds typically associated with HFT.

B. Comparative Analysis: Aster and Lighter Protocols

The decentralized derivatives market remains fragmented, with emerging protocols offering distinct architectural advantages that influence arbitrage execution.

Aster: Aster is positioned as a sophisticated challenger, providing both Perpetual Mode (an order book environment with comprehensive risk management features) and a 1001x Mode for ultra-high leverage.[19] Crucially for institutional arbitrageurs, Aster supports **Hidden Orders** in its Professional Mode.[20] This feature allows large entities to place significant orders without revealing their total size or strategy, thereby mitigating execution signaling risk and market impact, a significant advantage for capitalizing on funding spreads.

Lighter: Lighter focuses on infrastructural performance, operating as an application-specific ZK-rollup on Ethereum, employing a verifiable matching engine.[3] The protocol aims to deliver the security of full decentralization with the high throughput of a centralized exchange, underscoring the trend towards proprietary, app-specific infrastructure to optimize derivatives execution.[21]

The coexistence of sophisticated, proprietary DEX architectures, such as Hyperliquid's L1 and Lighter's L2, results in fragmented liquidity and varying funding rate calculations. This ensures that the Law of One Price is enforced *locally* within each DEX environment but is often violated *between* competing venues. For instance, Lighter data might show Solana (SOL) with a negative funding rate (-0.13%) while Hyperliquid shows a positive one (0.04%).[22] These inter-DEX discrepancies maintain the necessity of monitoring multiple exchanges and executing cross-DEX funding arbitrage strategies.

IV. Quantitative Arbitrage and Mean Reversion Strategies

A. Funding Rate Arbitrage (Cash-and-Carry)

Funding rate arbitrage is a low-risk strategy designed to capture the yield generated by the periodic funding payment while ensuring market neutrality against directional price risk.[12]

The classical implementation involves the Cash-and-Carry approach: if the perpetual contract is trading at a premium (positive funding), the trader simultaneously shorts the perpetual contract (to receive the funding payment) and purchases an equivalent notional amount of the underlying spot asset (the hedge).[12] This strategy is effectively delta-neutral, locking in the funding yield less trading fees and borrowing costs.

While delta-neutral, the strategy is highly exposed to execution risks and basis risk—the risk that the spread between the futures and spot prices moves detrimentally during the opening or closing phases of the trade. Furthermore, if collateral is managed poorly, the high leverage available (up to 125x) introduces significant liquidation risk, emphasizing the importance of rigorous maintenance margin monitoring.[1] The strategy is highly preferred because the periodic payment is guaranteed if the position is held through the funding interval, making the profit highly deterministic, provided the execution is flawless.[12]

B. Statistical Arbitrage: Cointegration and Mean Reversion

Statistical arbitrage is a sophisticated approach based on the foundational principle of mean reversion: the tendency for asset prices or pricing spreads to return to their historical average following a significant divergence.[24]

To prove the statistical viability of a mean-reverting relationship, quantitative analysts rely on **Cointegration Tests**, such as the Engle-Granger and Johansen tests.[26] These methods establish that the perpetual futures price and the spot price, or related funding rates, maintain a long-term, statistically stable relationship. Without proof of cointegration, the trading spread is classified as non-stationary, rendering mean-reversion assumptions invalid.[25]

Once stationarity is confirmed, the dynamics of the spread are often modeled using the Ornstein-Uhlenbeck process, which helps in calibrating the speed of mean reversion and estimating the "half-life" of the divergence.[27] This calibration is essential for determining optimal trade holding periods. Trading signals are then generated using **Z-Score models**, which quantify how many standard deviations the current spread has moved from its historical mean, providing objective entry and exit thresholds.[26]

The implementation of statistical arbitrage in cryptocurrency markets requires highly realistic backtesting protocols. Given the volatility and fragmented nature of the market, backtests must use minute-binned data, incorporate best bid/ask quotes, and explicitly account for execution gaps, slippage, and execution failure.[27] Since the successful outcome of a trade hinges on the ability to fill the required size at the quoted price, models that ignore these microstructure constraints often generate simulated profitability figures that are unattainable in real-world trading environments.[27]

C. Momentum and Sentiment Indicators (Open Interest Divergence)

Funding rates and price action can be combined with Open Interest (OI) data to generate powerful reversal signals. OI represents the total number of unsettled contracts and is a proxy for the commitment of new capital entering the market.[2]

Standard interpretation suggests that if both the price and the OI are rising, it confirms a robust trend backed by new liquidity.[28] Conversely, divergence between price and OI often signals a pending reversal:

- A **Bearish Divergence** occurs when the price makes higher highs, but the Open Interest concurrently registers lower highs, suggesting diminishing strength and potential capital withdrawal.[29]

A highly predictive signal is generated by integrating OI divergence with extreme funding rate signals. When the funding rate exceeds a predefined abnormal threshold (e.g., a Z-Score greater than ± 4.0) while simultaneously showing price/OI divergence, it strongly indicates that the aggressive leveraging [6] is reaching an unsustainable climax, preceding a high-conviction market reversal.[6]

V. Advanced Predictive Modeling of Funding Rate Dynamics

A. Time-Series Forecasting and Predictive Edge

The utilization of advanced forecasting models is critical for moving beyond reactive arbitrage toward predictive, high-alpha strategies. Empirical analysis confirms a causal relationship between the funding rates of futures contracts and the underlying market price movements, notably demonstrating Granger causality for assets like Ethereum.[30] This establishes a strong quantitative basis for integrating funding rates as an explicit feature in price prediction systems.

For competitive execution, quantitative analysts must utilize **Predicted Funding Rates** which update in real-time, allowing for execution with minimal latency, rather than relying solely on **Realized Funding Rates** which only become available periodically upon payment.[31]

B. Adaptive Quantitative Models: The Kalman Filter (KF)

Traditional mean-reversion strategies often assume a fixed relationship or hedge ratio between the perpetual contract and the spot asset. In volatile crypto markets, this assumption introduces significant basis risk that erodes profitability. The **Kalman Filter (KF)** addresses this by providing an optimal linear algorithm that dynamically tracks the spread's mean-reversion behavior.[32]

The KF is highly valuable because it continually updates the estimate of the latent (hidden) variable—the optimal hedge ratio—based on the latest observable market data.[32] This adaptive property is essential for maintaining a high-fidelity hedge under market stress, making the KF the necessary engineering solution for maximizing the Sharpe Ratio of a perpetual futures arbitrage strategy. The Kalman Filter minimizes estimation errors and can be customized to handle non-white noise (correlated noise) frequently observed in financial time series data, further enhancing the accuracy of factor estimation.[33]

C. Deep Learning and Multi-Asset Portfolio Optimization

For comprehensive risk management and yield maximization, sophisticated modeling techniques such as Deep Learning are deployed. **Long Short-Term Memory (LSTM) neural networks** are favored for time-series forecasting due to their superior ability to capture temporal dependencies in highly volatile cryptocurrency price data.[34]

A significant evolution in this field is the move toward multi-task learning models that optimize trading plans across several correlated assets (e.g., BTC, ETH, LTC) simultaneously.[34] Because major cryptocurrencies exhibit significant correlation, models that ignore these co-movements provide incomplete risk pictures.

These advanced models move beyond optimizing for simple statistical error metrics (like Mean Squared Error, MSE) and instead focus on maximizing **risk-adjusted profitability** by minimizing the **Negative Sharpe Ratio** loss function.[34] By structuring the objective function this way, the model implicitly manages co-movement risk and diversification benefits, ensuring the resultant portfolio strategy is robust against systemic market sell-offs. For instance, the systematic integration of high-frequency market microstructure features into these prediction systems ensures they maintain computational efficiency and competitiveness required for high-frequency decision environments.[35]

VI. Implementation, Execution, and Risk Management Frameworks

A. High-Frequency Execution in Decentralized Environments

Profitability in basis arbitrage is directly correlated with technological superiority. Given that net margins per trade are often razor-thin, potentially ranging from 0.01% to 0.1% [36], rapid execution and minimal latency are crucial for success.[36] Automated arbitrage systems require robust infrastructure (often cloud-based or specialized VPS setups) offering 24/7 uptime and low-latency connectivity to multiple exchanges, supporting cross-exchange opportunities.[38] The requirement includes real-time access to low-latency order books and instant alerts to ensure fleeting price spreads are captured before they disappear.[38]

B. DEX Execution Optimization: Managing Gas and Congestion

Operating high-frequency arbitrage strategies on decentralized exchanges introduces unique execution challenges, particularly related to gas fees, transaction queuing, and finality. Even high-performance L1s like Hyperliquid's HyperEVM, designed for speed, can experience congestion.[39]

To ensure consistent profitability on-chain, quantitative teams have developed specialized, proprietary optimization strategies. A documented example of successful high-value arbitrage operation demonstrates several key engineering principles [39]:

1. **Parallelization:** Utilizing a large number of segregated wallets (e.g., over 100) to initiate arbitrage transactions concurrently, which prevents order queueing bottlenecks associated with a single wallet.[39]
2. **Internal Rate Limiting:** Implementing both block-based rate limits (e.g., maximum of 8 arbitrage transactions per block) and time-based limits (increasing profit requirements if transaction volume exceeds a threshold in a 12-second window) to manage network saturation.[39]
3. **Dynamic Profitability Gating:** The most crucial optimization involves **Gas Price Control**, where the required Return on Investment (ROI) for execution is dynamically increased when the underlying network gas price surges.[39] This mechanism treats gas fees not as a static input, but as a dynamic variable that directly gates execution eligibility. The instantaneous profitability check is adjusted to ensure that the calculated $Profit_{net}$ still exceeds a required minimum threshold *after* subtracting trading fees and the highly volatile gas fee component, confirming that specialized cost governance is integral to successful DEX HFT.[35]

C. Rigorous Performance Evaluation and Risk Metrics

The performance of any quantitative trading strategy must be assessed against standardized metrics that account for risk exposure.[41] These key performance indicators (KPIs) include:

Performance Evaluation Metrics

Metric	Importance and Function
Cumulative Return	Measures overall strategy effectiveness regardless of timeframe.[41]
Sharpe Ratio	Evaluates return quality by accounting for

	volatility and risk taken.[41]
Maximum Drawdown (MDD)	Quantifies the worst-case capital decline, essential for risk management.[41]
Profit Factor	Assesses overall profitability efficiency and capital utilization.[41]
Win Rate	Indicates strategy consistency and psychological sustainability.[41]

Risk management must prioritize the avoidance of liquidation, which terminates positions that fail to satisfy maintenance margin requirements.[7] Risk mitigation includes defining leverage limits [1], controlling position sizing based on calculated market impact [42], and implementing robust security protocols, such as encrypted storage for API keys and IP allow lists, especially when coordinating activities across multiple centralized and decentralized venues.[38]

The increasing efficiency of crypto markets, driven by technological improvements and heavy venture capital investment in perp DEX infrastructure [3], mandates a strategic shift. Arbitrage profitability is diminishing for simple, reactive strategies, necessitating a transition toward advanced, predictive systems. Future quantitative advantage relies on accurately forecasting *when and where* the funding rate will deviate next, thereby monetizing subtle, temporary market anomalies through machine learning and adaptive filtering techniques like the Kalman Filter.[30]

VII. Conclusions

Perpetual futures funding rates constitute a core quantitative signal in cryptocurrency markets, bridging the derivatives and spot ecosystems. The funding rate mechanism is inherently designed for mean reversion, but its extreme deviations serve as a critical leading indicator of systemic risk and excessive leverage, often preceding forced liquidations.

Success in this domain requires a two-pronged approach:

1. **Technical Sophistication:** Analysts must master the nuanced calculation mechanics of specific high-performance DEXs, recognizing that architectural choices—such as Hyperliquid's use of Impact Bid Price and its narrow clamping function—create predictable, exploitable horizons for carry trades.
2. **Algorithmic Excellence:** Strategies must evolve beyond simple deterministic arbitrage. The necessity of the Kalman Filter for dynamically adjusting hedge ratios and the shift toward deep learning models that optimize portfolio-level Sharpe Ratios demonstrates that advanced, adaptive quantitative methods are required to sustain alpha in increasingly efficient, fragmented markets.
3. **Execution Supremacy:** For decentralized execution, the integration of bespoke,

gas-aware optimization strategies—such as dynamic ROI gating and transaction parallelization—is not optional but mandatory, confirming that execution cost variability is the most significant non-market risk in competitive DEX arbitrage.

Works cited

1. Perpetual Futures - DayTrading.com, accessed December 16, 2025, https://www.daytrading.com/perpetual-futures
2. Crypto Futures Explained: Understanding Perpetual Contracts - CoinAPI.io, accessed December 16, 2025, https://www.coinapi.io/blog/crypto-futures-explained-understanding-perpetual-contracts
3. Lighter raises $68 million at a $1.5 billion valuation as VC bets flood back into perp DEX infrastructure: report | The Block, accessed December 16, 2025, https://www.theblock.co/post/378358/lighter-raises-68-million-1-5-billion-valuation-vc-bets-flood-perp-dex-infrastructure-report
4. What is Funding Rate? Crypto Perpetual Futures Guide - Cube Exchange, accessed December 16, 2025, https://www.cube.exchange/what-is/funding-rate
5. Perpetual Futures Pricing* - Wharton's Finance Department, accessed December 16, 2025, https://finance.wharton.upenn.edu/~jermann/AHJ-main-10.pdf
6. Arbitrage-Aware Routing for Funding Rate Prediction Systems - ResearchGate, accessed December 16, 2025, https://www.researchgate.net/publication/397883352_Arbitrage-Aware_Routing_for_Funding_Rate_Prediction_Systems
7. "A Quantitative Analysis on Bitcoin Perpetual Inverse Futures" by Yue Wu, accessed December 16, 2025, https://digitalcommons.iwu.edu/uer/vol17/iss1/12/
8. IS THERE A FUTURE IN PERPETUAL FUTURES? - NYU Stern, accessed December 16, 2025, https://www.stern.nyu.edu/sites/default/files/assets/documents/Duron-Carielo_Is%20There%20A%20Future%20In%20Perpetual%20Futures.pdf
9. Funding - Hyperliquid Docs - GitBook, accessed December 16, 2025, https://hyperliquid.gitbook.io/hyperliquid-docs/trading/funding
10. Understanding the Funding Rate in Perpetual Futures - One Trading, accessed December 16, 2025, https://www.onetrading.com/blog/understanding-the-funding-rate-in-perpetual-futures
11. What is the funding rate? - Coinbase Help, accessed December 16, 2025, https://help.coinbase.com/en/international-exchange/funding/what-is-the-funding-rate
12. The Ultimate Guide to Funding Rate Arbitrage - Amberdata Blog, accessed December 16, 2025, https://blog.amberdata.io/the-ultimate-guide-to-funding-rate-arbitrage-amberdata
13. Funding Rates | Product Docs - Coin Metrics, accessed December 16, 2025, https://gitbook-docs.coinmetrics.io/market-data/market-data-overview/funding-r

ates/funding-rates
14. Understanding Funding Rates in Perpetual Futures and Their Impact - Coinbase, accessed December 16, 2025, https://www.coinbase.com/learn/perpetual-futures/understanding-funding-rates-in-perpetual-futures
15. Understanding Perpetual Futures: A Guide for Cryptocurrency Traders - Investopedia, accessed December 16, 2025, https://www.investopedia.com/what-are-perpetual-futures-7494870
16. Introduction to Funding Rate - Bybit, accessed December 16, 2025, https://www.bybit.com/en/help-center/article/Introduction-to-Funding-Rate
17. Hyperliquid on Chainlink Ecosystem | Every Chainlink integration and partnership, accessed December 16, 2025, https://www.chainlinkecosystem.com/ecosystem/hyperliquid
18. Hyperliquid Integration Guide - Chainlink Documentation, accessed December 16, 2025, https://docs.chain.link/ccip/tools-resources/network-specific/hyperliquid-integration-guide
19. Understanding Aster (ASTER) in One Article | Binance Academy on Binance Square, accessed December 16, 2025, https://www.binance.com/en/square/post/33523359093185
20. Aster's Meteoric Rise in DeFi Perps and The Binance Connection - Medium, accessed December 16, 2025, https://medium.com/coinmonks/asters-meteoric-rise-in-defi-perps-and-the-binance-connection-bcb54bd04a7d
21. Lighter Project Introduction, Team, Financing and News_RootData, accessed December 16, 2025, https://www.rootdata.com/Projects/detail/Lighter?k=NzIwMQ%3D%3D
22. Lighter trade volume and market listings | CoinMarketCap, accessed December 16, 2025, https://coinmarketcap.com/exchanges/lighter/
23. Lighter Statistics: Markets, Trading Volume & Trust Score - CoinGecko, accessed December 16, 2025, https://www.coingecko.com/en/exchanges/lighter
24. Mastering Mean Reversion Strategies in Crypto Futures: Tools, Techniques, and Risk Management | OKX, accessed December 16, 2025, https://www.okx.com/learn/mean-reversion-strategies-crypto-futures
25. Optimal Entry and Exit with Signature in Statistical Arbitrage - arXiv, accessed December 16, 2025, https://arxiv.org/html/2309.16008v4
26. What Is a Statistical Arbitrage Crypto Bot? | Explained Simply - WunderTrading, accessed December 16, 2025, https://wundertrading.com/journal/en/learn/article/statistical-arbitrage-crypto-bot
27. Evaluation of Dynamic Cointegration-Based Pairs Trading Strategy in the Cryptocurrency Market - ResearchGate, accessed December 16, 2025, https://www.researchgate.net/publication/354776945_Evaluation_of_Dynamic_Cointegration-Based_Pairs_Trading_Strategy_in_the_Cryptocurrency_Market
28. Leveraging Open Interest for Bull and Bear Market Signals - Investopedia,

accessed December 16, 2025,
https://www.investopedia.com/articles/technical/02/112002.asp
29. Open Interest — Penunjuk dan Strategi - TradingView, accessed December 16, 2025, https://my.tradingview.com/scripts/openinterest/
30. Predicting Ethereum price with perpetual futures contract funding rates - Aaltodoc, accessed December 16, 2025, https://aaltodoc.aalto.fi/items/7a663327-a08a-4f52-b274-33e881be7c7f
31. Predicted Funding Rates | Product Docs - Coin Metrics, accessed December 16, 2025, https://gitbook-docs.coinmetrics.io/market-data/market-data-overview/funding-rates/predicted-funding-rates
32. Mean Reversion Strategies for Algorithmic Trading - LuxAlgo, accessed December 16, 2025, https://www.luxalgo.com/blog/mean-reversion-strategies-for-algorithmic-trading/
33. Estimating an affine term structure model of interest rates with correlated noise | PLOS One, accessed December 16, 2025, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0318076
34. Cryptocurrency price prediction and portfolio optimization based on LSTM and multi-task neural network - AIMS Press, accessed December 16, 2025, https://www.aimspress.com/article/doi/10.3934/QFE.2025023?viewType=HTML
35. Optimizing Prediction System Routing with Funding Rate Signals - ResearchGate, accessed December 16, 2025, https://www.researchgate.net/publication/397883105_Optimizing_Prediction_System_Routing_with_Funding_Rate_Signals
36. High-Frequency Arbitrage and Profit Maximization Across Cryptocurrency Exchanges, accessed December 16, 2025, https://medium.com/@gwrx2005/high-frequency-arbitrage-and-profit-maximization-across-cryptocurrency-exchanges-4842d7b7d4d9
37. International High-Frequency Arbitrage for Cross-Listed Stocks - Chaire de recherche du Canada en gestion des risques - HEC Montréal, accessed December 16, 2025, https://chairegestiondesrisques.hec.ca/wp-content/uploads/2022/03/21-04.pdf
38. Crypto Arbitrage Trading: Unlock Profits from Price Discrepancies in 2025 | Zignaly, accessed December 16, 2025, https://zignaly.com/crypto-trading/arbitrage-strategies/crypto-arbitrage-trading
39. We Made $5 Million With an Arbitrage Bot on HyperEVM - Moomoo, accessed December 16, 2025, https://www.moomoo.com/news/post/60007567/we-made-5-million-with-an-arbitrage-bot-on-hyperevm
40. Mastering Crypto Arbitrage Bot Development - Rock'n'Block, accessed December 16, 2025, https://rocknblock.io/blog/mastering-crypto-arbitrage-bot-development
41. Predicting Price Movements in High-Frequency Financial Data with Spiking Neural Networks - arXiv, accessed December 16, 2025,

https://arxiv.org/html/2512.05868v1
42. metaAndAssetCtxs | Hyperliquid info - Chainstack Docs, accessed December 16, 2025,
https://docs.chainstack.com/reference/hyperliquid-info-meta-and-asset-ctxs