CHAOS LABS

Perpetual Futures Liquidity and Funding Rate Considerations for Ethena

An exploration of risks to the Ethena protocol emanating from all aspects of perpetual futures. Particular focus is on funding rate dynamics, futures liquidity, and estimated slippage.

Ethena

November 9th, 2023

Perpetual Futures Liquidity Assessment Report

Omer Goldberg
omer@chaoslabs.xyz

Shai Kritz
shai@chaoslabs.xyz

Craig Le Riche
craig@chaoslabs.xyz

October 2023

Abstract

This report analyzes the problem of tatonnement in perpetual future funding rate adjustments to changes in short open interest from a market microstructure standpoint. The funding rate mechanism exists to incentivize price convergence to its underlying index. Excess activity on one side of a perpetual futures market affects the funding rate as market makers adjust their prices according to their inventory. This affects funding rates which in turn attracts flow, exploiting any potential funding or price differential. As a result, funding rates display mean reverting characteristics around certain levels, defined by external dynamics and funding rate configurations.

Open interest is analyzed from both an absolute quantum perspective as well as weekly changes.

A deep dive into historical funding rate performance across exchanges follows, covering all aspects relevant to Ethena's use case. There is particular focus on how these funding rates have reacted to previous changes in open interest and the persistence of these changes.

Using historical performance, a value-at-risk measure for the insurance fund is proposed and simulated against various growth and tax rate levels.

Lastly, we measure the expected slippage distribution of trading different volumes of perpetual futures.

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Chapter 1

Introduction

The Ethena protocol issues the synthetic dollar USDe, backed by long liquid staking tokens and short ETH perpetual futures. Ethena must execute these hedges on various exchanges as part of the mint process. The final value of USDe received against an amount of collateral is calculated after the hedge is executed to avoid the protocol taking on any price risk.

This report dives into the feasibility of executing these perpetual futures hedges. Aspects covered include the slippage expected, the impact on funding rates using historical data, and all aspects related to the exchange open interest.

This analysis aims to provide an upfront estimate of the workability of the Ethena protocol mechanism design. Historical data is used, and the assumption is made that past behaviors and trends will persist.

Chapter 2

Open Interest Analysis

This report starts with an assessment of ETH perpetuals open interest. Open interest (OI) is highly relevant for Ethena as the protocol will add significant short OI if successful, and the market needs to absorb this without affecting funding rates too much.

This assessment of open interest dynamics is intended to provide context to later analyses of funding rates and their response to changes in OI. Together, they will provide the basis for analyzing the extent of short open interest that Ethena could be expected to take on safely and its potential size and growth rate.

Due to their differentiated funding rate dynamics, the analysis examines linear and inverse perpetuals separately.

Inverse perpetuals provide the perfect hedge for Ethena as collateral is held in ETH LSTs, reducing the need to rebalance positions as prices change. The larger linear perpetuals markets offer greater liquidity and will likely be able to sustain more open interest. They simply require an extra step to ensure that the notional value of collateral and hedges matches the USDe supply.

Should Ethena need to exchange margin and LSTs, there is the option of the primary market with no slippage, as these transactions are unlikely to be highly time-sensitive.

1 Linear Perpetual Futures

Open interest in linear ETH perpetual futures grew from approximately $150m in the first half of 2021 to $6bn around a year later. Since then, there have been significant movements in OI, but the market size was significantly hampered by the FTX collapse. There has been a recovery over 2023 to the current level of around $5bn.

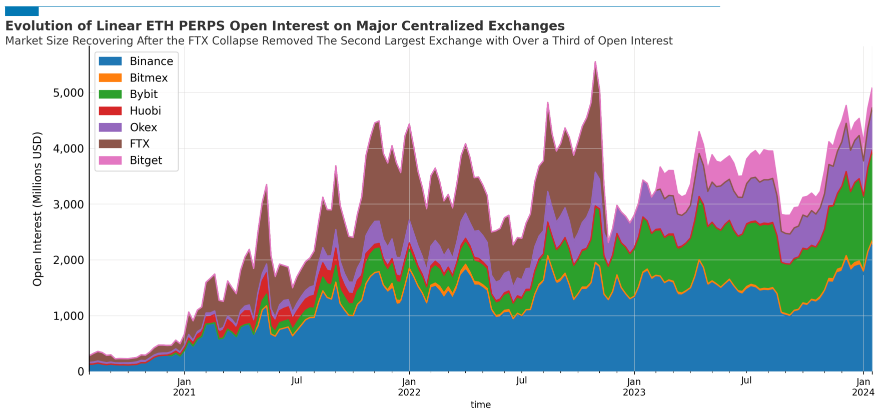


Figure 2.1: Linear ETH Perpetuals market evolution. Note Biget data is only available from 19 Feb 2023.

These open interest weights are used throughout this report to measure open interest weighted linear funding rates, the primary measure used to study USDe's funding footprint.

There has been a healthy trend towards greater diversity of this open interest share amongst exchanges, which helps mitigate some platform dependency. Despite this, there is still approximately 32 percent market share with Binance, which poses risks in insolvency, requiring open interest to be re-homed.

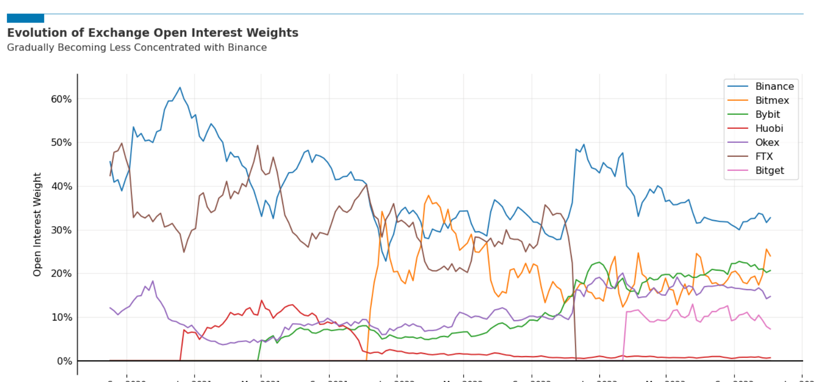


Figure 2.2: Relative open interest share of significant linear ETH perpetual markets.

A rational assumption is that significant changes in open interest are usually the result of one side of the market attracting interest rather than balanced but growing interest overall. If this is the case, funding rates should see similarly large weekly moves, and given that these OI movements tend to persist for long periods, funding rates' natural inclination to revert is put to the test.

The chart below shows the distribution of weekly open interest changes over the past three years. The broad distribution provides comfort that a reasonably wide range of movements in open interest have occurred and given funding rates a reasonable stress test.

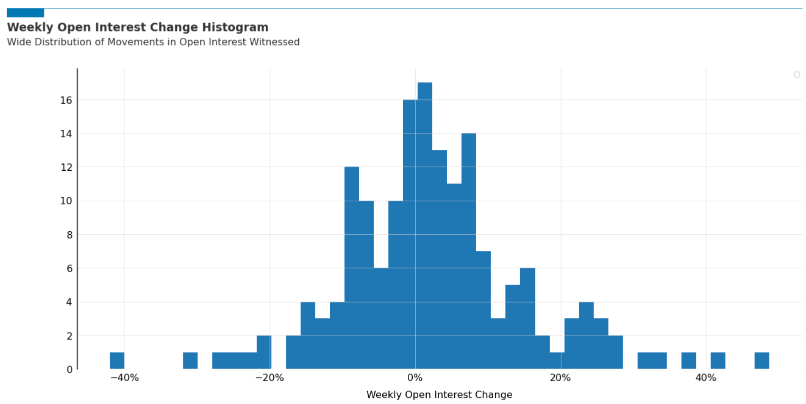


Figure 2.3: Histogram showing the distribution of Weekly Open Interest Movements.

2 Inverse Perpetual Futures

The inverse perpetuals market peaked in terms of open interest in late 2021. Like linear perpetuals, open interest has been stable over the past year. However, at around $1.2bn, and should market conditions improve, there is the possibility that this product will grow again.

The breakdown of open interest between exchanges is even more concentrated than linear futures, with approximately 55% of open interest with Deribit.

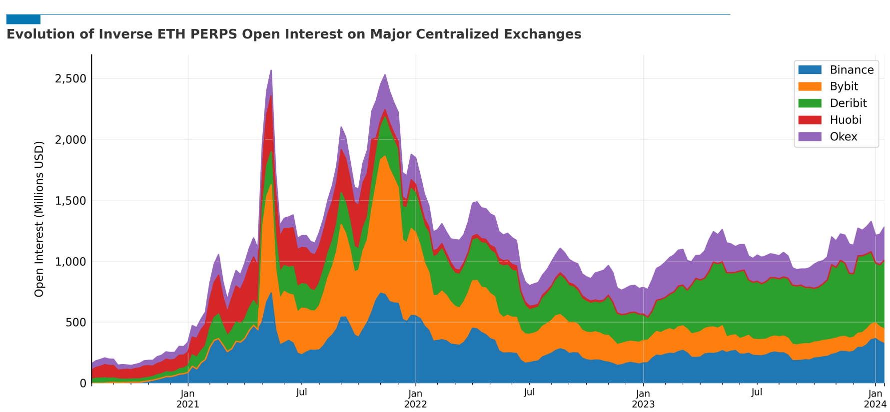


Figure 2.4: Inverse ETH Perpetuals market evolution.

These have seen less variance in weekly moves in open interest than in linear futures. They also have much lower trading volumes than open interest, indicating longer-term, more stable open positions. This could indicate less ability to absorb large, fresh open interest than linear futures.

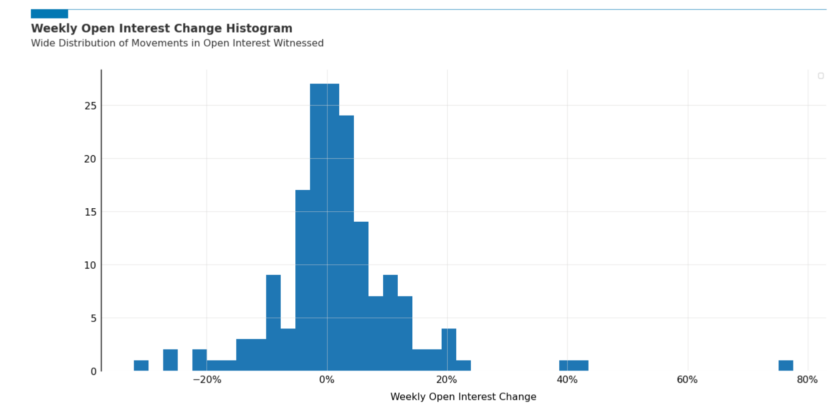


Figure 2.5: Histogram showing the distribution of Inverse ETH Perpetuals Weekly Open Interest Movements.

3 Open Interest Growth Relationship with ETH Market Capitalization

The amount of ETH perpetual open interest has been highly dependent on ETH market capitalization historically. Plotting these factors together shows an almost one-to-one relationship over the previous bull market of 2020-2021. Perpetual open interest held up relatively better over the market downturn, obscuring what has continued to be a powerful relationship recently. Our analysis estimates that open interest moves between 1.2% and 1.45% for every 1% change in market capitalization.

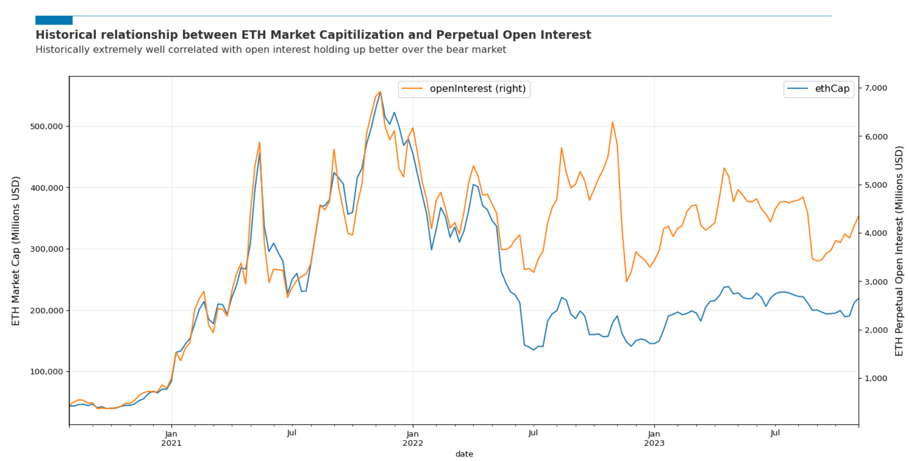


Figure 2.6

4 Open Interest Summary

- Open interest has grown from \$150m in mid-2020 to \$6.2bn currently across linear and inverse perpetuals.
- Most of this growth happened from late 2020 to late 2021.
- Since then, linear open interest has fluctuated from \$3bn to \$6bn without much growth. Inverse open interest dropped from \$2.5bn to \$1.2bn over this period.
- The FTX collapse caused two successive weekly 30% reductions in total open interest. Since then, the lost open interest has returned on other exchanges.
- There has been a transition of linear open interest from almost exclusively on Binance and FTX to a more diverse split as other exchanges have bootstrapped their activity.
- Weekly open interest moves have been large. Historical weekly movements in open interest indicate a highly adaptive market to changes in supply and demand.
- ETH open interest moves in line with market capitalization with a beta of between 1.2 and 1.45.

Chapter 3

Funding Rate Analysis

This assessment of historical funding rates' behavior serves as the foundation of analyses into their expected behavior involving Ethena.

Linear and inverse perpetuals are again considered separately to gain insights into their idiosyncratic historical traits.

1 Linear Perpetual Futures

This report is concerned with material risks to Ethena. Intra-day movements in funding rates do not pose much risk to Ethena's solvency as their effect is a capped, slow erosion of collateral. The maximum negative rate on Binance of -100%, for example, implies a maximum loss of 0.091% of notional in any single 8-hour period.

The risk focus rather focuses on periods where the average level that funding rates converge around shifts negative for a sustained period of time. The persistence of negative rates creates a much greater risk to Ethena than point-in-time movements, as the additive effect of prolonged negative rates can have a material impact on Ethena's solvency.

There have only been a few occasions previously where all exchange funding rates moved negative for a sustained period of time. These are mostly event-driven and revert quickly once the event's impact passes. The following sections measure each of their accumulated impact and drawdowns in more detail.

Ethena intends to hedge its ETH exposure with various exchanges and, therefore, is exposed to aggregate funding rates. The benchmark used to track this through time is the open interest weighted funding rates, using the open interest shares from the previous section.

This open-interest-weighted funding rate displays vastly different behavior from pre-2022 to the period after that. This lines up with two significant trends in open interest. The more volatile period for aggregate funding rates was associated with rapid trend growth in open interest and a less competitive exchange dynamic.

The major spike lower in ETH funding rates in September 2022 was caused by speculators taking long ETH spot positions hedged with perpetuals, hoping to profit from ETH PoW tokens. This one-off outlier event is excluded from some later analyses alongside data including it. The intention is to remove the outsized impact of this aberration that affects specific metrics due to its magnitude.

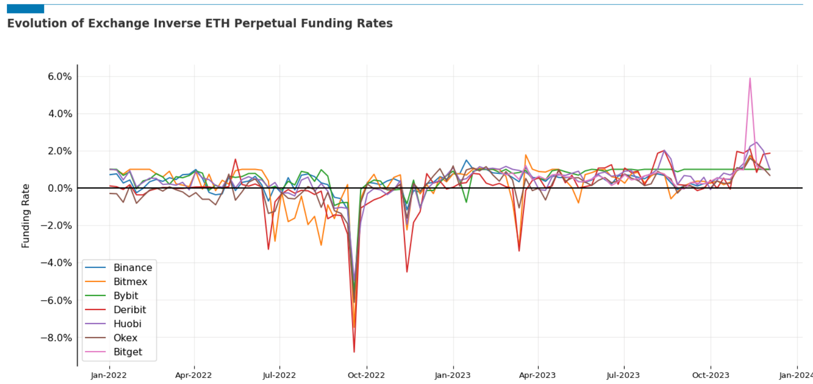


Figure 3.1: Funding rates since January 2022, with significantly lower variability.

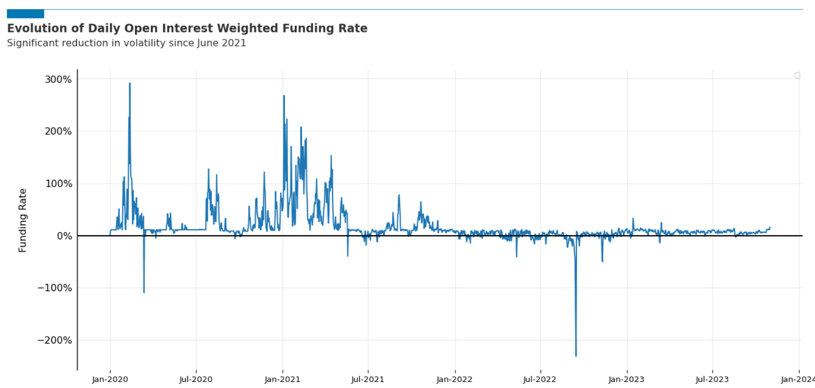


Figure 3.2: Data back to January 2020.

Looking exclusively at the period from January 2022 and removing the outlier merge period 11-15 September 2022, the daily average funding rate displays apparent mean reversion to a positive level. The only periods that appear to violate this for a sustained period are around April 2022, June 2022, and September 2022—other than the September Merge event already mentioned, other periods where funding rates traded around a negative rate for a period coincided with market stress and deleveraging.

The April 2022 period of reverting around a negative rate lasted around three weeks and averaged -3.3%. June 2022 also lasted approximately three weeks and averaged -4.8%. If the extreme 11-15 September funding is included, this period lasted five weeks and averaged -17.9%.

Funding rates in 2023 have been more positive and less volatile than in 2022. Improved market conditions and no further deleveraging could explain this, and if so, funding rates could transition back to a positive skewness in a re-leveraging cycle.

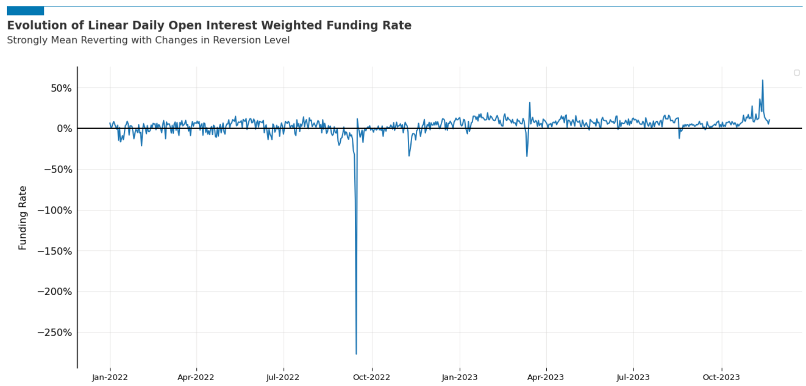


Figure 3.3: The more stable 2022 and later open interest weighted funding rate.

2 Inverse Perpetual Futures

Inverse perpetuals have been more susceptible to negative impulses than linear perpetuals. In general, the median level of inverse perpetuals is similar to linear perpetuals with more severe negative moves.

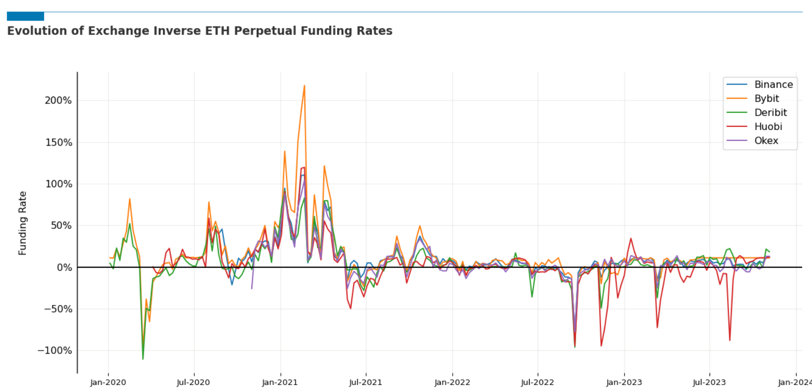


Figure 3.4: Weekly average funding rates.

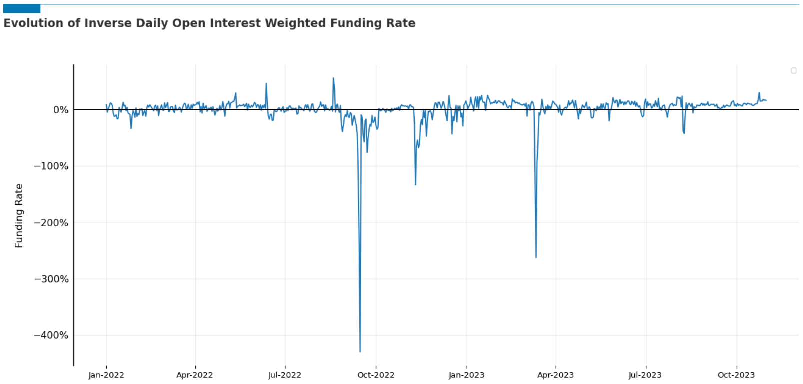


Figure 3.5: The more severe negative impulses can be seen in this daily average funding rate chart.

3 Exchange Funding Rate Correlations

There is no significant funding diversification benefit to holding positions on different exchanges, as most are highly correlated. Funding rate arbitrageurs likely capture divergences before they can have much effect on rates. The exception to this amongst larger exchanges is Bitget.

Benefits to diversification around managing exchange risk remain.

Daily Average Funding Rate Correlations between Exchanges

	Binance	**Bitmex**	**Bybit**	**Deribit**	**Huobi**	**Okex**	**Bitget**
Binance	100%	69%	83%	74%	79%	82%	49%
Bitmex	69%	100%	72%	68%	65%	74%	22%
Bybit	83%	72%	100%	71%	79%	80%	8%
Deribit	74%	68%	71%	100%	70%	75%	15%
Huobi	79%	65%	79%	70%	100%	78%	42%
Okex	82%	74%	80%	75%	78%	100%	32%
Bitget	49%	22%	8%	15%	42%	32%	100%

Table 3.1: Exchanges with significant open interest have average daily funding rates that move with an approximately 80% correlation.

4 Funding Rate Conclusions

Funding rates are highly mean reverting in almost all market conditions. There have been periods where the level funding reverts to is negative, but these have been transitory, and rates have tended to move positive within weeks. Even during these times when rates have gone negative for a period of weeks, the average level has not been at or below LST APRs, except for speculation around the merge.

Inverse perpetual funding rates have historically had more dramatic negative moves than linear margined perpetuals. This could be a function of them being smaller, less developed markets.

The period around the Ethereum Beacon Chain Merge with the application layer created a once-off circumstance with material and persistent negative rates. This can be interpreted as contaminating the dataset. Therefore, results are reported with and without the peak of this period, 11 - 15 September 2022, to keep these outliers from overinfluencing the analysis outcomes.

Below is a summary of historical perpetual funding rates.

Observed Funding Rate Summary Statistics

	Overall	**2022+**	**2022+ (excl. Merge)**	**Inverse**
Mean	7.0%	3.6%	4.2%	4.9%
Median	6.0%	5.1%	5.1%	5.5%
Volatility	18.4%	13.8%	7.7%	26.9%
Skewness	-2	-13	-0	-9
Kurtosis	72	253	6	122

Table 3.2: The Ethereum transition to proof of stake (the Merge) created the potential for ETH holders to benefit from gaining ETHPOW tokens on a Proof of Work fork. This led to speculators holding ETH hedged with short perpetuals positions, creating massive negative funding between 11-15 September 2022. Removing this outlier event from the sample dramatically reduces the observed volatility, negative skewness, and kurtosis of observed funding rates.

Chapter 4

Funding Rate Response to Changes in Open Interest

1 Historical Funding Rate Response to Changes in Open Interest

Funding rates correlate strongly positively with open interest. This implies that historically, the long side has driven changes in open interest most of the time. Ethena would be offsetting this bias in the market and would benefit, but could reduce the magnitude of this positive correlation.

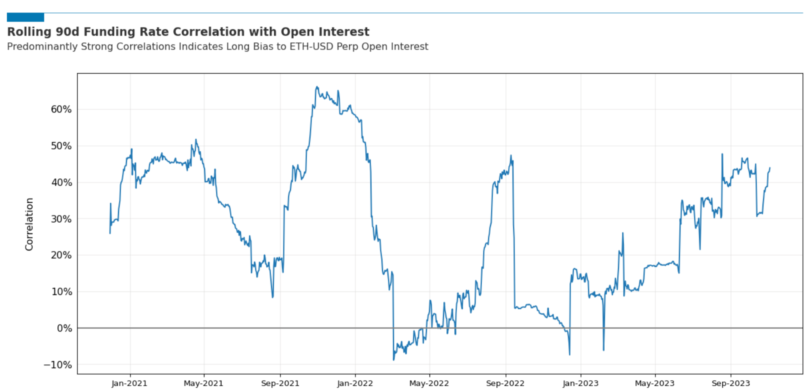


Figure 4.1: This chart plots the 90-day correlation between daily percentage changes in open interest and changes in the funding rate. Besides a brief spike negative over the USDC depeg, the abnormal conditions around the Merge, and a period of unusual behavior starting in early 2022 until April (explored in more detail below), movements in funding rates have been highly correlated with changes in open interest. This indicates a natural long bias to ETH Perpetual open interest.

Times with low and negative correlations are analyzed in more detail to look for hidden tail risks.

Examining the early 2022 period with low correlation between funding rates and open interest more closely, it is important to recognize upfront that the correlation never went more than 6% negative. A possible inference is that when increasing the granularity to daily timeframes and making them less frequent, there is almost no evidence of periods with significant build-ups of short open interest historically. Over this period, it appears that decreases in open interest caused funding rates to drop (possibly due to liquidations), while increases had limited impact.

This does not imply that there were no periods of negative funding rates. The observation is that they typically revert over a timeframe of days and do not generally cluster at negative levels.

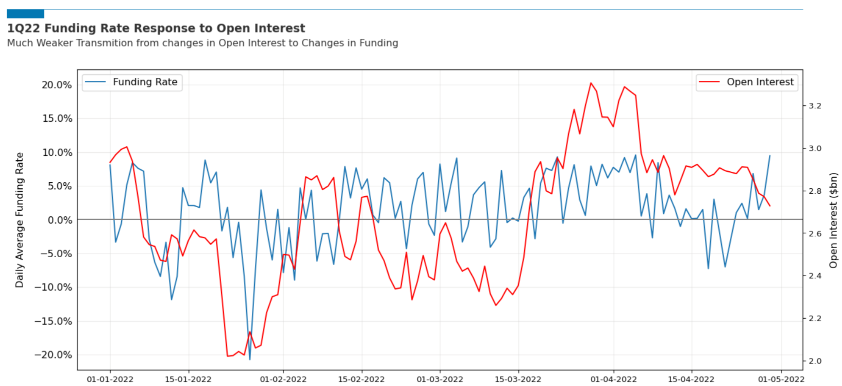


Figure 4.2: Large changes in open interest without much reaction from funding rates differentiate February-April 2022 from other periods.

Comfort can be taken from the fact that increases in perpetual open interest can be reasoned to almost always coincide with increased demand for long positions over less granular periods. The implication for Ethena is that growing perpetual open interest creates excess long positions, which add a degree of balance to the protocol's need to hedge. There has been no evidence of prolonged negative responses to increasing open interest or positive responses to decreasing open interest.

2 Analysis of Historical Funding Rate Drawdowns

Negative funding rates pose a risk to the depletion of Ethena's insurance fund. To assess the historical impact of this risk, we analyze the drawdowns as they occur in Ethena's context. This is done by calculating the percentage decrease experienced by Ethena from the highest cumulative return point to the present level.

The chart below shows the cumulative funding rate return from the perspective of a short ETH Perpetual holder. The data is computed by compounding returns daily to mimic Ethena's realized funding return. The orange series shows the negative divergence from previous highs in realized funding to measure the distribution of drawdowns due to negative funding rates.

The largest drawdown of 4.3% was observed over the Ethereum Merge, where external factors contributed to consistently negative funding. Excluding this period, the largest drawdown was 2.0%.

When including staking rewards into historical performance, the largest drawdown becomes 2.9% and 1.2% if the Merge period is excluded.

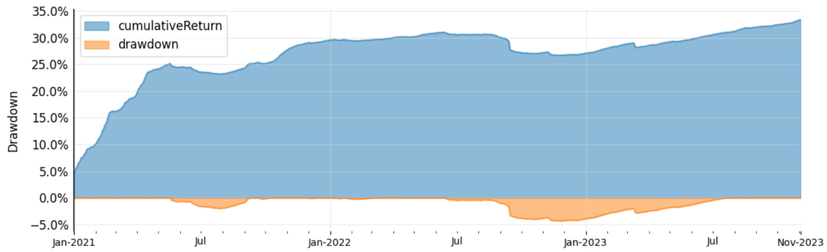


Figure 4.3: Most of the Positive Return from ETH Funding Rates Occurred before mid-2021. The largest drawdown observed was 4.3% over the Ethereum Merge.

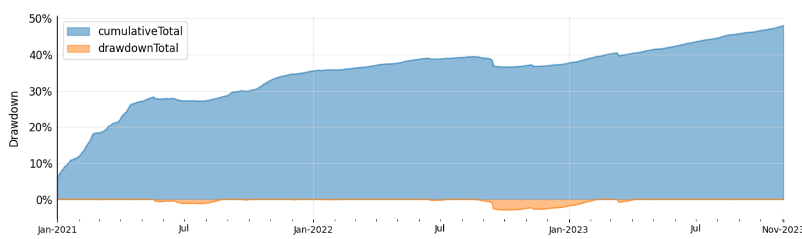


Figure 4.4: Including staking rewards into the .

Chapter 5

Insurance Fund Considerations

The requirements of the insurance fund are measured across the two dimensions of growth rate assumptions and ongoing tax on protocol revenues. The tax rate is defined as the proportion of protocol revenue accruing to the insurance fund.

A Value at Risk (VaR) approach is used to measure the worst likely drawdown. VaR models the full spectrum of potential outcomes and selects the $x\%$ worst outcome as its measure of risk. Due to the nature of the insurance fund, we take the most conservative stance of using the absolute worst historical observed outcome as the level for VaR here.

VaR takes in a set of scenarios and simulates the performance of a strategy over these, reporting a realized outcome. This analysis uses the most recent 1,130 days realized funding rates as scenarios and the cumulative realized drawdown over successive days as the outcome.

Using this VaR, various growth assumptions and tax rates are simulated to identify the largest shortfall between the growth from zero of the insurance fund and the daily VaR. This informs the recommended amount to seed the insurance fund upfront.

VaR is commonly used to measure risk in banks and investment firms.

1 Insurance Fund Contingency Requirement

Historical drawdowns are used to estimate the liquidity requirements of the insurance fund. While it is impossible to predict all possible future scenarios, the past 30 months have provided a diverse array of unique events to be helpful. The merge, in particular, stressed funding rates in a unique situation unlikely to repeat.

A daily protocol value at risk (VaR) is calculated using historical scenarios of funding rate performance while using a more conservative flat 4.2% staking rewards performance, in line with recent trends and higher stake rates. The initial VaR is calculated over the most recent 1,300 days, although as the market matures, this could increase to five years, in line with many traditional finance models.

Large drawdowns for the Ethena protocol will be incremental over periods where historical daily returns locally cluster around negative levels. Because of this, it is recommended to **measure VaR as the worst drawdown over the observation period**, rather than a percentage threshold as is usually the case. Using a percentage would reduce the sample size too much and miss tail risk events.

The most significant drawdown observed has been 4.3% over the merge. We use this worst observed outcome as the VaR measure for Ethena as a percentage of TVL. It is recommended always to hold sufficient insurance fund reserves to cover future drawdowns of this amount.

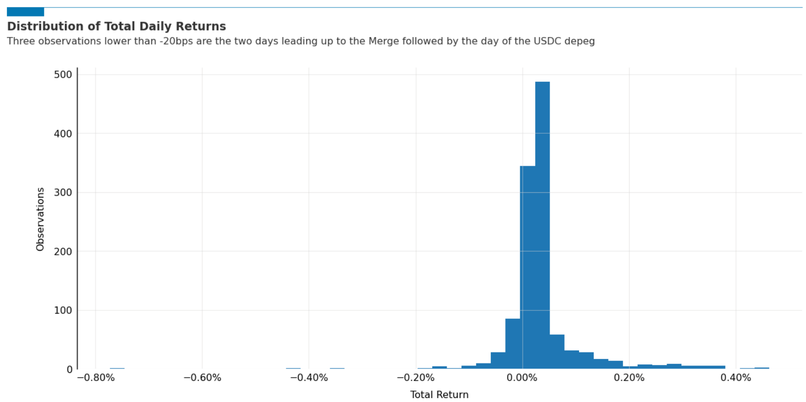


Figure 5.1: 88% of total daily returns would have been positive using historical funding rate performance. Examining the three outliers less than -20bps, the two most extreme outcomes are from the two days leading up to the Ethereum Merge, and the third most extreme is from the USDC depeg. Funding rates are exposed to event risks.

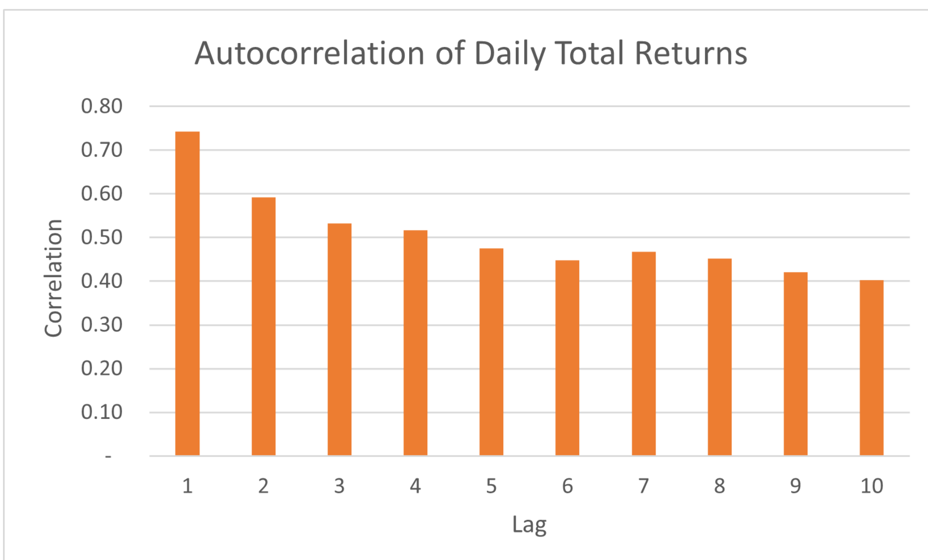


Figure 5.2: Daily total returns are highly autocorrelated, creating clustering over periods. This chart shows the correlation between the historical return of Ethena's strategy and the return on subsequent days. The strong positive results indicate a clustering of returns across time periods.

2 Insurance Fund Tax Rate

To estimate the necessary tax rate to keep the size of the insurance fund, the scenarios are run using a range of growth rate assumptions and tax rates to optimize for the lowest rate that allows revenue to cover incremental contingencies.

For an idea of the growth of an initial supply of $100m over the 2.75-year scenario period, the table below is included.

	Linear	**Exponential**
50%	$ 241 917 808	$ 412 970 894
100%	$ 383 835 616	$ 1 702 146 326
200%	$ 667 671 233	$ 28 749 810 620
400%	$1 235 342 466	$8tn

Table 5.1: Terminal Supply over the 1,130 day scenario period.

2.1 Linear Growth Rates

A linear growth rate assumption grows supply and, therefore, revenues earlier. Under this assumption, optimal tax rates will be lower for the same terminal supply versus exponential growth rates.

The series on the graph below are labeled by growth rate and tax rate (e.g., 400g_50t is a scenario with a 400% growth rate and a 50% tax rate). Each series represents the insurance fund requirements in excess of revenues generated from its portion of revenues. This can be used to estimate the amount needed on day 1 to supplement the fund as the protocol grows. This can also be used to target a tax rate that would contain the contingency if necessary.

All series eventually flatten out with a 20% tax rate, although it could be more efficient to increase this a little at higher growth rates to contain the total excess requirement.

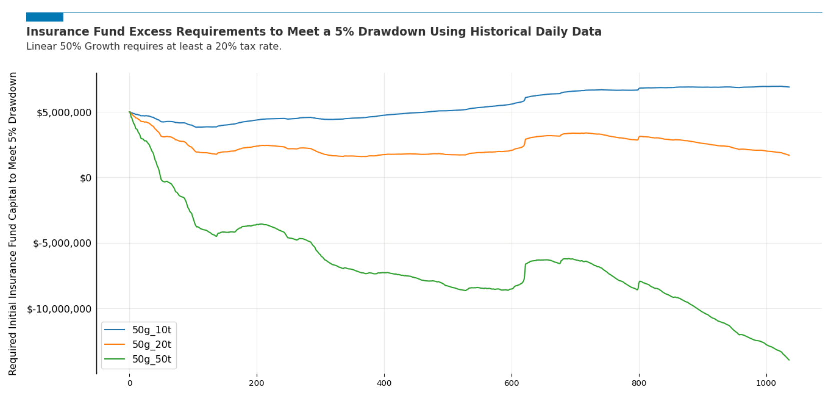
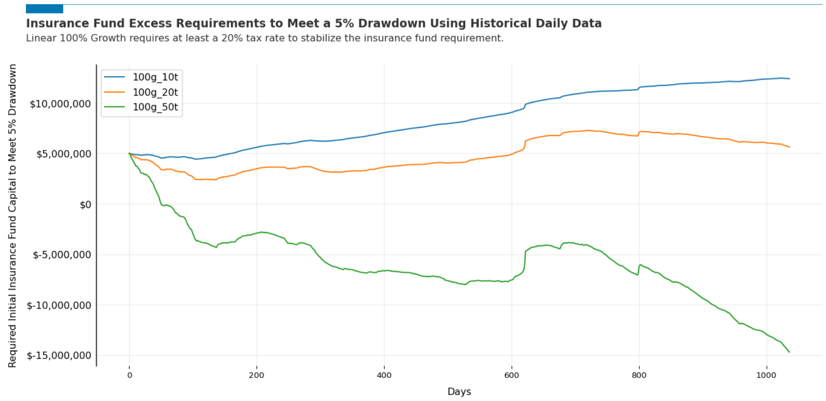


Figure 5.3: The lines on this chart represent the estimated initial capital required to ensure the insurance fund is capitalized to meet its VaR requirement, given historical performance. Negative values indicate revenue earned in the insurance fund is sufficient to cover requirements. The highest value in the series is used to estimate the initial requirement.



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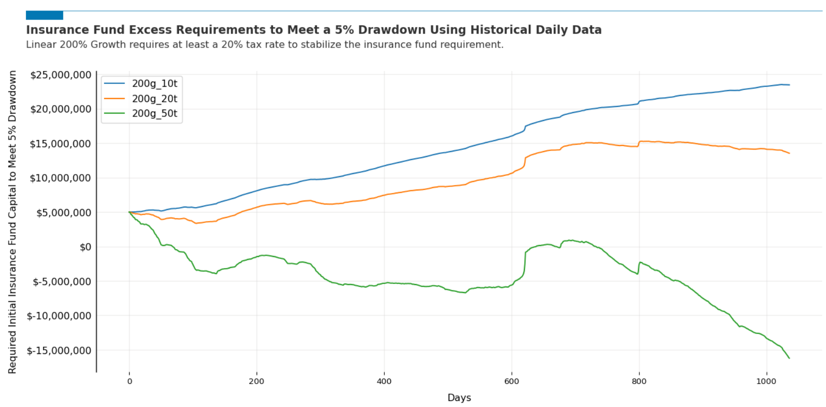

Figure 5.5: The lines on this chart represent the estimated initial capital required to ensure the insurance fund is capitalized to meet its VaR requirement, given historical performance. Negative values indicate revenue earned in the insurance fund is sufficient to cover requirements. The highest value in the series is used to estimate the initial requirement.

2.2 Exponential Growth Rates

Exponential growth rates shape TVL growth, putting much greater strain on additional insurance fund requirements to contain contingencies.

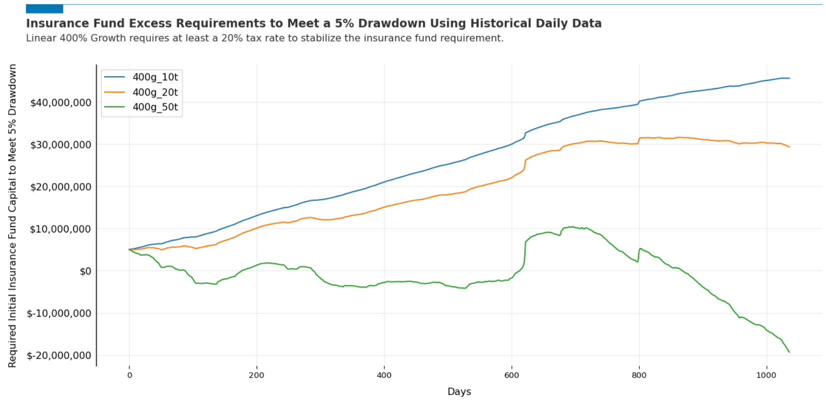

Figure 5.6: The lines on this chart represent the estimated initial capital required to ensure the insurance fund is capitalized to meet its VaR requirement, given historical performance. Negative values indicate revenue earned in the insurance fund is sufficient to cover requirements. The highest value in the series is used to estimate the initial requirement.

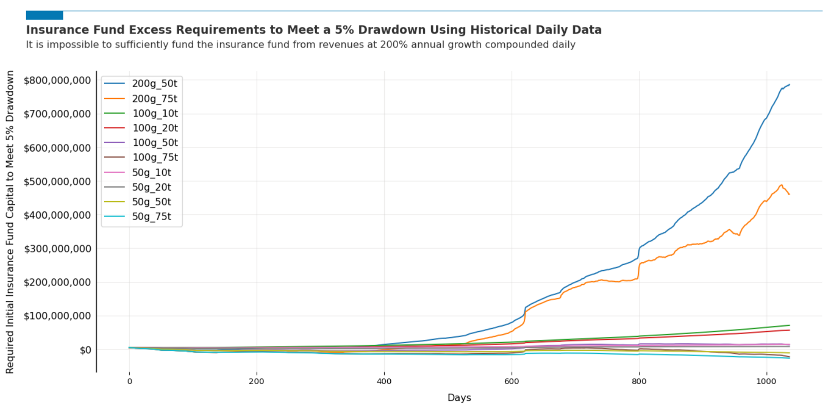

Figure 5.7: It is not possible to fund the insurance fund from revenues at 200% exponential growth.

3 Initial Insurance Fund Seed Requirement

Data from the maximum contingency in the tables below, combined with growth rate and tax rate assumptions, can be used to estimate the amount of additional funding the insurance fund could require.

Linear Growth:

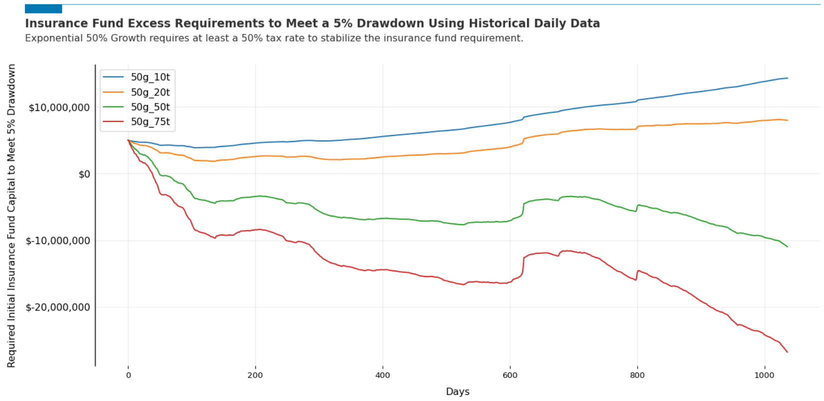

Figure 5.8

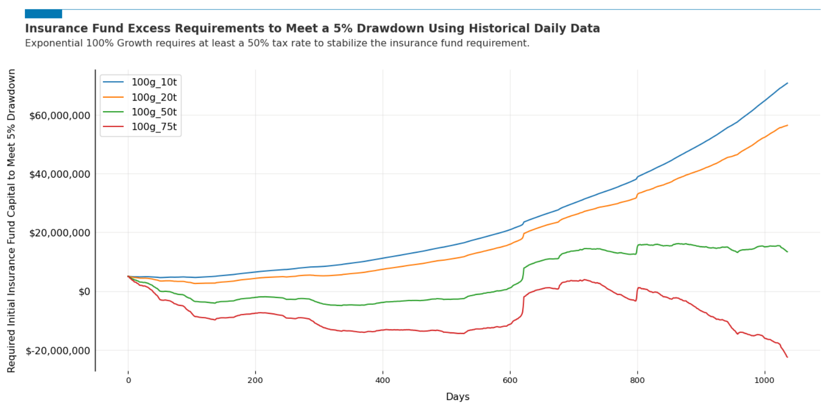

Figure 5.9

Tax/Growth Rate	**50%**	**100%**	**200%**	**400%**
10%	$6 946 091	$12 467 350	$23 511 553	$45 599 959
20%	$4 997 116	$ 7 281 348	$15 284 471	$31 589 891
50%	$4 992 789	$ 4 992 789	$ 4 992 789	$10 403 372

Table 5.2: This table models the maximum VaR the insurance fund would have shown using historical market data and a range of tax and linear growth assumptions. Setting the tax rate in response to forecast growth can help maintain a stable insurance fund requirement by balancing revenues with VaR contingencies.

Exponential growth:

4 Insurance Fund Conclusions

This section aims to provide a quantitative overview of the required size, tax rate, and initial requirements of the insurance fund, given growth assumptions and previous scenarios.

It is reasonable to assume that higher tax rates will inhibit growth, creating a lever to

Tax/Growth Rate	50%	100%	200%
10%	$ 14 323 842	$ 70 762 810	$ 1 307 233 840
20%	$ 8 129 223	$ 56 418 304	$ 1 176 977 148
50%	$ 4 992 789	$ 16 166 836	$ 786 207 075
75%	$ 4 989 184	$ 4 989 184	$ 488 355 502

Table 5.3: This table models the maximum VaR the insurance fund would have shown using historical market data and a range of tax and exponential growth assumptions. The more backloaded growth curve puts greater pressure the insurance fund VaR, requiring greater additional funding.

control insurance fund contingencies by increasing or decreasing the tax rate.

The frameworks employed here could also provide the basis for ongoing funding risk management methodology, adjusting the tax rate to control risk by maintaining sustainable growth.

The estimates of the starting size for the insurance fund as a function of growth assumptions and the tax rate employed are shown in the tables below.

Linear Growth

Growth/Tax	10%	20%	50%
50%	$ 6 946 091	$ 4 997 116	$ 4 992 789
100%	$ 12 467 350	$ 7 281 348	$ 4 992 789
200%	$ 23 511 553	$ 15 284 471	$ 4 992 789
400%	$ 45 599 959	$ 31 589 891	$ 10 403 372

Table 5.4: Estimated starting insurance fund requirements to stabilize the fund at a level higher than the daily VaR with linear growth.

Exponential Growth

Growth/Tax	20%	50%	75%
50%	$ 8 129 223	$ 4 992 789	$ 4 989 184
100%	$ 56 418 304	$ 16 166 836	$ 4 989 184

Table 5.5: Estimated starting insurance fund requirements to stabilize the fund at a level higher than the daily VaR with exponential growth.

Assuming a starting supply of $100m USDe and a starting tax rate of 10%, we estimate the required initial insurance fund to cover severe events at approximately $33m to cover Ethena up to $1bn. This follows from an estimated 300% average linear annual growth and the associated projected revenues.

Should Ethena grow faster than this or experience consistent exponential growth, either more funding will be required, or the tax rate will need to be increased in line with the table 5.5.

Chapter 6

Estimating Market Short Open Interest Tolerance

Like all market dynamics, funding rates are complex processes, affected non-linearly by numerous factors. This complicates estimating the effect that short open interest from Ethena will have on them.

This section attempts to create a simplified model of funding rate behaviors, considering historical movements in funding rates with open interest and the mean-reverting characteristic of funding rates. The intention is to estimate the amount of short open interest Ethena could add to the market without affecting the medium-term funding rate trajectory to the point that it turns negative. Even with negative rates, Ethena would still earn revenue from staking rewards, but this point is chosen as the point where the marginal contribution from funding rates subtracts rather than adds to the total yield.

Given the complexity and number of evolving factors, this analysis provides a rough guideline using past behaviors.

1 Differentiating Between Temporary and Persistent Funding Rate Effects

Changes in market open interest driven by a particular side impact prices by adding to the demand for that side of the market, thus upsetting the equilibrium achieved before. This change in prices, in turn, draws fresh interest into the market, and some of the price impact dissipates while some remains persistently.

In this analysis, the impact of changes in short open interest demand is broken down into a temporary impact and a persistent impact. The temporary impact is assumed to vanish within a day, while the persistent portion remains. For Ethena specifically, this persistent portion is assumed to be the long-term consequence of hedging stETH deposits with ETH perpetual futures. It is used to estimate the rate at which it is estimated that open interest could be added in current conditions.

A daily time series is used to align with the daily cadence of Ethena operations.

$$\Delta fundingRate \sim temporaryFundingImpact + persistentFundingImpact$$

Put formally:

$$\Delta fundingRate = f(\Delta openInterst) + g(\Delta openInterst) + \epsilon$$

Where the function *f()* represents the temporary funding impact, *g()* the persistent funding impact, and ϵ random variance. In this model, we assume linear functions *f*, and *g*.

The temporary funding impact can be interpreted simply as the effect incremental open interest has on market makers' inventory and the amount they adjust prices while this is arbitraged away, while the persistent funding impact is the impact that remains due to a longer-term imbalance.

To estimate the total funding impact, the following simplifying assumptions are made:

1. The total funding impact is a linear function of the percentage change in open interest.
2. The temporary funding impact dissipates after a day.
3. Changes in the funding rate are exclusively caused by changes in open interest on one side of the market.

Data for this analysis is from 1 June 2021 to 15 November 2023.

To begin with, the daily change in average funding rate is plotted against daily percentage changes in open interest with outliers removed so as not to impact the linear regression overly. The assumption in this analysis is that traders, in the aggregate, have historically been so long-biased that changes in open interest have approximated changes in demand for long positions.

The r^2 coefficient of 10.7% indicates a positive relationship between daily changes in open interest and changes in the daily funding rate, but there remains significant other variation. The assumption that changes in open interest are solely due to appetite for long positions is likely overly simplifying. Therefore, the resulting elasticity of the funding rate to changes in open interest of 53% can be treated as a lower bound for the actual elasticity in reality.

Next, to avoid the assumption that it is solely long interest driving changes in open interest, samples where the funding rate and open interest move in the same direction are plotted and regressed separately from samples where they move in opposite directions.

It is still assumed that the sole factor driving movements in funding rates but that either side of open interest can dominate.

Here, the assumption is made that open interest is the sole factor driving funding rate changes, but the side driving this demand changes. This overestimates the linear relationship and the resulting elasticities due to sampling bias and should form an upper bound for analysis.

Days where funding rates moved in the same direction as changes in open interest can be interpreted as long positions driving the changes. More long open interest increases funding rates, and less long positions decrease funding rates.

Historically, on days assumed to be dominated by long activity, for every 1% change in open interest, there has been a 1.07% in the absolute level of the funding rate. This relationship has accounted for 47% of variability in daily funding rates.

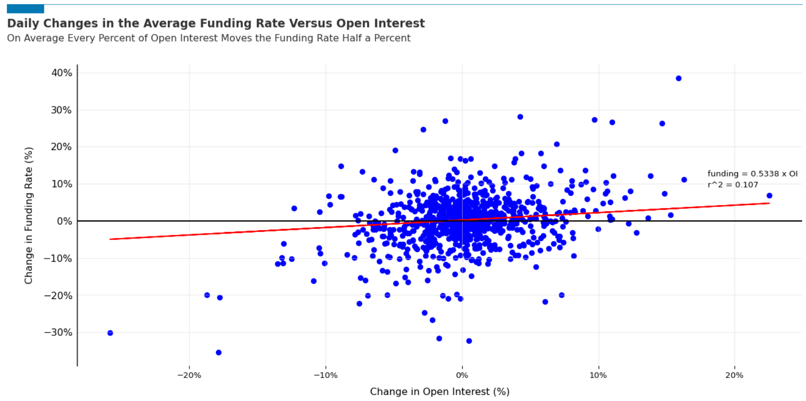

Figure 6.1: a weakly positive relationship exists between changes in daily open interest and changes in the daily average funding rate. The 10.7% r^2 coefficient indicates some relationship with significant noise. This results from the complex relationship between movements in open interest and the funding rate.

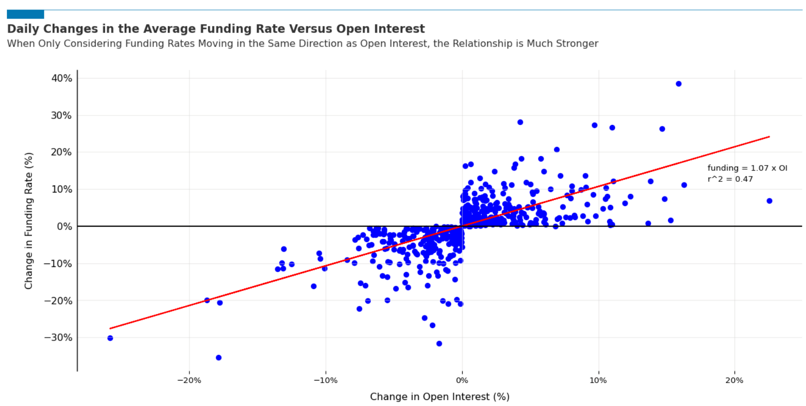

Figure 6.2: When limiting the sample to funding rate changes that move in the same direction as open interest changes, the elasticity of funding on movements in open interest is much closer to 1 and explains 47% of total funding rate variance.

Days where funding rates moved in the opposite direction as changes in open interest can be interpreted as short positions driving the changes. Greater short open interest decreases funding rates, and fewer short positions increase funding rates.

Historically, on days assumed to be dominated by short activity, for every 1% change in open interest, there has been a 0.98% in the absolute level of the funding rate. This relationship has accounted for 31% of variability in daily funding rates. This is a significantly weaker relationship than when open interest changes are driven by long positions.

Assuming that the combined plot 6.1 forms a lower bound to the linear long-term impact of changes in open interest on one side of the market and that the plot where open interest movements are driven by short positions 6.3, the range of the linear total funding impact due to percentage changes in open interest is estimated to lie in the range [0.107, 0.984].

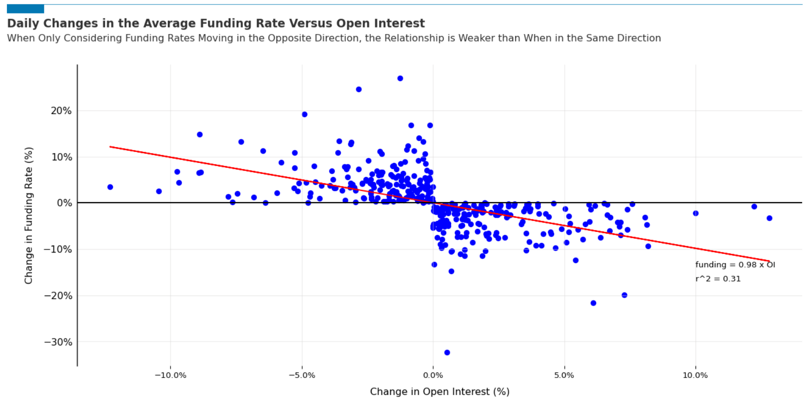

Figure 6.3: Despite a similar elasticity of the funding rate to percentage changes in open interest, days where short open interest is dominant do not fit a linear model as well. Only 31% of the variance in funding rates on these days can be explained by changes in the funding rate this way.

2 Temporary Market Impact

To estimate the temporary market impact under the assumption that this temporary impact lasts exactly one day, the correlation of a day's movement in the funding rate with the one-day lagged move is performed over the period from 1 June 2021 to 15 November 2023.

The resulting one-day autocorrelation comes to -19%, confirming the mean-reverting properties of funding rates. Isolating the sample to the day after a negative movement in funding rates, the autocorrelation increases in magnitude to -30.3%. There has been a significantly stronger reflex for funding rates to revert when they decrease.

3 Persistent Funding Impact

This model is interested in estimating the amount of short open interest Ethena could add to ETH perpetual futures without impacting funding rates to the point that the strategy becomes unviable. The *persistentFundingImpact* portion of this model is intended to estimate the linear impact of increased short open interest on the level funding rates revert to.

To obtain a best guess for short open interest specifically, the midpoint between the combined sensitivity to changes in open interest and the changes driven by short interest of 0.545 is used.

From this, the temporary market impact due to changes driven by short positions of 0.303 is subtracted to estimate the permanent impact short open interest has on funding rates.

$$persistentFundingImpact = totalFundingImpact - temporaryFundingImpact$$
$$\implies persistentFundingImpact = 0.545 - 0.303 = 0.242$$

This simplified model estimates the persistent elasticity of changes in perpetual futures funding rates on short ETH open interest. The definition of persistent has been left intentionally vague up to now at a time point of more than one day.

Prior analysis in this report in 2.1 shows many significant periods of significantly changing open interest over short periods. Meanwhile, 3.3 shows a rapid normalization in trend funding rates. There have been periods where this trend of funding has fallen and risen, but there is no significant permanent impact observable in the data.

The conclusion is that the persistent funding impact acts over a relatively short time frame of a few weeks and that over longer timeframes, the market adapts to the changes. This aligns with the three periods of negative returns, all lasting 3-5 weeks.

Over short periods of a month or less, Ethena should be able to grow by up to approximately \$1bn without affecting the level that funding rates tend towards moving negative. This follows from approximately \$6.2bn in ETH perpetuals open interest, an average funding rate of 5.7% in 2023, and the persistent funding impact estimated at 24%.

This is derived by estimating the amount of short open interest that would need to be added to the market over a short time horizon to cause the level that the funding rate reverts around, as measured by the persistent funding rate, to turn negative. The persistent funding impact function used is the estimated 24% elasticity multiplied by the change in open interest over this short time.

$$
\begin{aligned}
& fundingRates < 0 \\
\iff & persistentFundingImpact > 5.7\% \\
\iff & 24\% \times \Delta shortOpenInterestPercent > 5.7\% \\
\iff & percentageChangeOpenInterst > 23.5\% \\
\implies & shortOpenInterestDollarChange > \$1.46bn
\end{aligned}
$$

Over longer periods where the market has more time to adapt to the new open interest, it will likely be able to grow significantly more. Adding BTC futures to the mix will also allow more scalable growth.

The growth of the decentralized perpetual market will also increase total open interest, increasing the potential scalability of Ethena further.

Chapter 7

Estimating Slippage in Perpetual Futures Markets

The primary objective of this section is to estimate the distribution of available ETH perpetual futures liquidity across market conditions.

Further to this we aim to quantify the estimated contribution of individual exchanges to the best price at various levels of trade size. This can be used along with estimated open interest capacities and funding profiles of the exchanges to inform hedging allocation strategies.

1 Methodology

This methodology aims to make minimal assumptions while using historical behaviors to inform projections.

Orderbook liquidity on each exchange and overall across all eligible exchanges is sampled in fixed quantities (100ETH, 250ETH, 500ETH, etc.), and the slippage from the spot price of ETH is recorded. This slippage can be positive or negative depending on the skew of prices and the orderbook volumes. The Slippage of a flow of amount k is expressed as:

$$Slippage_k = abs[\frac{1}{\sum V_i} \sum_{i=0}^{n} P_i \times V_i - P_{MarketMid}]$$

$$s.t. \sum_{i=0}^{n} V_i = k$$

Where P_i, V_i are the price and volume of the i^{th} order on a particular side of the orderbook, and k is the sampled flow amount.

First, to estimate the amount of liquidity available to hedge LST mints, the 95th and 99th percentile of the largest negative slippage is used. The extremely conservative assumption that execution against one exchange's liquidity resets all orderbooks due to common market makers is made to measure a lower bound for liquidity. This means that at each time point, the exchange with the least slippage is sampled at each slippage. This measure mimics a simple hedging strategy of using best bid each time and provides some insight into how much each exchange could need to absorb short open interest.

Plotting daily observed liquidity through time allows any emerging trends to become clear and behavior to adapt. Each exchange is plotted separately to measure individual contributions. Orderbooks from the following exchanges are sampled daily from 1 February 2023:

- Binance
- Bybit
- Deribit
- Huobi
- OKX

2 Results

Ethena should be able to execute hedges of up to approximately $19m with acceptable median slippage of 1.8bps, close to exchange transaction costs. This is a conservative measure of liquidity, executing the whole trade on a single exchange. It should be treated as an upper bound on expected slippage incurred.

As trade sizes grow, so does slippage, and it is interesting to note that at all sizes, the 1% least liquid observations incurred approximately 2.5 times the slippage of the median.

Historical Slippage in basis points using the methodology above:

	Median	**95%**	**99%**
500 ETH	1.8	3.5	4.4
1,000 ETH	2.8	5.1	7.0
5,000 ETH	10.6	17.4	23.1
10,000 ETH	21.8	35.0	50.8

Table 7.1: Results of the above methodology applied from 1 February 2023 - 5 November 2023. Under these conservative assumptions and using the tail of the liquidity distribution, up to 1,000 ETH ($19m) clears within 5bps most of the time and 7bps almost always.

Liquidity has been tighter and more consistent on Binance and OKX over the period sampled from March 2023. 500 ETH (approximately $950,000) consistently clears within 2.5bps on each of these exchanges, while the others incur around 10bps of slippage.

Gaps in any of these series are where there was insufficient orderbook liquidity to fulfill a trade of the specified size.

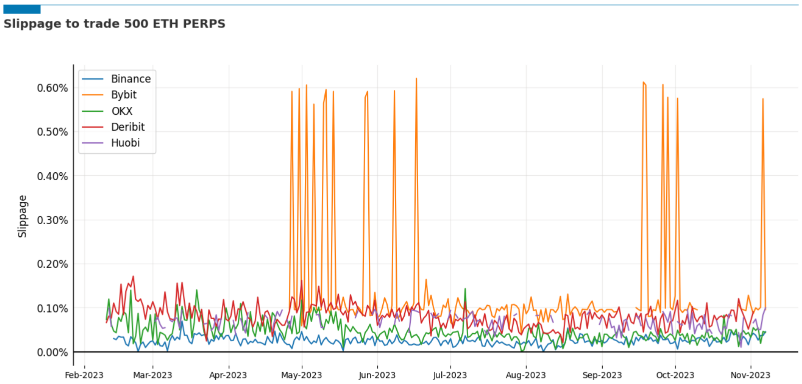

Figure 7.1: Deepest Liquidity at Binance and OKX mostly clearing within 2.5bps. Others are wider and less consistent.

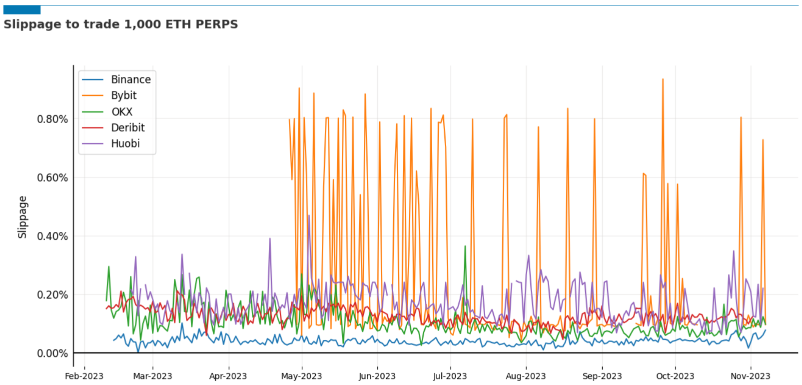

Figure 7.2: Binance and OKX mostly clearing within 5bps.

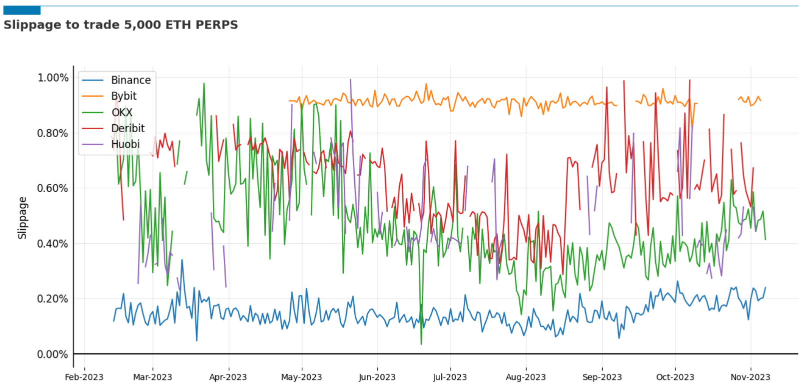

Figure 7.3: Binance and OKX clearing between 10 and 20bps.

2.1 Combined Liquidity

Relaxing the assumption of shared liquidity across exchanges to estimate the slippage should a large exchange default. This stress test estimates the slippage cost of re-hedging positions from the current largest exchange.

Aggregate median orderbook liquidity within 50bps has historically been approximately \$125m (60,000 ETH) recently, and approximately half that in the 1% tail of the distribution. Within 1%, there is a median of around \$165m liquidity.

In the event that an exchange used by Ethena to place ETH perpetual hedges on defaults, Ethena would be left with a naked long stETH position backing USDe. The protocol would need to cover this quickly to avoid exposing itself to price risk.

This could be achieved by either re-hedging with perpetuals on an alternative exchange, or temporarily swapping the naked stETH for a stablecoin. We estimate the ability to re-hedge using stressed orderbooks.

Removing the current largest weighted exchange, Binance, from the liquidity distributions reduces this liquidity to a median of approximately \$84m (38,000 ETH), and a 1% tail of \$39m.

		Percentile	
Spread (bp)	**Median**	**95**	**99**
5	5 621	1 933	1 097
10	14 237	5 778	3 745
15	23 376	10 219	7 038
20	31 828	16 192	12 736
25	39 294	21 991	17 528
50	60 011	35 548	28 424
75	67 615	41 812	33 437
100	78 900	54 022	42 799

Table 7.2: ETH Perpetual orderbook liquidity in ETH observed within defined spreads from mid.

		Percentile	
Spread (bp)	**Median**	**95**	**99**
5	3 877	1 095	594
10	10 371	3 776	2 119
15	17 210	7 003	4 459
20	22 877	11 477	8 653
25	27 137	15 111	11 593
50	37 931	23 400	17 338
75	43 642	26 717	20 597
100	53 881	35 950	27 861

Table 7.3: ETH Perpetual orderbook liquidity in ETH observed, excl. Binance, within defined spreads from mid.

While it is impossible to forecast behavior over such an event exactly, it is reasonable to assume that Ethena could migrate the positions over multiple trade blocks over a short period of a few minutes. This could allow for the orderbook to rejuvenate and absorb a larger total order.

At \$100m total supply, Ethena could likely re-hedge Binance positions in one trade for approximately 50bps slippage. Beyond this, it would likely become necessary to break the re-hedges up into smaller blocks.

Making the following assumptions on execution:

1. The market completely resets to the worst execution level of each order.
2. Orderbook depth matches the 1% least observed liquidity over the period.
3. Orders of $20m can be absorbed repeatedly over this period.

The results show an estimated cost to re-hedge of 50-385bps of the notional previously with Binance.

USDe Supply ($m)	**Estimated Slippage (bps)**	**Number of Trade Blocks**
100	50%	1
250	85%	4
500	185%	8
1,000	385%	16

Table 7.4: Estimated Slippage incurred to re-hedge Binance's share of Ethena hedges.

The options available to Ethena in an exchange default can be seen in the diagram below.

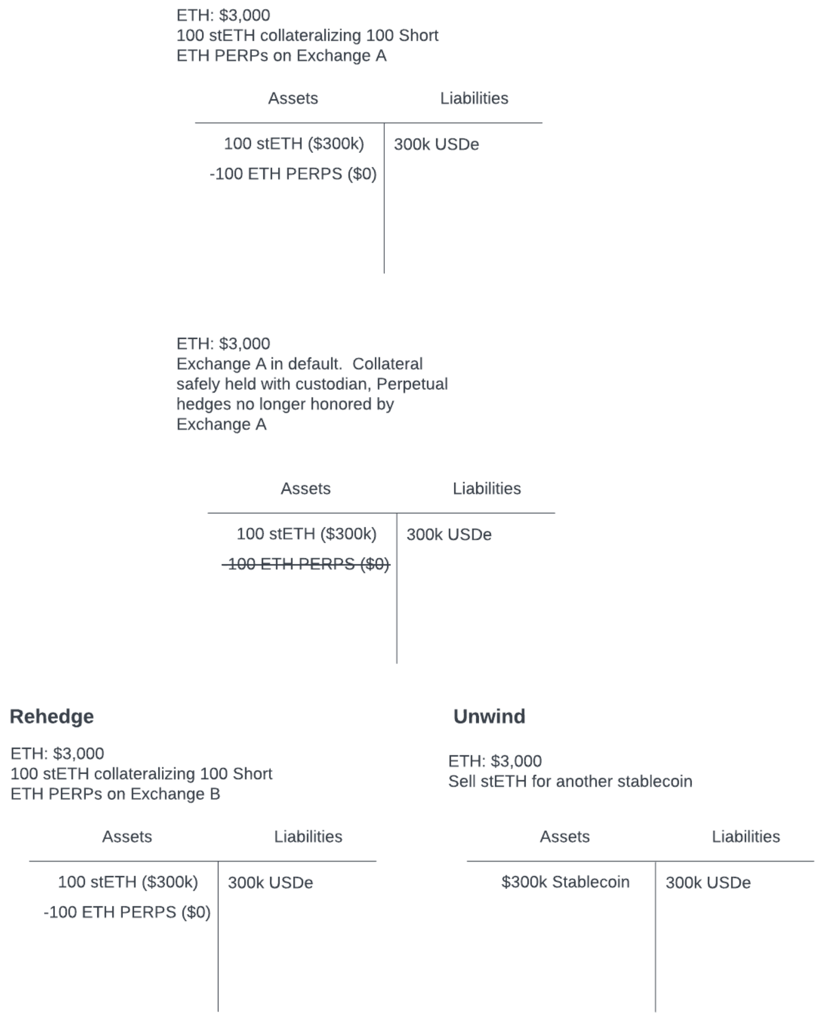

Figure 7.4: Diagram showing the potential options for Ethena should an exchange default. Ethena would be left with an unhedged stETH position, which could be covered by re-hedging on a different exchange, swapping for a stablecoin, or a combination of the two.

Market development in a bull market should add depth, reducing spreads in all market conditions.

This can be further reduced in the future should Ethena scale to BTC futures, further diversifying market exposure.

This analysis is a best effort to forecast the impact of an extreme market event. The actual results could vary considerably.

This analysis is purely meant as a stress test of the largest exchange and is not reflective of Binance in any way.

Chapter 8

BTC Dynamics

As Ethena scales, it can add other tokens as collateral to back USDe. The most relevant currently is BTC. This section explores the funding rate dynamics of BTC perpetual futures. The focus is on the viability of absorbing short open interest while maintaining positive average funding rates over the medium term.

The evolution of historic BTC Perpetual open interest is analyzed both in absolute terms and relative to ETH perpetuals. The focus then moves to funding rates and drawdowns in the strategy of hedging long BTC spot positions with short BTC perpetual futures.

1 BTC Open Interest

The BTC perpetual market is significantly larger than ETH when measured by open interest. Even the more limited sample of exchanges in 8.1 and 8.2 below currently have approximately 50% more open interest than measured for ETH.

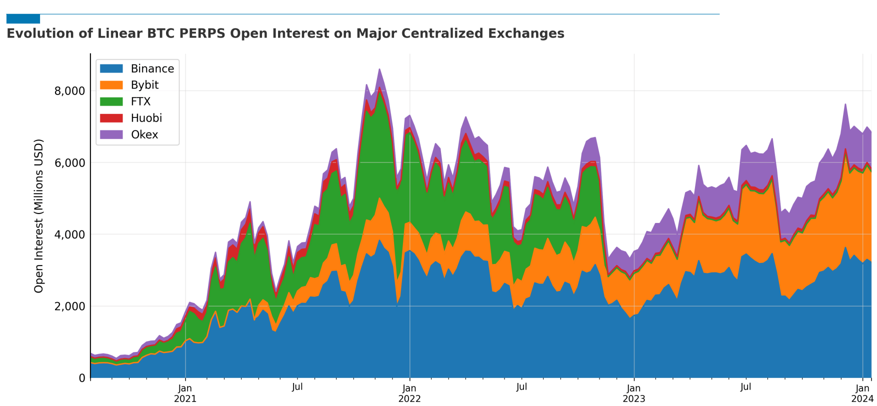

Figure 8.1: Linear BTC Perpetuals market evolution. Note this is a sample of larger exchanges. The total open interest is larger than displayed.

Interestingly, unlike ETH perpetuals, inverse BTC perpetuals are slightly more volatile than linear BTC perpetuals.

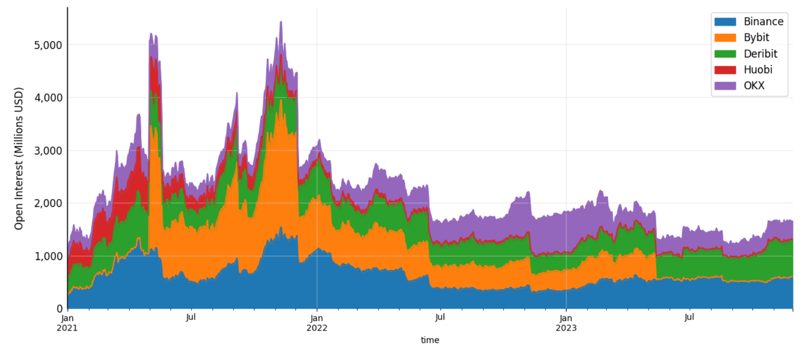

Figure 8.2: Inverse BTC Perpetuals market evolution.

2 BTC Funding Rates

Similar to the ETH perpetuals markets, BTC perpetual funding rate volatility and magnitude reduced significantly from mid-2021.

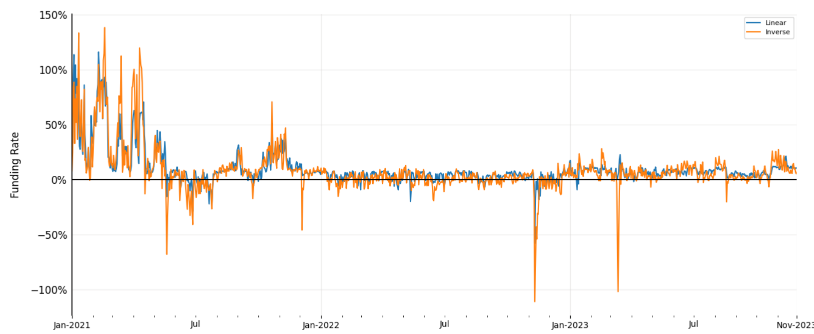

Figure 8.3: BTC Open Interest Funding Rates of Linear and Inverse Perpetuals.

	Linear	**Inverse**
Mean	10.0%	8.5%
Median	6.5%	5.0%
Volatility	16.4%	21.0%
Skewness	3	2
Kurtosis	12	11

Table 8.1: BTC Daily Open Interest Weighted Perpetual Funding Rates Since January 2021.

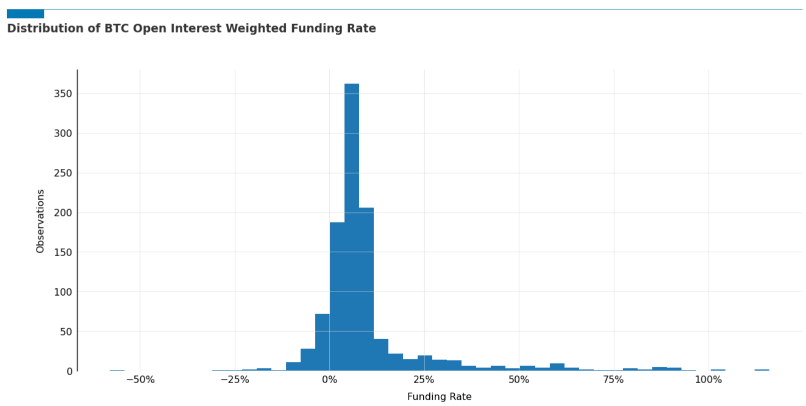

Figure 8.4: BTC Open Interest Funding Rates of Linear and Inverse Perpetuals.

2.1 BTC Funding Rate Drawdowns

Data to calculate drawdowns uses the daily, linear open interest weighted funding rate to calculate the historical funding rate return of short BTC perpetuals. The absence of a period like ETH perpetuals experienced over the merge where funding rates sustained at very negative levels means the drawdowns have been very shallow.

BTC perpetuals have almost exclusively reverted to a positive level since January 2021. Linear perpetual funding rates have been negative on 11% of days over this period. However, these have not clustered and are usually followed by positive funding days.

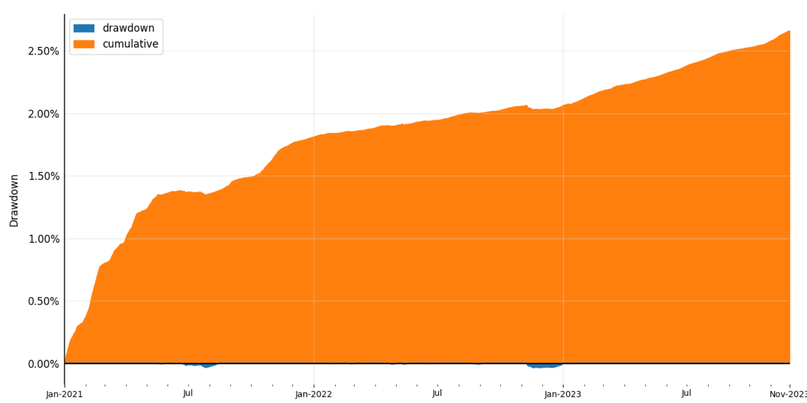

Figure 8.5: BTC Funding Rate Return and Drawdowns of Linear Perptuals.

3 BTC Perpetuals Summary

This historical analysis of BTC perpetual futures as potential collateral for Ethena looks very favorable. Despite some drastic movements in open interest, funding rates have only moved negative for short consecutive periods and typically revert to a positive level reasonably quickly. The longest consecutive negative daily funding rates recorded over this period was 2.

The result is very shallow drawdowns for short BTC perpetual futures holders.

BTC perpetual markets are also well developed, with over $8bn in open interest currently. This implies there is likely capacity to absorb at least $3bn-$4bn of incremental short open interest without harming funding rates, given the reaction to previous open interest moves in both directions.

Chapter 9

Risks

This section summarizes the main risks discussed previously, discussing their relevance for Ethena. Each risk is summarized and discussed individually.

1 Perpetual Market is Too Small to Absorb Ethena Open Interest

There is the risk that Ethena cannot scale as the perpetual futures market cannot absorb enough short ETH open interest. Analysis from the preceding chapters found over $6.2bn in open interest currently. This has steadily grown as the industry has recovered from the FTX collapse in October 2022. Further growth can also be expected with improving market conditions.

Open interest also has significant room to grow in a bull market. Data from August 2020 saw open interest grow 25x over the next 15 months.

While markets were less mature at the start, it is reasonable to expect more favorable market conditions to attract a lot more open interest capable of offsetting and dampening the impact of Ethena on the perpetual markets.

Conservatively, we expect at least 5x growth from here as more capital flows into the space, given the previous cycle's 25x growth. This would grow ETH perpetuals open interest to around $18bn.

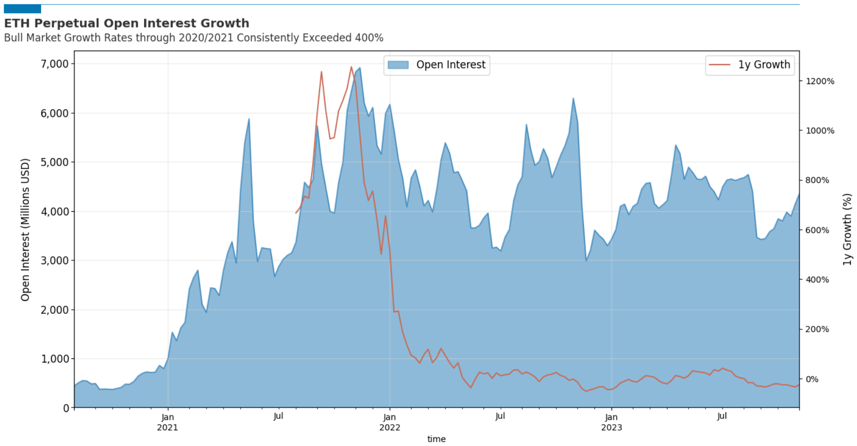

Figure 9.1

This gives Ethena ample room to grow in the ETH market, while the option to scale to the BTC market in the future provides another, even larger market to build on.

2 A Period of Persistent Negative Funding Rates Drains the Insurance Fund

Revenue to the Ethena protocol is dependent on a positive contribution from the sum of staking yield and funding rate. Should the funding rate persist at a negative level below the level of staking yield, Ethena will erode its insurance fund.

The historical funding rate performance analysis found that ETH perpetual funding rates mostly revert to a positive level. While there have been many days with negative funding rate yields, these have mostly been normal fluctuations as part of the perpetual price discovery process and do not persist.

The two main exceptions to this, the mid-2021 deleveraging and the Ethereum merge event caused less than 5% drawdowns. Both times, after a temporary dip, revenues reverted to an average positive level and grew from a cumulative basis to new highs.

The insurance fund should use this to guide its provisions to protect against downswings.

Expanding perpetual markets in a bull market has historically attracted significant long interest, further enabling USDe scaling.

The opportunity to scale to BTC futures looks even more promising from a funding rate perspective, with BTC funding rate yields typically higher and less volatile than ETH yields.

3 Ethena's Short Open Interest Causes Funding Rates to Naturally Move Negative

Ethena's short open interest could have a significant effect on funding, potentially causing rates to revert around levels more negative than the staking yield persistently.

Analysis of the historical reaction of funding rates to short open interest indicated an estimated ability to scale to at least $1bn without causing funding rates to move negative on a sustained basis.

Forecasted growth of perpetual futures markets in more favorable market conditions would dampen the effect of Ethena's short open interest further, allowing greater scale. Should the market grow 5x+, Ethena can grow beyond $5bn+ without causing funding rates to persist at negative levels.

Another factor likely to keep funding rates positive is the positive interest rate component (also called baseline funding) set on many exchanges. Currently, this is set to 10.95% on 60% of open interest weighted exchanges and 0% on the rest. This means that when perpetual prices are in line with their underlying indices on all exchanges, there is an open interest weighted positive funding rate of 6.6%, roughly in line with the observed behavior in 2023.

4 Slippage Causes Losses

In the event of an exchange failure, Ethena would be exposed to slippage while migrating perpetual futures exposures. Analysis of historical order book depth at their 1% least liquid points historically indicates just over 50bps of slippage should Binance's largest weighting need to be re-hedged at $100m, growing to 385bps at $1b. This slippage would only apply to the portion hedged with Binance, and the estimated losses to the protocol would be in the region of 20-150bps of supply.

Even should Ethena suffer significantly worse slippage, the insurance fund should be able to absorb these losses.

Chapter 10

Recommendations

1 Insurance Fund Starting Size

Historical returns the Ethena strategy would have earned imply that the insurance fund should have sufficient capital to cover a 4.3% drawdown at all times. Simulations of the estimated bootstrapping growth given historical yields recommend that Ethena starts with an approximately $33m insurance fund to ensure full coverage in all conditions as it grows to $1bn supply.

The assumption underlying this is 300% linear annual growth and a starting 10% tax rate. Should growth exceed this or compound persistently, it is recommended to adjust the insurance fund tax rate accordingly (see below).

2 Insurance Fund Tax Rate Strategy

The insurance fund tax rate strategy controls the percentage of protocol revenues that accrue to the insurance fund. This has two effects: first, it likely impacts supply growth through changes in USDe APR, and second, it impacts the growth rate of the insurance fund.

Insurance fund revenues are a function of USDe supply, the protocol yield rate, and the insurance fund tax rate. In a rapidly expanding supply environment, the insurance fund is pressured as revenues accrue gradually while risks grow more quickly.

When this happens, speeding up the rate at which the insurance fund grows, slowing supply growth, or both will help maintain Value at Risk within an acceptable tolerance. It is recommended to use the tax rate as a risk mitigation tool.

Appendix A

About Chaos Labs

Chaos Labs is a cloud-based platform that develops risk management and economic security tools for decentralized finance (DeFi) protocols. The platform leverages sophisticated and scalable simulations to stress test protocols in adverse and turbulent market conditions. By partnering with DeFi protocols, Chaos Labs aims to create innovative solutions that enhance the efficiency of DeFi marketplaces.

The Chaos Labs team exhibits exceptional talent and represents diverse expertise, encompassing esteemed researchers, engineers, and security professionals. Chaos Labs has garnered its experience and skills from renowned organizations, including Google, Meta, Goldman Sachs, Instagram, Apple, Amazon, and Microsoft. Additionally, the team boasts members who have served in esteemed cyber-intelligence and security military units, further contributing to their unparalleled capabilities.

You can explore our past and ongoing projects for customers like Aave, GMX, Benqi, dYdX, Uniswap, Maker, and more in the Research and Blog sections of our website.