CHAOS LABS

Liquid Staking Token Market Risks on Ethena

A methodology for quantifying the liquidity risks of Liquid Staking Tokens (LSTs) used as collateral in the Ethena protocol, offering key metrics for ongoing risk assessment.

Ethena

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LST Market Risks on Ethena

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Abstract

This report presents a methodology for measuring the liquidity risk of liquid staking tokens (LSTs) used as collateral on the Ethena protocol. Ethena issues a synthetic dollar, USDe, backed exactly 100% by long positions in LSTs and offsetting short positions in ETH-USD perpetual futures.

Market risks posed by LST liquidity manifest through users' conversion of xETH tokens to ETH when redeeming USDe. The closer to the fair value of the xETH token that can be realized for ETH, the more efficient the primary peg stability mechanism of USDe will function. The design of Ethereum means there is a duration mismatch between the ability of liquid staking tokens to increase supply and redeem supply. This duration mismatch causes a natural basis, unique to each LST design.

The case study of Lido stETH is presented, covering all functional aspects of stETH and their impact on stETH liquidity, redemptions, and its peg maintenance. The natural basis of ETH-stETH and the distribution of this basis are comprehensively analyzed.

The total amount of available stETH liquidity is measured and stress tested for scenario analysis of potential future outcomes. The risk measures: the median and stressed expected stETH slippage and propensity to repeg after moving different spreads from fair value informs the ultimate risk and precautions needed when onboarding LST collateral.

To anticipate future tail events, a range of catalysts for more serious liquidity events than have been previously observed is covered with early warning monitoring solutions and some risk mitigation recommendations.

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Chapter 1

Introduction

Ethena USDe is backed by allow listed LST tokens and offsetting ETH futures positions to create fully collateralized and delta-neutral backing to USD. Users of Ethena are subject to the risk that USDe loses its peg to $1, either temporarily or permanently.

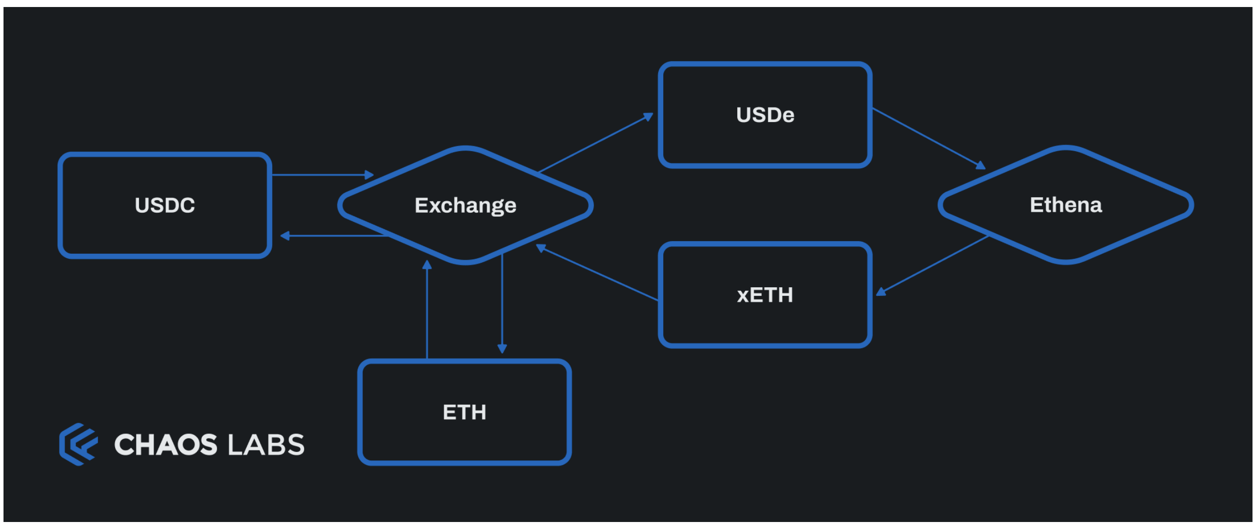


Figure 1.1: In the case where USDe trades below $1, the diagram below shows the potential arbitrage. The fewer frictions in each of these steps, the smaller the arbitrage that is profitable and the tighter USDe will trade to its peg. In particular, this report focuses on swapping xETH for ETH. ETH-USDC liquidity is assumed to be adequate.

Risks specifically posed by liquid staking tokens can be broken down into solvency and liquidity risks. USDe is backed by xETH tokens and offsetting ETH perpetuals. Solvency risks, such as a permanent (or perceived as potentially permanent, such as in the USDC case in March 2023), significant reduction in the value of xETH relative to ETH would cause (or be perceived to cause) USDe to become temporarily undercollateralized. This would make it impossible to maintain its peg permanently, resulting in a haircut.

Liquidity risks related to LSTs arise from their collateralization of USDe and their role in peg stabilization. The ability to swap between xETH and ETH (and ETH-stablecoin, although this is assumed) as close to fair value across market conditions with as little slippage and other frictions as possible will directly translate into USDe stability around $1. The closer the amount of ETH received/sent when swapping against xETH by users, the closer to $1 that arbitrages will be profitable, and the closer USDe will trade to peg. This is not the only or necessarily the primary determinant of USDe volatility around its peg, but the bounds of profitable arbitrage define the broader trading range of the stablecoin. Should the price diverge beyond this, profitable arbitrage should incentivize users to perform trades, returning the price into the bounds defined by arbitrage costs.

The price ranges of LST tokens come about and are a function of a duration mismatch between the ability to mint and redeem LSTs with their issuing protocols. It is primarily frictionless and immediate to create more supply when their prices rise above the price of ETH while redeeming is subject to a variable lag. Because of this, a natural basis exists dependent on LST protocol designs. Since the Shapella upgrade, both the size of this basis and its volatility have reduced significantly.

This report provides a detailed assessment of the initial onboarded collateral Lido stETH. All aspects of protocol design, risk mitigants, and exchange liquidity inform the ultimate results.

Consideration is also given to the implication of having sophisticated trading firms as the primary market users of Ethena, involved in the minting and redeeming of USDe. These entities are used to providing intermediary services such as market-making on exchanges where they manage short-term mismatches in their exposures.

They will likely be able to handle short-term liquidity conditions related to LSTs used to back USDe similarly. The time to converge from the most extreme short-term divergences is an important measure to determine their risk in minting/redeeming and, therefore, ultimately, the USDe peg.

This report measures the entire distribution of available liquidity, particularly how it behaves under stress, to understand the potential limits to arbitraging USDe under the peg. This, in time, can be an input informing the potential sustainable and safe growth of USDe.

In particular, ETH-xETH liquidity is analyzed as ETH-Stablecoin pairs are some of the most liquid across market conditions.

The observed liquidity distribution over relevant historical conditions informs a base case. From this, the median slippage to clear different trade sizes measured the expected slippage faced by primary users of Ethena. In contrast, the tail of the distribution can measure expected performance in times of stress.

To measure the ability of sophisticated users of Ethena to mitigate short-term price fluctuations, the observed mean reversion behavior of ETH-xETH prices is analyzed. This also provides a measure of the ability of a LST to handle many sales over a short period.

Risks that could cause further deterioration in realized slippage are further covered, exploring tail risks that could destabilize the functioning of Ethena.

Chapter 2

Lido

The following is a high-level primer of the Lido protocol, focussing on how its design affects price stability and liquidity.

stETH has minimal friction or limits to mint as it is immediately issued to the minter, and the ETH is assigned to a validator. The current staking limit is 150 000 ETH per rolling 24-hour window (currently approximately $250m), meaning there is available validator capacity for most reasonable sizes Ethena is likely to encounter in the near term. The ETH still needs to pass through the Ethereum activation queue, which dilutes rewards slightly for all stETH holders. In contrast, in the queue, but from a liquidity perspective, it is frictionless to mint stETH. For this reason, it is rare for stETH to trade persistently above its peg as the arbitrage to bring prices in line from above is nearly frictionless (just gas and 1bp Curve pool costs + slippage).

Redeeming stETH for ETH is more complex due to the design of Ethereum staking requiring a cooldown period of at least 27 hours in the withdrawal queue. There are also Ethereum redeem rate limits of 13 validators (416 ETH) per epoch (6.5mins) for the exit queue currently. Should withdrawal requests spike in times of stress, the exit queue could add days or more to redemptions. Users requesting a stETH redemption receive an unstETH NFT representing their request.

Lido ETH in the activation queue and rewards that have been skimmed from a liquidity buffer that can be used to process withdrawal requests quicker. This process is not immediate and requires daily oracle updates aligning the beacon chain state with the application layer. This update happens around noon UTC.

The result is access to a pool of ETH in between 1 to 24 hours. This provides an additional margin of safety against prolonged depegs of stETH by reducing the duration mismatch between withdrawals and stETH liquidity requirements. If the requested withdrawal amount exceeds the current buffer size, it can still be finalized using the inflows that arrive in subsequent days.

Lido has published an analysis of the liquidity buffer:

> "*Based on the history of ETH staked via Lido, Execution Layer rewards, and our current estimate of Consensus Layer rewards, we conclude that there is a 97% probability that the protocol buffer has more than 1000 ETH on any given day, a 40% probability that the buffer exceeds 5,000 ETH and a 15% chance that it contains more than 10,000 ETH (when there is no demand for withdrawals).*"

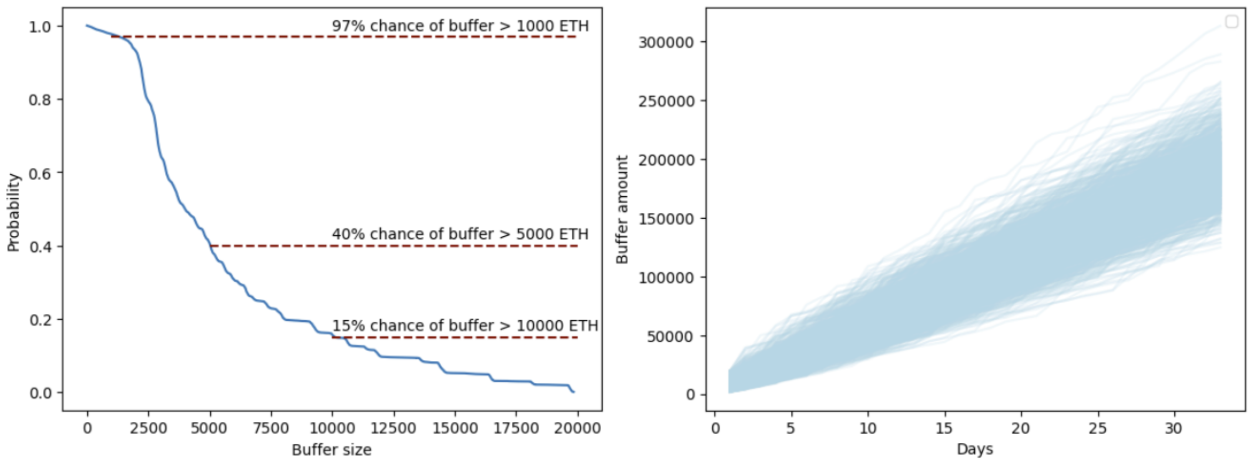


Figure 2.1: Source: Lido Blog

Data from the 30 days up to 10 October for the distribution in size of the liquidity buffer is shown below. Although the liquidity buffer is well capitalized from a dollar and typical redemption standpoint, this liquidity is shared across all use cases. Demand for redemptions by Ethena will likely correlate with other redemptions during times of stress and will likely not be available. There is also considerable volatility in the liquidity buffer size.

Ethena is not reliant on the Lido primary market to furnish redemptions. These risks should be considered purely in the context of stETH performance relative to its peg.

Measure	**ETH Available (last 30 days)**	**ETH Available ($m)**
Median	15 075 ETH	$24.1m
Average	21 534 ETH	$34.3m
Minimum	6 818 ETH	$10.9m
Maximum	90 885 ETH	$145.4m

Table 2.1: Source: Dune

For a longer-term perspective on the liquidity buffer:

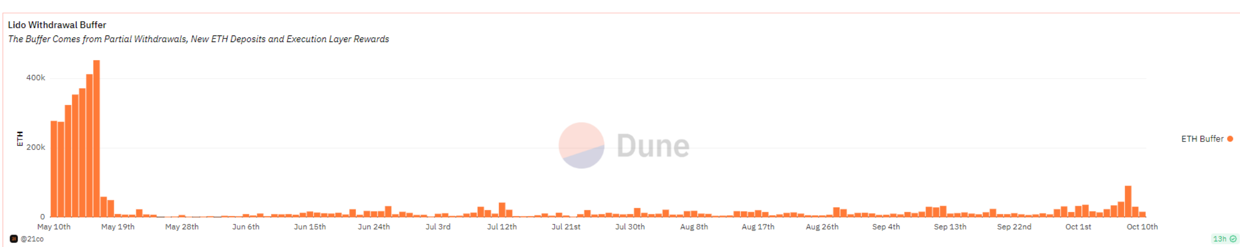


Figure 2.2: Source: Dune

There is a duration mismatch between the liquidity requirements of arbitrageurs and allowable redemptions of a few hours in the case of redemptions against the liquidity buffer to days for larger redemptions and when the withdrawal queue is congested. The duration mismatch means that stETH typically reverts to a level slightly below 1:1 with ETH. Should it trade more than the swap fee + gas costs to mint and swap, it is instantly profitable to arbitrage, so stETH seldom persists much above the price of ETH. **The discount basis**

has been stable at around 4bps below ETH since Shapella with some variation, particularly to the downside.

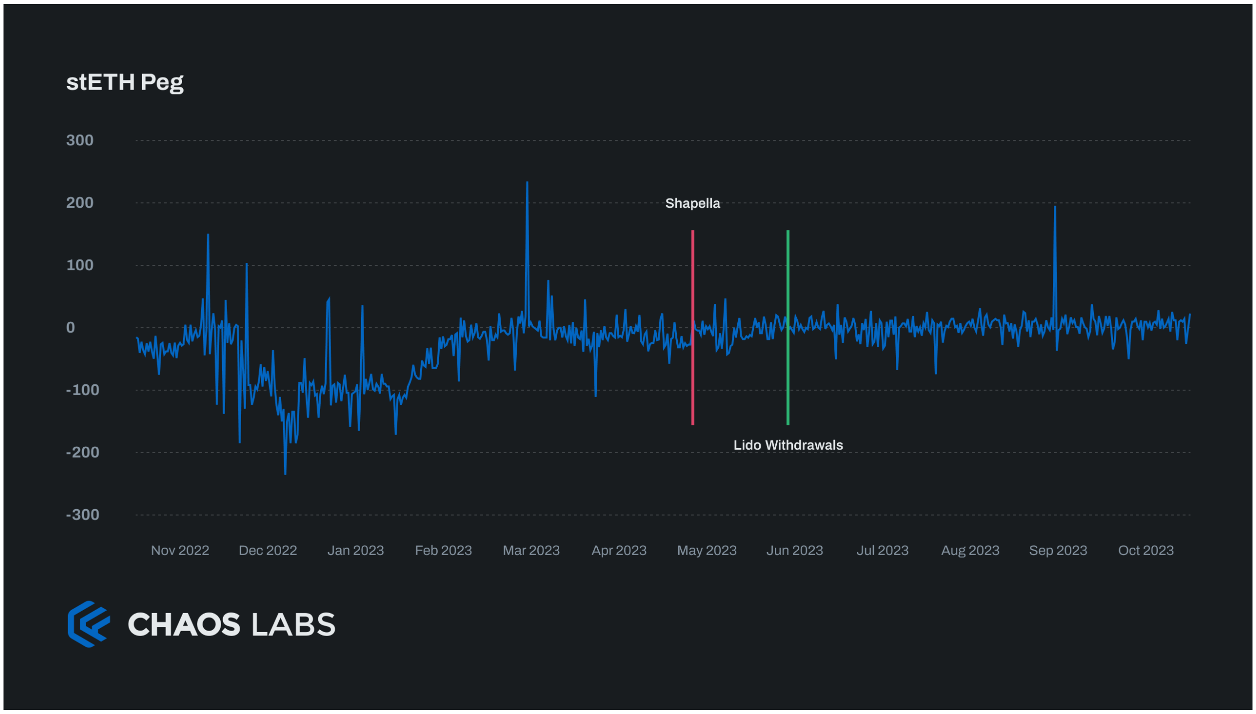


Figure 2.3: S

stETH is more than 10bps below peg 3.3% of the time since Shapella, more than 7bps below peg 18% of the time, and more than 5bps below peg 31% of the time.

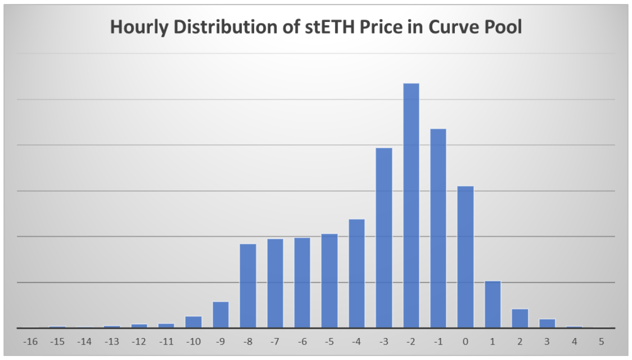


Figure 2.4: Source: Dune

Trade prices over this period are similar, with more of the distribution above par. Arbitrageurs likely immediately backrun buy trades, meaning prices rarely settle there for long. The growth in stETH supply over this period creates the right skew vs the average price chart. There is the potential that this shifts left in times of stress.

Lido has processed over 1.5m stETH in withdrawals without any issues since May. These have all been processed smoothly, and the diversity of users (and consistently diverse day-to-day) redeeming implies a diverse array of arbitrageurs keeping the stETH price in line.

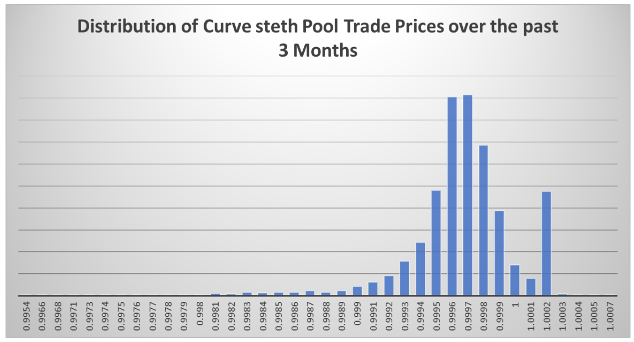


Figure 2.5: Source: Dune

Last 30 Day (to 10 October 2023) Lido Withdrawals

	Withdraw Requests	**Users Requesting Withdrawal**
Median	7 507	87
Average	12 465	91
Minimum	1 011	59
Maximum	84 189	167

Table 2.2: Source: Dune

Withdrawals and number of withdrawers through time

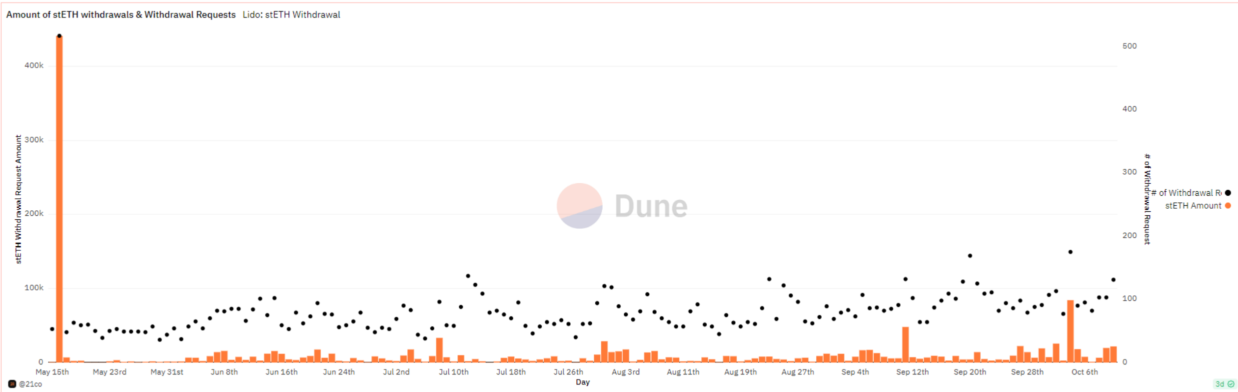


Figure 2.6: Source: Dune

The time to redeem ETH for stETH with Lido usually averages between 12 and 18 hours. The recent 84,000 stETH withdrawal requests on 4 October 2023 increased this to over four days for users requesting on 5 October.

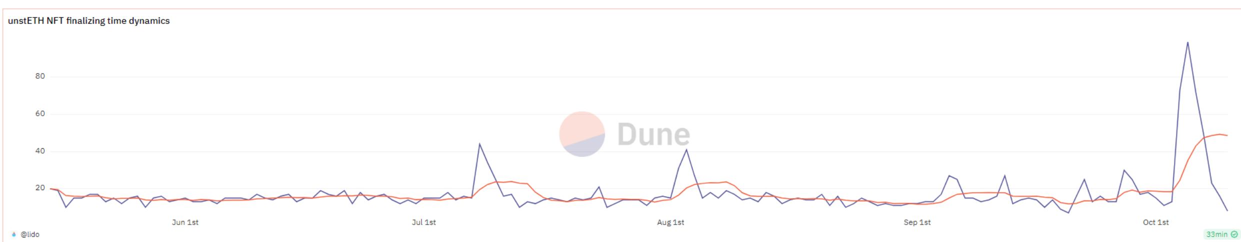


Figure 2.7: Source: Dune

It should also be noted that the stETH peg has not been affected by increases in the withdrawal queue. The recent withdrawal request spike on 4 October 2023 also had no noticeable effect on the peg, and stETH behaved normally.

Since its inception in 2020, Lido validators have earned 379,000 ETH in rewards and have been slashed for 1,298 ETH. This makes their historical slashing rate, 0.34%, one of the best. There have been no prior instances of slashings resulting in stETH losing value relative to ETH. All slashings have been minor, isolated instances covered by the insurance fund.

Lastly, should there be a case of mass slashings of one or more Lido validators, the protocol goes into bunker mode, pausing redemptions for at least 16 days and halting redemptions for at least 16 days. This edge case is discussed in more detail in the conditions for a significant depeg section.

Chapter 3

stETH Liquidity

Currently, most stETH liquidity sits in the Curve ETH-stETH pool. Liquidity in this pool has continually trended lower since withdrawals were enabled. This has not harmed the stETH peg; recent evidence shows relatively low liquidity utilization. There is enough liquidity for normal conditions, but it could pose risks to the peg as liquidity requirements have a fat right tail.

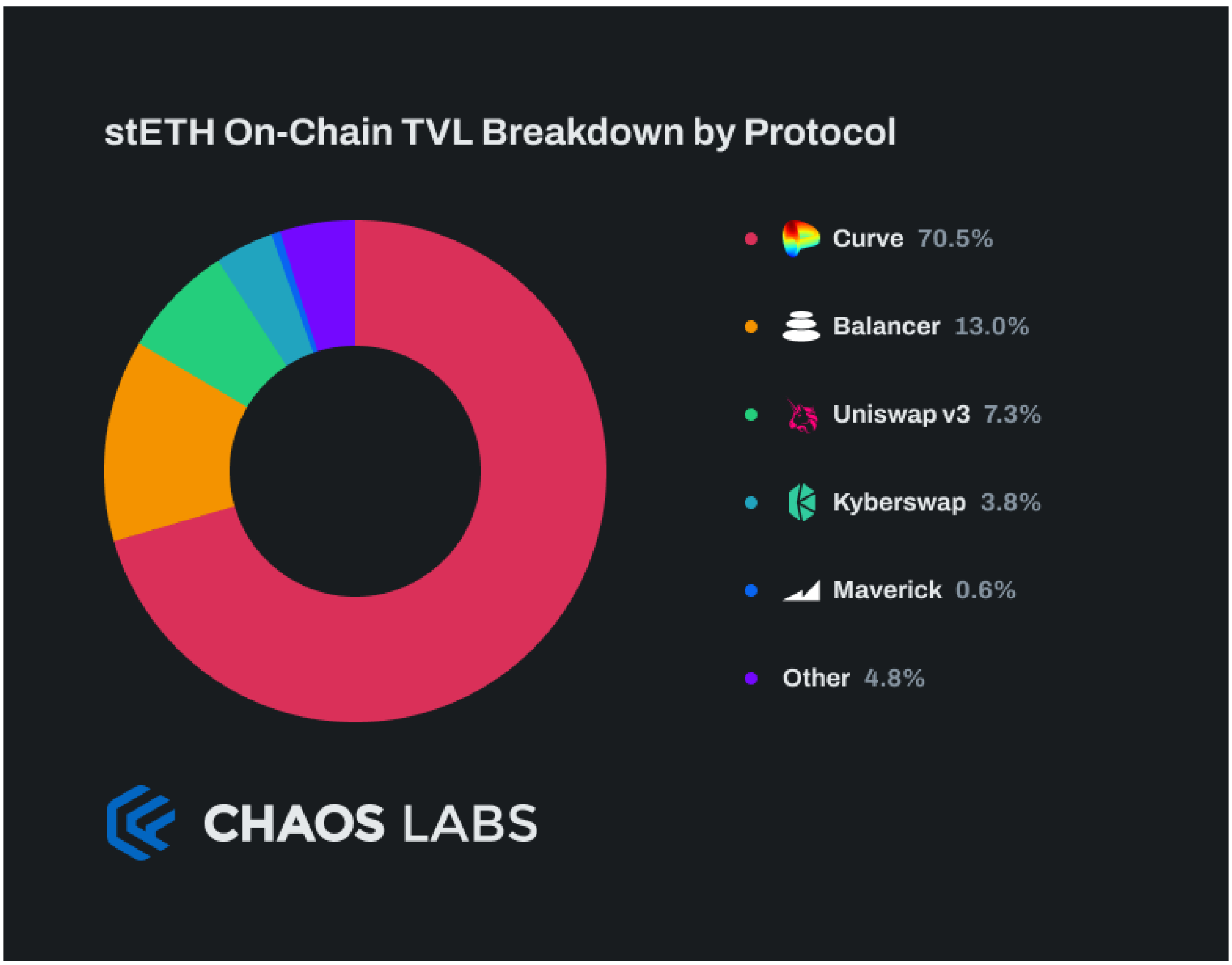


Figure 3.1

stETH hourly price volatility relative to ETH has been 0.08% since withdrawals were enabled. This volatility compares to USDC 0.06% and USDT 0.04% relative to their $1 peg. stETH observed price dynamics impact USDe through its peg stability arbitrage mechanism, and historical ETH-stETH volatility implies performance comparable to price stability mechanism (PSM) designs using fiat collateralized stablecoins in most conditions.

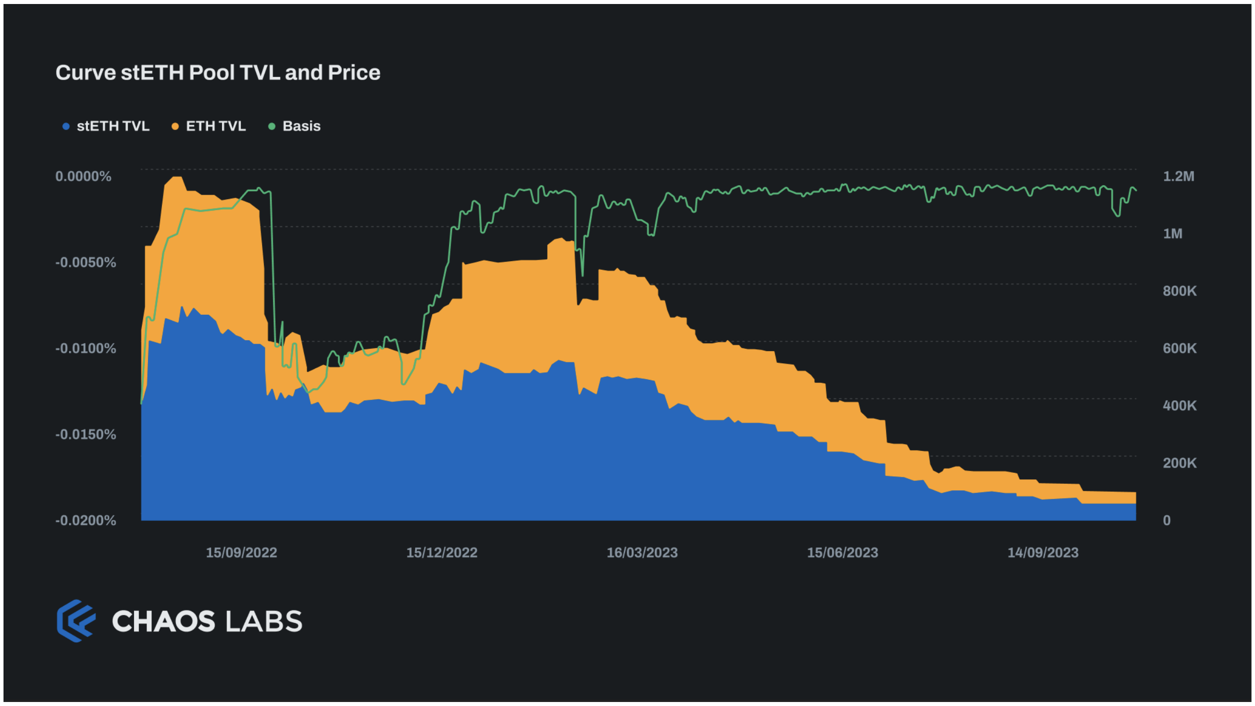


Figure 3.2

Uniswap v3 stETH adds significantly to liquidity at the touch. Data since April 2023 shows an average of 75% of relevant pool liquidity within 1bp of the live tick.

Currently, there is approximately 10,000 ETH of liquidity within 1bp and 14,000 ETH liquidity within 10bps in the Uniswap v3 WETH-wstETH pool. This pool has a 1bp trading fee, the same as the Curve pool.

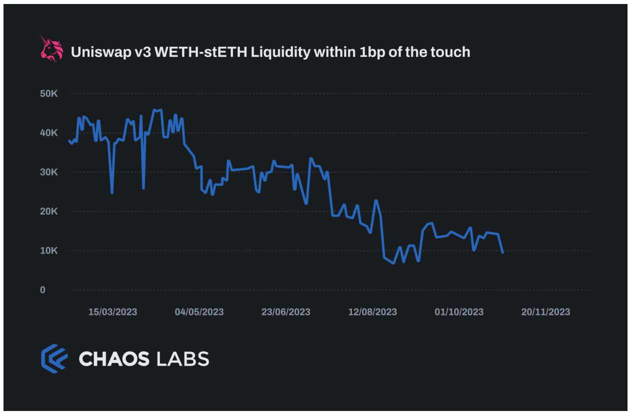


Figure 3.3

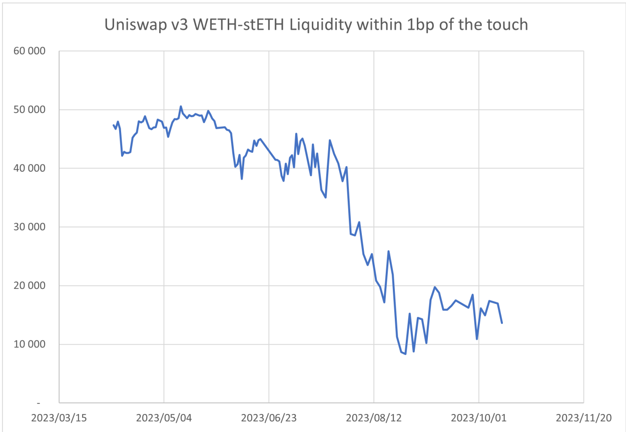


Figure 3.4

Uniswap is also where most volume currently trades. This has evolved considerably through time.

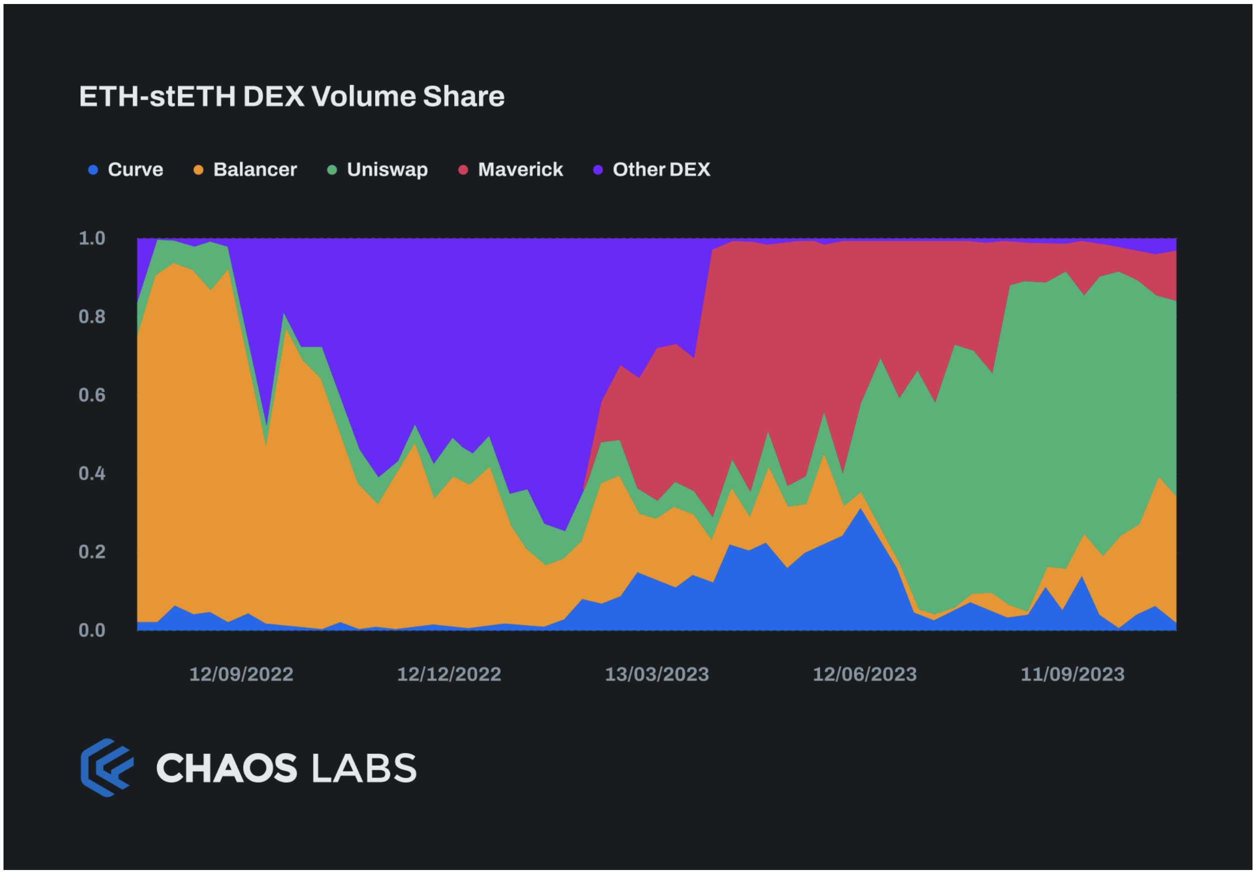


Figure 3.5

The Balancer WETH-wstETH Composable Stable Pool has much lower TVL than the curve pool. As of 18 October 2023, it has 4,281 WETH liquidity available to be swapped against wstETH. It sees a higher volume share due to its much higher amplification coefficient (currently 5,000 vs. Curve's 30), leveraging this liquidity to a more significant effect. The result of this pool configuration is that this pool will likely be the first liquidity source drained in any depeg scenario and is thus excluded from any liquidity stress analysis.

The Maverick pool has a similar highly leveraged configuration to the Balancer pool.

Declining DEX pool liquidity has not affected the stETH peg, and since withdrawals were enabled, the price action has followed a relatively tight and stable distribution. Curve pool utilization has recently drifted upward in response to paused LDO incentives. These have recently been replaced by stETH incentives, which should stabilize TVL, all else equal.

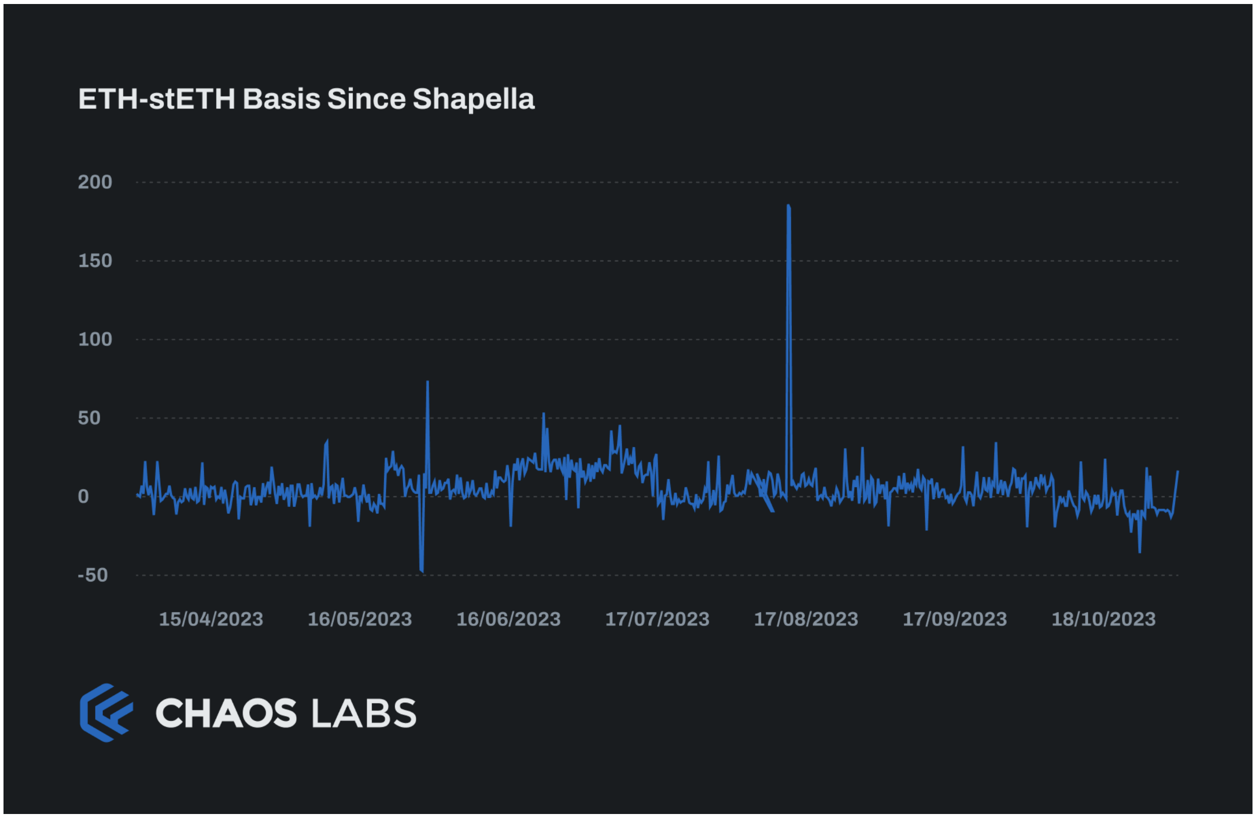


Figure 3.6

In the future, there could be deep ETH-stETH liquidity on centralized exchanges. This is not the case currently, with only 138 ETH worth of bids sampled within 10bps of mid. OKX and Huobi are the only live markets paired with ETH currently.

stETH pools paired with USDT liquidity are growing rapidly on OKX and Bybit. These volatile-stable pools are more volatile, making the total liquidity within 100bps an equivalent measure. There is currently just over 850 ETH of liquidity in these two markets.

1 Summary

stETH has just over 80,000 in liquidity on either side, broken down amongst four major stETH liquidity pools on-chain.

The largest is the Curve stETH pool, which is the least concentrated. It functions as the

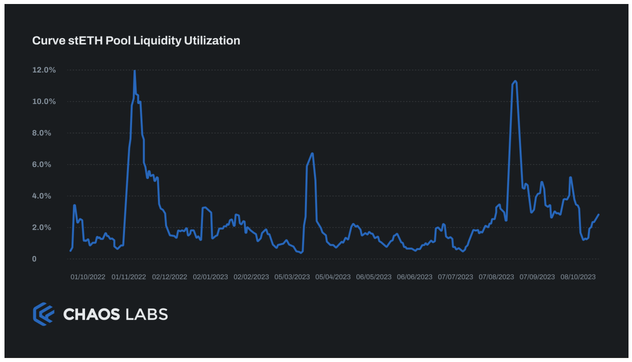


Figure 3.7: Other than a brief spike around the rapid ETH price drop in August, volumes in the Curve stETH pool have drifted lower since Shapella. TVL dropping in the pool has more than offset the volume drop, and utilization has recently increased, suggesting an equilibrium could have been found.

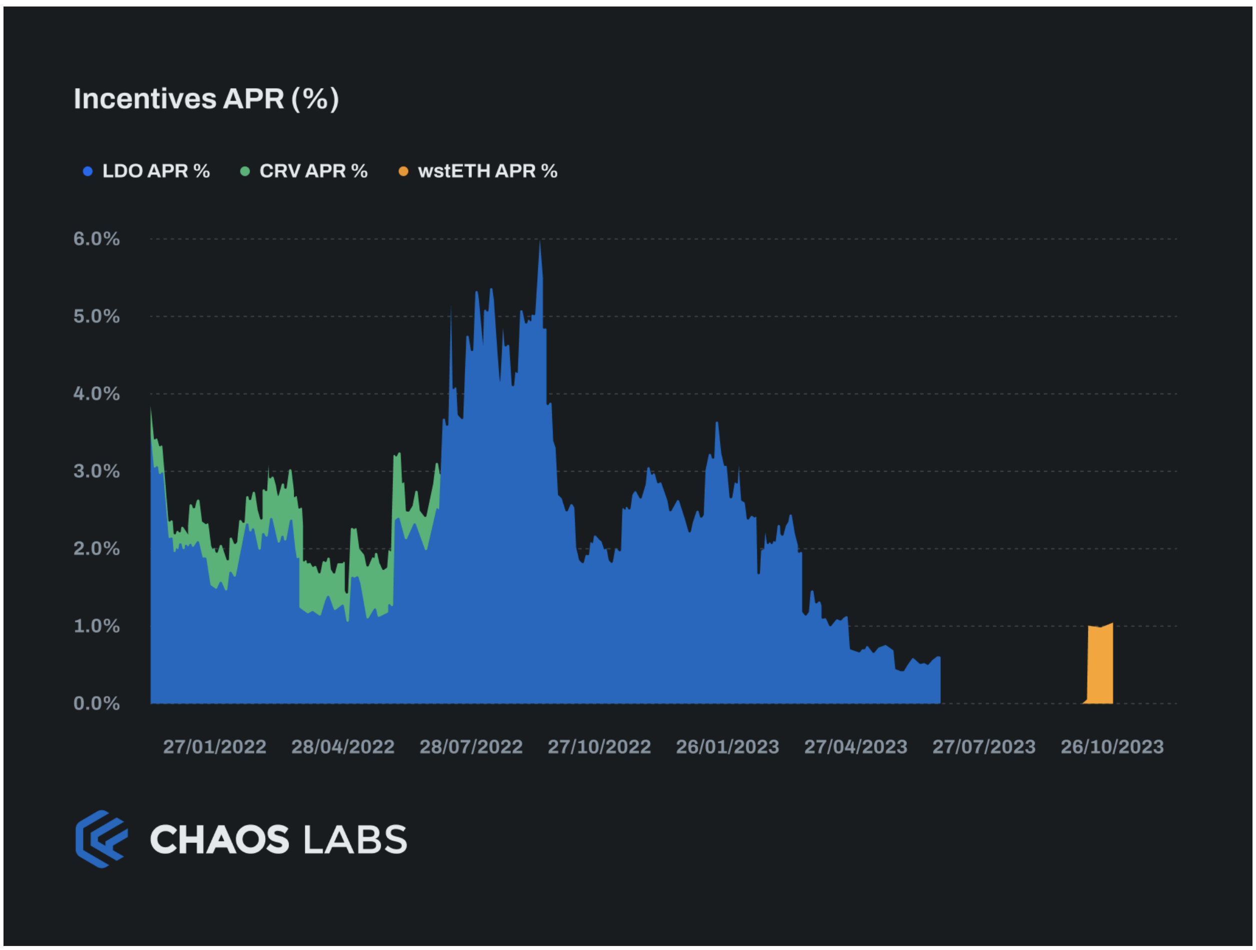


Figure 3.8: Lido LDO liquidity incentives to the Curve pool ended in early June 2023. In early October 2023, stETH incentives were introduced, adding approximately 0.95% to the pool yield. This should support TVL in the near term if continued.

liquidity of last resort should the ETH-stETH price move beyond about 10bps. This pool currently has around 64,000 stETH and 64,000 WETH for $205m in TVL.

Another 10,000 stETH and WETH in Uniswap v3 are concentrated within 10bps of par.

There are approximately 5,000 WETH and stETH in the Balancer pool.

Lastly, on Maverick. There are 1,600 stETH and 800 WETH.

The non-Curve pools provide highly concentrated liquidity within 10bps of par. This is where most trading will happen during normal conditions. The Curve pool liquidity sets the price once it moves beyond this range.

There is barely any ETH-stETH liquidity on CEXs currently. 138 ETH of bids within 10bps of mid was sampled across the Huobi and OKX live markets.

Chapter 4

wbETH Liquidity

1 wbETH Supply

Binance launched its liquid staking token, bETH, in January 2021 as a rebasing token, similar to stETH. On 2 May 2023, soon after the Shapella upgrade, a wrapped version was launched as wbETH.

Supply and growth were low until Binance announced the delisting of its bETH pairs in favor of wbETH pairs on 31 August 2023. This analysis focuses on behavior after that date as a true reflection of the token.

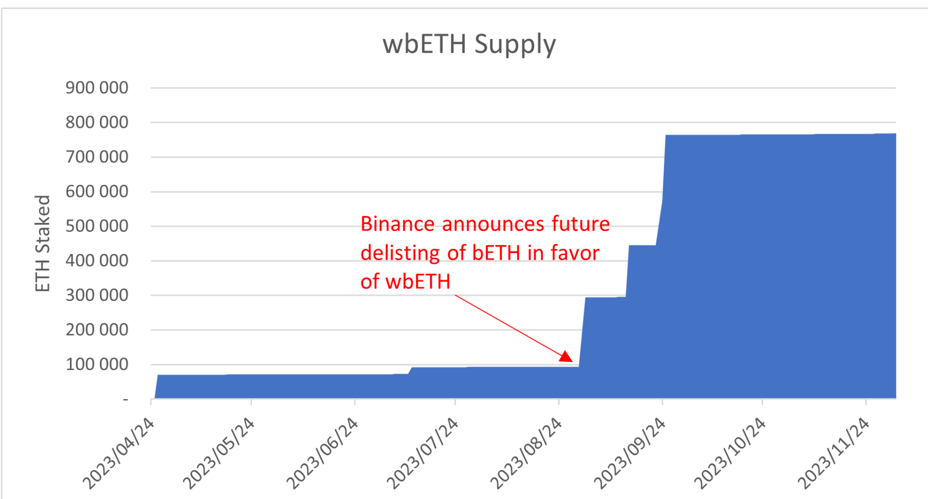


Figure 4.1: wbETH supply since launch. Binance's announcement to transition bETH to wbETH on 31 August 2023 catalyzed rapid supply migration.

2 wbETH Peg Performance

The summary statistics comparing wbETH peg stability with stETH show similar but slightly greater divergence. The slightly wider average divergence can be attributed to the fact that it has not been around for long, and the market is still developing.

Despite this, wbETH has tracked its peg closely and has not shown signs of a significant, sustained deviation. The longest time it has traded more than 50bps below peg is 15 minutes,

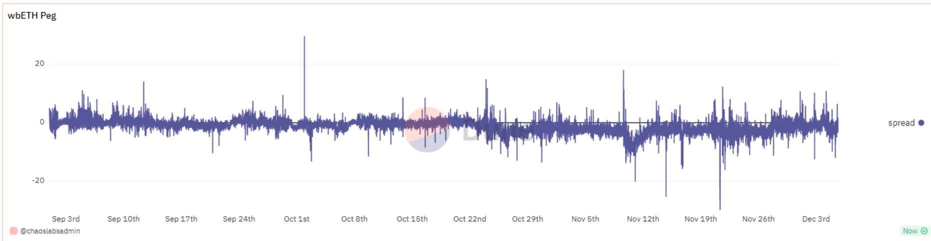


Figure 4.2: wbETH has traded close to its peg since Binance prioritized it over bETH.

the same as stETH.

It does exhibit greater variance relative to peg ad measured both by volatility and the longest time spent over 10bps and 20bps below peg. This is unlikely to pose a solvency risk to Ethena and should be recoverable from the insurance fund.

Peg Performance Summary Statistics:

	wbETH	**stETH**
Average	-6.7	-3.4
Median	-6.3	-3.1
Volatility	12	9
Max below -10bps	1980	115
Max below -20bps	575	70
Max below -50	15	15

Table 4.1: Data since 2 September 2023, after Binance announced its liquidity migration from bETH to wbETH.

3 wbETH Liquidity

Unlike stETH, most wbETH liquidity is on Binance. This improves capital efficiency to the point where slippage is approximately double stETH slippage up to 5,000 ETH ($11m) trades.

Orders of larger size would likely need to be cleared OTC, or broken up into smaller blocks.

wbETH Slippage by trade size:

ETH Flow	**Slippage**
500	3.0
1 000	5.5
2 000	7.1
5 000	49.6

Table 4.2: The slippage incurred to sell different amounts of wbETH.

4 wbETH Conclusion

At the current scale, wbETH does not appear to pose any specific liquidity risk. The close ties between its primary mint-redeem market and its main liquidity on Binance have enabled it to maintain its peg reasonably well so far.

There is currently sufficient secondary market liquidity for up to 5,000 ETH ($11m) of wbETH at reasonable slippage. Beyond that there would need to be further growth in the wbETH supply.

Chapter 5

LST Risk Methodology

Three dimensions are covered in determining the available LST liquidity under times of stress. The first is the recently observable liquidity distribution across all venues. The design of AMMs means liquidity is relatively consistent over short time horizons, with just the mid-price fluctuating according to flows. Orderbook exchange liquidity, by comparison, fluctuates constantly. Historical liquidity provides an assumptionless measure of available liquidity. The tail of the distribution, either 95% or 99%, serves as a good measure of stressed liquidity.

To standardize the measure of liquidity across the two exchange designs, we propose sampling order book liquidity within predefined ranges of par by regular intervals over at least a month and defining stressed conditions as the 5% least observed liquidity over this period. For AMMs (excl. Uniswap v3 style), this can be done similarly using current or projected TVL, deterministic slippage, and observed pool mid-prices. Concentrated liquidity AMMs need to be sampled similarly to order book exchanges due to the evolving shape of liquidity at different ticks.

This outcome is an objective and robust measure of immediate stressed liquidity while making minimal assumptions. The output measures the worst rate the LST is exchangeable for ETH at 95% or 99% of the time.

Another measure is computed to further the analysis to understand the propensity of stETH to return to its peg, essential for those willing to take on inventory risk to arbitrage mispricings. The distribution of time spent more than x bps from peg. This allows a distribution of time spent beyond x bps and enables tail risks to be analyzed.

Lastly, other qualitative details of the LST are discussed, along with potential risks that have yet to materialize. The requirements for a significant depeg of 5%+ are also discussed, with some ideas for monitoring and mitigants.

1 Curve Pool Available Liquidity

The Curve pool has by far the deepest DEX pool liquidity. The Uniswap, Balancer, and Maverick pools currently contain less than 20,000 ETH liquidity, mostly available close to fair value. These pools are where ETH-stETH trades happen in normal conditions. Once this approximately 20,000 ETH tight liquidity range is breached, the Curve pool sets the price of ETH-stETH. **For that reason, it is necessary to dive deeper into the dynamics of the Curve stETH pool.**

Combining pool slippage, trading fees, and mid-level distribution in ETH-stETH, we get the following estimated trade levels from mid.

Curve Pool ETH Slippage (bp) within Defined Slippage vs Pool TVL

Pool TVL/Flow Size	500 ETH ($810k)	1 000 ETH (1.65m)	2 000 ETH ($3.25m)	5 000 ETH (8.1m)	10 000 ETH ($16.2m)
, -75%	5.1	10.3	20.9	56.8	163.4
-50%	2.6	5.1	10.3	26.3	56.8
-25%	1.7	3.4	6.9	17.3	35.8
-10%	1.4	2.9	5.7	14.4	29.4
0%	1.3	2.6	5.1	12.9	26.3
+25%	1.0	2.1	4.1	10.3	20.9
+50%	0.9	1.7	3.4	8.6	17.3
+100%	0.6	1.3	2.6	6.4	12.9

Table 5.1: Slippage above is measured as pure price impact due to bonding curve of the Curve AMM.

In reality, the mid-price of the pool will play a more significant role in determining the distance from fair value that trades execute. We've used prices sampled every minute since Lido allowed withdrawals and use the distribution of pool mid-prices to measure the effect of price movements throughout the entire range. The median and 95th percentile are shown below.

Adding the Above Curve Pool Slippage to the Distribution of stETH prices relative to ETH, the following is the median slippage likely to be experienced based on historical values since withdrawals were enabled:

Pool TVL/Flow Size	500 ETH ($810k)	1 000 ETH (1.65m)	2 000 ETH ($3.25m)	5 000 ETH (8.1m)	10 000 ETH ($16.2m)
-75%	9.1	14.3	24.8	60.7	167.4
-50%	6.5	9.1	14.3	30.3	60.7
-25%	5.7	7.4	10.8	21.3	39.7
-10%	5.4	6.8	9.7	18.3	33.4
0%	5.2	6.5	9.1	16.9	30.3
+25%	5.0	6.0	8.1	14.3	24.8
+50%	4.8	5.7	7.4	12.5	21.3
+100%	4.6	5.2	6.5	10.4	16.9

Table 5.2: Median sell execution level from fair value.

The following is the 95th percentile worst slippage likely to be experienced:

Pool TVL/Flow Size	500 ETH ($810k)	1 000 ETH (1.65m)	2 000 ETH ($3.25m)	5 000 ETH (8.1m)	10 000 ETH ($16.2m)
-75%	21.3	26.5	37.0	72.9	179.6
-50%	18.7	21.3	26.5	42.5	72.9
-25%	17.9	19.6	23.0	33.5	51.9
-10%	17.6	19.0	21.9	30.5	45.6
0%	17.4	18.7	21.3	29.1	42.5
+25%	17.2	18.2	20.3	26.5	37.0
+50%	17.0	17.9	19.6	24.7	33.5
+100%	16.8	17.4	18.7	22.6	29.1

Table 5.3: 95th percentile worst sell execution level from fair value

To estimate the stressed liquidity requirements of Ethena, the historical change in daily net issuance of existing successful stablecoins is taken into account. This should provide an upper bound to the instantaneous liquidity requirement as redemptions would typically happen in smaller blocks.

Using the 5% upper bound from the table above as a guide implies that the deep, tight Uniswap, Maverick, and tight portion of Curve liquidity should be sufficient to support USDe supply of up to $4bn with current conditions.

	95th Percentile Daily Net Redemption	
	Lower	**Upper**
USDT	-1.0%	1.5%
USDC	-1.3%	1.9%
BUSD	-2.9%	3.1%
DAI	-2.1%	2.5%
FRAX	-3.2%	4.9%
TUSD	-4.6%	7.2%
LUSD	-4.0%	3.2%

Table 5.4: Looking at the range of observed net issuance changes since January 2022, major stablecoins supply changes by less than 5% a day most of the time.

$$supplyLimit = \frac{tightLiquidity}{5\%}$$
$$supplyLimit = \frac{12{,}500ETH}{5\%} = 250,000ETH \ \ = \$4bn$$

Where tight liquidity is defined as liquidity within 10bps of stETH fair value.

2 Propensity to Repeg

The mean-reverting behavior of ETH-stETH affects trading firms' ability to take on temporary inventory risk in their arbitrage strategies. The time in hours to recover from prices significantly off its peg is used to measure this.

This analysis uses hourly data since 1 June 2023. Lido withdrawals were enabled on 15 May 2023, and the market took around two weeks to adjust to this new dynamic.

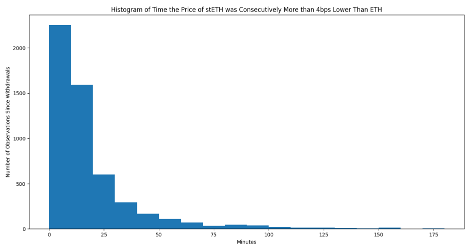
stETH was never more than 10bps off its peg for over 2 hours. 71% of the time, it drifted more than 10bps off its peg, and the stETH price corrected within an hour.

There is a tail in the amount it drifts off peg over short time horizons, though. Of the times it drifts more than 10bps off peg 36% of the time, it drifts over 15bps off peg and 15% of the time over 20bps.

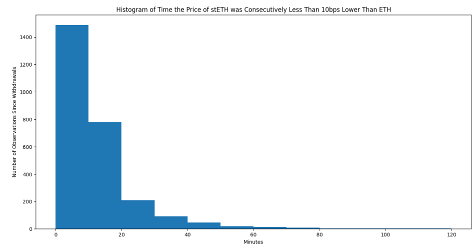
When it drifts further off its peg, its recovery is slightly better than when floating 10bps off the peg. Of the times stETH has been more than 15bps off the peg, it recovers to less than 15bps within an hour 77% of the time, and of times it drifts more than 20bps off the peg, it recovers to less than 20bps 79% of the time within an hour.

By comparison, the longest, either USDC or USDT, were more than 20bps below peg over the period was 40 minutes. The longest either was over 10bps below peg was 65 minutes, slightly better, but not drastically different to stETH. Both fiat-backed stablecoins typically trade slightly above par. There has been an instance of USDT trading more than 20bps above its peg for 110 minutes straight, and both traded more than 10bps above its peg for two straight days between 5 and 7 August 2023.

The fact that stETH has not had any persistent episodes of major depegs is a positive sign for the dynamic to repeg itself. There is a high degree of trust in Lido, and market participants are willing to profit from mispricings reasonably quickly. Lido is the largest DeFi protocol by TVL at over $17b currently. This metric demonstrates quantitatively the extent that users have voted with their wallets to trust stETH and the amount of interest in maintaining its peg.



(a)



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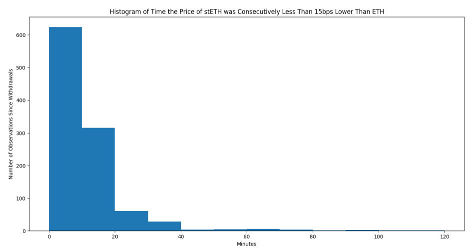

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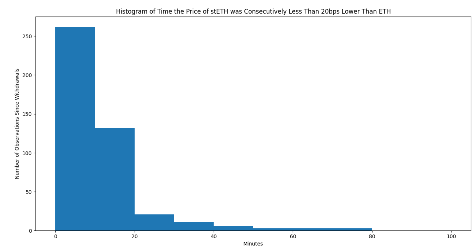

(d)

3 Lido Backstop

Lido maintains approximately 25,000 ETH as a last-line solvency backstop in case of extreme slashings. This should give some extra comfort that the solvency of stETH will always be maintained and any price depeg is transitory. The presence of this facility reduces the likelihood of significant depegs without a technical hurdle to arbitrage, as the expectation should always be that prices will revert. There is always a risk of larger slashings or other shortfalls in the Lido protocol, leaving stETH undercollateralized.

Chapter 6

Risks

1 Risks

1.1 A Significant stETH Depeg

Ethena holds stETH as collateral for its derivative hedges. Collateral for USDe comprises the sum of the value of stETH, the mark-to-market of the ETH derivative hedges, and the insurance fund. The extent to which stETH holds its peg, therefore, presents a risk to the protocol.

The conditions for a significant depeg

The Ethereum Shapella upgrade, enabling staked ETH withdrawals, reduces the need for deep liquidity as pools can be topped up from the primary market (minting/burning stETH), subject to a lag. Depegs are only possible if liquidity cannot be injected into DEX pools quickly enough to close liquidity mismatches. Because minting stETH is instant, this is only an issue on the redemption side, which would result from net stETH selling.

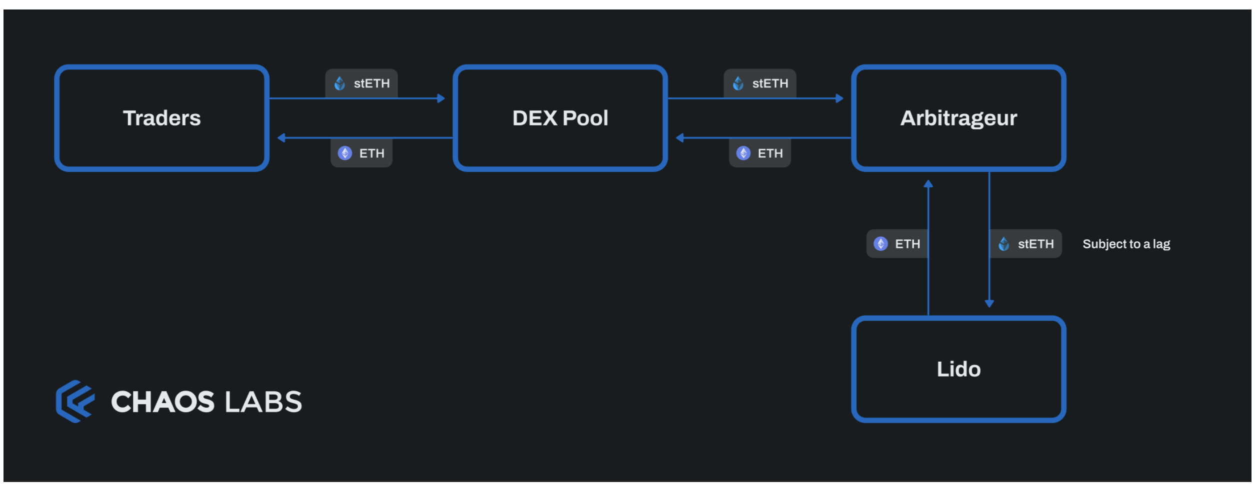

Figure 6.1

This does not mean that depegs cannot happen, though. If net selling sufficiently exceeds the liquidity buffer over a period, then it is possible that stETH trades below par with no instantaneous arbitrage available.

The conditions for such an event require a combination of significant stETH selling (lending protocol liquidations, for example) AND increased frictions to redeem stETH for ETH (a significant slashing event forcing Lido into 'bunker mode' for 16+ days, for example).

Without both of these triggers, any dislocation in price would likely be captured by arbitrageurs, bringing prices relatively back in line.

Definition: Significant depeg. *For this report on Ethena, a significant depeg is defined as one that affects the functioning of the protocol through the development of a permanent basis materially affecting USDe solvency through under collateralization. This is defined as a month's worth of average staking rewards, currently 30bps, for over a month consecutively. This length of time should be sufficient to clear any congested queues and suggests a permanent change to the ability of agents to capture arbitrage profits.*

Definition: Friction to Redeem. *Friction to redemption is defined as either uncertainty around the withdrawal amount, as would happen with significant slashings, or the inability to withdraw for a period that would make the cost of carry sufficiently uncertain. In this case, we use 16 days, which corresponds to just under 1.5m ETH redeemable at Ethereum rate limits; this is over 5% of the total staked amount.*

Assumption 1: *There exist profit-motivated agents with sufficient resources or the ability to flash borrow WETH competing for arbitrage opportunities. These agents will perform arbitrage activities if the return for doing so exceeds the cost of ETH, proxied by the staking rate.*

Assumption 2: *ETH liquidity is always sufficient for stETH arbitrage activities.*

Arbitrageur Profit Function: $ROI = \frac{Profit}{Capital} \div \tau$. Where τ is the time taken to realize the arbitrage.

Proposition. *For stETH to significantly depeg, it would require a combination of net stETH selling more than the sum of concentrated liquidity plus Lido liquidity buffer and frictions to redeem stETH. Concentrated liquidity consists of DEX and CEX liquidity within 10bps of fair value.*

Proof:

Firstly, if there is less net selling over a period than liquidity concentrated within 10bps in AMM pools, then AMM accounting dictates that the price cannot move beyond 10bps. Assume net selling exceeds liquidity in this range, and assumptions 1 and 2 above hold. Arbitrage agents will enter the market buying stETH for ETH and redeeming $\iff$ *the RoI they receive in return compensates them for doing so. If at any point the price of stETH is more than 30bps below ETH and there is no friction to redeem as defined above, then the following holds.*
$RoC \geq (30bps + stakingBaseFee \times \tau) \div \tau$
$\implies RoC \geq (0.003 + 0.033 \times \frac{16}{365}) \times \frac{365}{16} = 10\%$ *This is significantly higher than the staking yield, and therefore, arbitrageurs will deploy capital until this is no longer possible.*

The Lido protocol enters 'bunker mode', pausing withdrawals for 16 days when total validator slashings imply a reduction in the ETH backing stETH, i.e., total slashings are greater than total rewards over some period. At Lido's current 8.8m ETH staked and the range of daily staking APR, somewhere between 800 and 1,330 ETH slashed.

$$\Delta ETH = Rewards - Slashings$$
$$\implies \Delta ETH < 0$$
$$\iff = Rewards < Slashings$$
$$\iff ethStaked \times RewardAPR < Slashings$$

To monitor these risks, it is recommended to be aware of LST use in lending protocols and the performance of Lido validators for any early warning signs of potential mass slashings and take appropriate countermeasures.

The price of stETH mean reverts strongly to near the price of ETH under normal conditions, and the price process fits a mean reversion model well. There is also sufficient Curve liquidity within 4bps to cover redemptions up to $1.5m.

A significant risk to stETH liquidity available to primary market participants in redeeming USDe comes from the stETH price moving off its peg more severely, shifting the midpoint from where further slippage is incurred.

This risk results from the current situation where DEX liquidity is the primary source of price discovery. Improved centralized exchange liquidity broadens the range of liquidity options and reduces the likelihood of a depeg event.

Since Shapella, the price of stETH has tracked the ETH price closely. It has not traded more than 10bps away from its peg consecutively for over 65 minutes. Lido validators also have a track record of excellent performance, without any significant slashing incidents since inception. These factors, combined with the scale and trust in Lido, make a sustained basis of over 20bps unlikely post-Shapella, where stETH holders can redeem freely with the protocol subject to a small lag.

The point where a stETH depeg becomes a liquidation risk is covered below.

1.2 Risk of Liquidation due to a stETH depeg

stETH held by Ethena is used as collateral for the perpetual future hedges. Should stETH drift sufficiently off its peg, there is the risk that this collateral becomes insufficient, and the perpetual gets liquidated. The conditions for this to happen are investigated in this section.

The maintenance margin factor of a perpetual exchange defines the point where a position becomes under-collateralized and liquidatable. Exchanges set the maintenance margin factor to increase as position sizes increase as larger positions create greater insolvency risks. This maxes out at 0.5, implying liquidation at 2x leverage on all current exchanges.

Exchanges also treat collaterals differently, applying a haircut to riskier tokens. This applies a factor ≤ 1 to collaterals in calculating the dollar value of collateral.

This implies a collateral value of stETH collateral of:

$$collateralValue = (1 - depegPercentage) \times (1 - haircut) \times positionSize$$

Combining these, the point at which a stETH depeg causes the perpetual hedge to become liquidatable becomes:

$$
\begin{aligned}
& collateralValue < 0.5 \times positionSize \\
\iff & (1 - depegPercentage) \times (1 - haircut) < 0.5 \\
\iff & depeg > 1 - \frac{0.5}{haircut}
\end{aligned}
$$

Depeg Needed to Risk Liquidation as a Function of the Haircut Applied:

Haircut	Liquidation Depeg
10%	44%
15%	41%
20%	38%
25%	33%
30%	29%

Table 6.1: Table showing the point where a stETH depeg in percentage would cause the unlevered perpetual hedge to become liquidatable as a function of the haircut applied.

Currently, the most conservative exchange Ethena has onboarded to perform these hedges on employs a 20% haircut in valuing stETH collateral. This means that the price of stETH would need to depeg more than 38% from the price of ETH to cause a potential liquidation event.

1.3 Ethena Faces Mass Redemptions for USDe Crystallizing Losses

There is the risk that mass Ethena withdrawals in conjunction with Ethena stETH being redeemed at a discount leaves the protocol insolvent as the temporary stETH basis gets crystallized.

For this risk to play out, Ethena would need to see close to its entire supply redeemed, and, at the same time, realize a stETH basis. This would crystalize the loss of a stETH depeg. For Ethena to become insolvent, the losses from this event would need to exceed the value of its insurance fund.

Looking at the extremes of stablecoin redemptions across a range of popular stablecoins since January 2022, none have experienced a day with over 25% of their supply redeemed. Existing stablecoin redemption behavior does not indicate 100% redemptions are likely.

	Daily Issuance Change (%)	
	Max. Reduction	Max. Increase
USDT	-3.9%	1.7%
USDC	-7.2%	6.1%
BUSD	-14.7%	2.9%
DAI	-11.5%	28.0%
FRAX	-23.3%	10.0%
TUSD	-13.9%	54.5%
LUSD	-24.5%	28.1%

Table 6.2: The range of daily changes in issuance of major stablecoins since 1 Jan. 2022. There have been no instances of greater than 25% daily reductions in supply. There is also a clear trend towards more mature stablecoins seeing less daily movements in supply.

Even in this unlikely event, the many avenues to redeem stETH for ETH mean it is unlikely to trade significantly below the price of ETH for long, as evidenced by behavior since Shapella.

In total, there is a median of 15,000 ETH in the liquidity buffer, 80,000 ETH in DEX pools, and approximately 1,000 ETH tradable against stETH with minimal duration risk. Beyond this, withdrawals will be processed against the Ethereum withdrawal queue. The recent experience of 4 October demonstrated that 84,000 stETH could be redeemed over 4 days.

This indicates 190,000 stETH ($400m) available for redemption over a relatively short period of time.

1.4 Curve Platform Dependency

The largest liquidity currently resides in Curve, but this risk applies to all significant liquidity venues. It could also apply to CEX liquidity if that is where price formation moves over time.

Using data from the past three months, 73% of stETH sell trades in the Curve stETH pool that executed more than 10bps away from par happened between 31 July and 2 August over the Curve Vyper exploit. stETH averaged 11bps off its peg on 31 July and 7bps off its peg on 1 August before completely recovering in the second half of 1 August.

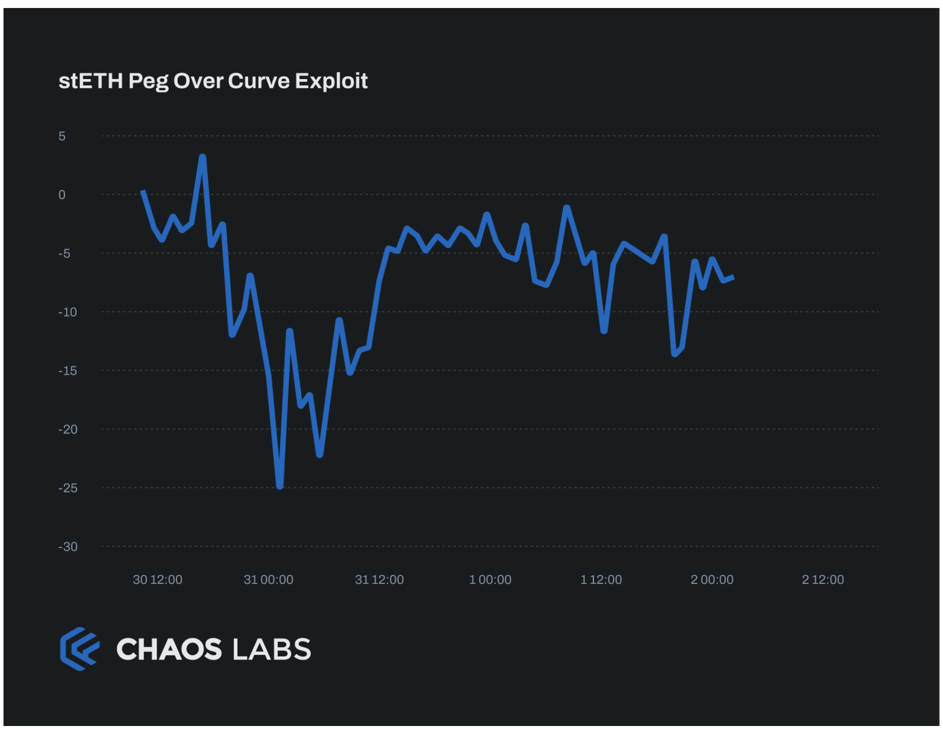

Figure 6.2

Closer inspection showed significantly fewer back runs of large flows, in conjunction with increased volumes meant prices did not have the impetus to repeg. Arbitrageurs potentially ran out of space for inventory.

There is the risk that any issues on Curve, particularly those affecting the stETH pool, cause liquidity provider capital to leave without a current alternative. This would leave stETH vulnerable from both a liquidity perspective and a price formation perspective should prices move beyond the tight ranges on Uniswap and Maverick.

Even though the stETH pool was unaffected by the exploit, the peg still suffered for around 36 hours. A more severe exploit could have lasted longer and been more dramatic.

This risk does not affect the solvency of Ethena, and the mint/redeem process with the protocol would be unaffected.

The main risk to Ethena is that this limits the ability of arbitrageurs to interact with the protocol to maintain its peg, as the ETH-stETH market function is impaired. The impact is poor user experience and a loss of confidence.

As alternative liquidity venues develop, this risk subsides.

1.5 Lending Protocol liquidations and other Rapid DeFi Sales

Using the Chaos Labs Asset Risk dashboard of stETH on Aave v3, there is over 23,000 stETH at risk of liquidation within 5%. There is insufficient liquidity on-chain to absorb these, and stETH could temporarily depeg from ETH.

These borrowings are almost exclusively lent against ETH borrows, meaning the risk taken is a significant short-term depeg against ETH.

A total of almost 1.5m stETH is currently deposited into DeFi protocols. Over 71% of this is in lending protocols presenting risks of some liquidity event.

The major risk posed by DeFi leverage is a temporary dislocation in the ETH and stETH prices. Like Curve platform risk, this affects the primary peg stability function of USDe, which could cause the stablecoin's volatility to increase. This affects user experience and trust, but the impact would be temporary and vanish once prices re-converge. The effect would be solely on the user experience of the Ethena primary market and does not affect protocol solvency due to the temporary nature of the impact.

1.6 Pool Yield and Token Incentives Affecting TVL Further

The stETH pool has not natively produced a high enough yield to beat simply holding the LST. This has resulted in the TVL drop; however, yields are still not high enough to beat holding.

The risk is that this situation leads to a continued drop in liquidity to the point where it is acceptable in normal conditions but at risk of temporary depegs.

The analysis in this report uses current liquidity, which is stressed in both directions. Should this liquidity drop, then the ability of USDe to scale and hold a tight peg would be impacted.

The Lido DAO solely manages this risk and affects all users of LSTs. There is nothing Ethena can do other than to monitor and inform the limits of a particular LST collateral. The close partnerships between Ethena and all partners, including Lido, allow Ethena to engage in positive initiatives to rectify liquidity issues and take proactive steps to manage this risk.

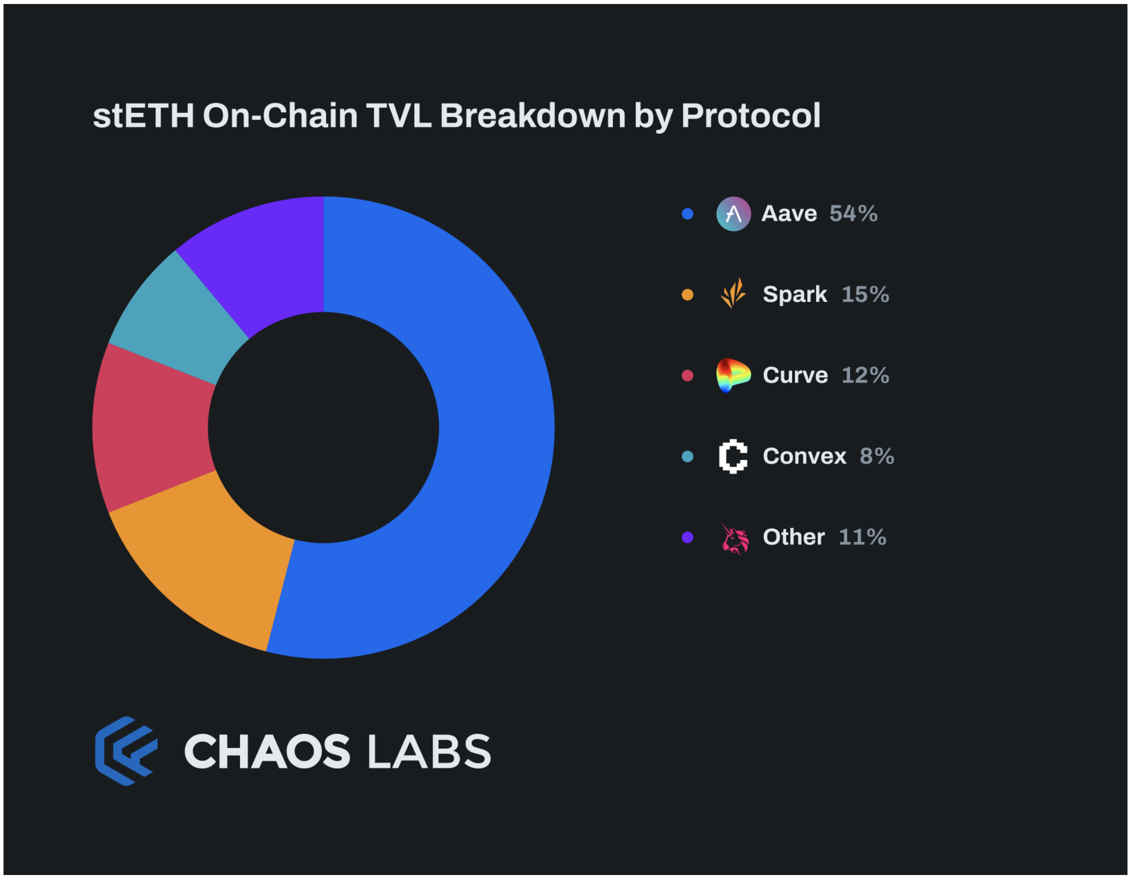

Figure 6.3

1.7 Impact of ETH Price Changes

While the solvency of USDe is unaffected by movements in the price of ETH, the functioning of the protocol operations can be. Fluctuations in the price of ETH primarily affect the size of Ethena's collateral balance sheet.

As the price of ETH fluctuates, Ethena will need to trade stETH against variation margin movements in the derivative hedges to keep the dollar value of stETH approximately equal to the supply of USDe. This ensures that yields are not leveraged up or down due to price movements. Should this not happen frequently enough, the yield on the product could become leveraged, and because this yield is volatile, there is a small chance that this causes greater variation in yield than forecast. If well managed, this is unlikely to cause issues.

Chapter 7

Recommendations

1 Rolling Mint and Redeem Caps

Mint and redeem caps have proven successful rate limits used to prevent a wide range of tail events in DeFi.

They also function as effective circuit breakers in a market event involving an LST collateral token and limit the strain Ethena users could put on Lido or other xETH redemptions.

These caps could be initially set as an expected upper bound on expected daily activity and transition to a percentage of supply based on observed user behavior.

2 Keep the Notional Backing USDe Stable Relative to Supply by Trading Futures PNL for LSTs

This suggestion aims at limiting the funding and liquidity risks posed by movements in the price of ETH.

To mitigate fluctuating yields, the protocol could monetize positive and negative PNL from the futures hedges and buy or sell LSTs for the same amount. The notional of the futures hedges will also need to simultaneously adjust proportionally to maintain delta neutrality.

This could be done with an awareness of the state of the secondary market in mind to minimize slippage.

3 Monitor Curve Pool, Uniswap, and Centralized Exchange Liquidity

Liquidity risk associated with Ethena primary market interactions can be monitored and inform protocol decisions.

This should inform the potential scale of Ethena and its required liquidity footprint. A possible benchmark for Ethena could be the ability to transact 2%-5% of its supply with tolerable slippage, in line with the upper bound of existing stablecoins mint and redeem activities.

Chapter 8

Conclusion

This report covers the market risks introduced by LST collateral backing on Ethena. This research aims to highlight the value of data-informed decision-making.

stETH liquidity on Curve is stressed both up and down to measure the slippage impact of changes in the pool TVL. This is important to be aware of as stETH TVL has dropped significantly over the past 12 months, meaning arbitrageurs have become more essential to keep prices close to fair value.

The mid-price of stETH relative to ETH plays a much more significant role in the distance from fair value stETH can be sold for ETH than slippage at current liquidity and most reasonable trade sizes. This mid-price fluctuates between a few bps above fair value to 16 bps below 95% of the time. Notably, strong mean reversion dynamics mean there is an opportunity for market participants to optimize their execution over reasonable time frames.

Any feedback or discussion around anything in this report would be greatly appreciated.

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.