tAsset Whitepaper v1.0

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ABSTRACT. This paper introduces tAsset, a new liquid staking token (LST) designed to consolidate the fragmented on-chain interest rate market. The first iteration, tETH, implements a leverage staking strategy by integrating Lido and Aave. Historical data backtesting demonstrates that tETH consistently outperforms stETH while maintaining minimal risk exposures. The primary risks identified include potential liquidation due to the depegging of the liquid staking token (LST) and interest rate fluctuations from over-utilization of the lending pool. Analysis indicates that tETH's risk management parameters provide substantial buffers against severe depeg events historically observed. Moreover, the protocol's safety mechanisms effectively mitigate interest rate risks, showcasing negligible impact on overall strategy returns.

1 tAsset Overview

tAssets are liquid staking tokens (LST) designed to unify the fragmented on-chain interest rates market across various blockchain networks. Holders of tAssets earn real yield in excess of the network's native rewards through interest rate arbitrage, while still being able to use tAssets for DeFi activities. Risks associated with tAsset strategies are closely monitored to ensure users can enjoy the highest real staking yield with minimal risks.

The first iteration of tAssets, tETH, addresses the interest rate fragmentation of ETH on the Ethereum blockchain. tETH also supports the implementation of the Treehouse Actively Validated Service (AVS). By holding tETH, users extend cryptoeconomic security to the Treehouse AVS.

This paper aims to quantitatively assess the viability of the tETH strategy and the effectiveness of the various risk management mechanisms put in place to ensure the safety of users' assets.

2 Definitions

- **LST**: Liquid staking tokens (LSTs) are tokenized receipts for staking assets. LSTs represent the staked tokens and can be used in DeFi applications while still earning staking rewards.

- **AVS**: Actively Validated Services (AVS) are distributed applications that inherit the security of an underlying blockchain's security mechanisms. AVSs can take many forms, including systems like Layer 2s, data availability layers, oracle networks, bridges, etc.

- **Leverage**: Leverage refers to the use of borrowing to increase the potential return of an investment. It allows users to open larger positions than their actual capital would normally permit, effectively amplifying both gains and losses.

- **Collateral**: Collateral is the asset that a user must provide to secure the borrowed funds used for leveraging. This collateral, often referred to as margin, acts as a safety buffer for the lender, ensuring that potential losses can be covered. If the value of the collateral falls below a certain threshold due to market movements, a margin call may occur, requiring the user to deposit additional funds or liquidate positions to maintain the position.

- **LTV**: Loan-to-value (LTV) is a term used to express the ratio of a loan amount to the value of the collateral. It is a critical factor in determining the risk level for lenders when providing loans. The higher the LTV ratio, the riskier the loan is perceived to be, as it indicates a smaller equity cushion for the lender in the event of default.

- **Depeg**: Depegging refers to the loss of a fixed exchange rate between two assets. In the context of tETH, depegging refers to the process of disassociating the value of wrapped staked Ethereum (wstETH) from its pegged value to Ethereum (ETH), thereby causing unfavorable risks that may lead to the liquidation of the collateral used in the strategy.

- **Wrapped Assets**: A wrapped asset is a tokenized representation of an underlying asset. This process involves "wrapping" the original asset by depositing it into a smart contract, which then issues the wrapped version of the tokens on the target destination. In the context of wstETH, it is designed to maintain a constant balance despite the fluctuating nature of staking rewards. wstETH maintains a fixed balance of stETH for users while incorporating an underlying share system to reflect staking rewards, allowing users to seamlessly participate in DeFi activities.

3 Strategy mechanisms

Version 1.0 of tAsset employs a leveraged staking strategy, utilizing borrowed assets to capitalize on the discrepancy between borrowing costs in lending markets and the Ethereum staking rate.

This section aims to quantitatively illustrate the mechanisms employed by the LST platform and the lending market, which are then integrated into the Treehouse Protocol to optimize real staking yields while minimizing risks.

The strategy is executed in the following sequence:

- Stake the native asset into an LST platform.
- Supply the LST to a lending market to receive a receipt token representing the collateral in the lending pool.
- Borrow more of the native asset from the lending market, receiving the debt token.
- Stake the borrowed native asset back into an LST platform.
- Repeat for a given number of times based on the desired risk tolerance level until the arbitrage opportunity is fully eliminated.

For each rehypothecation step i-th, the amount (A) of LST received from the LST platform by staking the native asset (NA) is given by:

$$A_{LST}^{(i)} = \frac{A_{NA}^{(i)}}{p_{LST/NA}} \tag{1}$$

where $p_{LST/NA}$ is the spot price of LST/NA at the time of staking.

The amount of suppliedLST received from the lending platform by supplying $A_{LST}^{(i)}$ is given by:

$$A_{suppliedLST}^{(i)} = A_{LST}^{(i)} \tag{2}$$

Using the above LST as collateral, the amount of native asset borrowed from the lending market is given by:

$$A_{NA}^{(i)} = \frac{p_{LST}}{p_{NA}} \cdot A_{LST}^{(i)} \cdot R_{\text{LTV}} \tag{3}$$

where $R_{\text{LTV}} \leq R_{LTV}^{\max}$ is the Loan-to-Value ratio defined by the strategy, and $R_{LTV}^{\max}$ is the maximum Loan-to-Value ratio allowed by the lending platform. p_{NA}, p_{LSY} are the lending market's USD prices of native asset and the LST, respectively.

Borrowings from lending markets will often result in the receipt of a debt token, which can take the form of either floating rate debt or fixed rate debt. These debt tokens are rebasing tokens that are pegged 1:1 to the borrowed tokens.

$$A_{variableDebtNA \text{ or } stableDebtNA}^{(i)} = A_{NA}^{(i)} \tag{4}$$

From Eq.(1), Eq.(2), and Eq.(3), it can be seen that after each rehypothecation step, the value (in the native asset) of the initial liquidity $A_{NA}^{(i)}$ is reduced by the decay rate R_d:

$$R_d = \frac{p_{LST}^{lending}}{p_{LST/NA}^{liquid} \cdot p_{NA}^{lending}} \cdot R_{\text{LTV}} \tag{5}$$

where $p_{LST}^{lending}$ and $p_{NA}^{lending}$ are the prices of the LST and the native asset on the lending platform and $p_{LST/NA}^{liquid}$ is the price of LST to the native asset defined by the liquid staking platform.

4 Strategy return formula

With n rehypothecation steps, the total NA amount staked to the LST platform is given by:

$$A_{stakedNA} = \sum_{i=0}^{n} A_{NA}^{(i)} = \frac{A_{NA}^{(0)} \cdot (1 - R_d^{n+1})}{1 - R_d} \tag{6}$$

Total LST amount supplied to the lending market is given by:

$$A_{suppliedLST} = \sum_{i=0}^{n} A_{LST}^{(i)} = \frac{A_{NA}^{(0)} \cdot p_{LST}^{NA} \cdot (1 - R_d^{n})}{1 - R_d} \tag{7}$$

Total amount of native asset borrowed from the lending market:

$$A_{borrowedNA} = \sum_{i=1}^{n} A_{NA}^{(i)} = \frac{A_{NA}^{(0)} \cdot R_d \cdot (1 - R_d^{n})}{1 - R_d} \tag{8}$$

Note that from Eq.(7) & (8), the tAsset v1.0 strategy does not engage in the supplying and borrowing of the asset at the n-th step. By not supplying all the final LSTs, the strategy ensures that it retains a certain amount of liquidity, which can be used to react to various adverse market conditions.

As such, the total expected daily earnings (E) can be expressed as the following (in the native asset):

$$
\begin{aligned}
E &= E_{stakedNA} + E_{suppliedNA} - E_{borrowedNA} \\
&= A_{stakedNA} \cdot r_{\text{LST}} + \frac{A_{suppliedLST}}{p^{lending}_{LST/NA}} r_{\text{supply}} - A_{borrowedNA} \cdot r_{\text{borrowing}} \\
&= \frac{A^{(0)}_{NA} \cdot (1 - R^n_d)}{1 - R_d} \cdot r_{\text{LST}} + \frac{A^{(0)}_{NA} \cdot (1 - R^{n+1}_d)}{1 - R_d} \cdot r_{\text{supply}} - \frac{A^{(0)}_{NA} \cdot R_d \cdot (1 - R^n_d)}{1 - R_d} \cdot r_{\text{borrowing}}
\end{aligned}
\tag{9}
$$

where the r_{LST}, r_{supply}, $r_{\text{borrowing}}$ represent the daily interest rates for staking with a LST, supply and borrow on a lending market, respectively. All of these rates have been adjusted to account for the impact of the tAsset on their respective pools.

Therefore, the tAsset strategy's daily percentage yield r is given by:

$$
r = \frac{(1 - R^{n+1}_d) \cdot r_{\text{LST}} + (1 - R^n_d) \cdot (r_{\text{supply}} - r_{\text{borrowing}} R_d)}{1 - R_d}
\tag{10}
$$

5 Strategy backtesting

5.1 Methodology

As the first tAsset, tETH is backtested with historical data to evaluate its performance and risk management mechanisms given the following strategy parameters:

- LST Platform: Lido
- Lending Market: Aave
- Debt Token: Variable Debt
- Initial Principal: 500 ETH
- LTV: 0.8
- Number of rehypothecation: 1
- Backtest duration: 1 year. Specifically, from June 9, 2023, to June 9, 2024

Using the strategy mechanisms discussed above, the Ethereum Mainnet was forked at block 17436912 to deploy 500 ETH to the tETH v1.0 strategy. As a result, we obtained a portfolio consisting of three tokens:

- wstETH: 354.2838966653234 (wrapped Lido Staked ETH)
- awstETH: 443.39964821544254 (Aave's aToken representing that amount of wstETH in the portfolio that is supplied and used as collateral)
- variableDebtWethEth: 399.50854504645565 (Aave's variable debt token on the portfolio's ETH borrowings)

To simulate the returns of the strategy, we calculated the returns of each assets using the interest rate model of Aave and Lido.

For Lido, the balance of wstETH remains unchanged, but the price of wstETH/ETH changes at each "TokenRebased" event. Therefore, we used web3 calls to the Lido contract to retrieve every rebase event and calculate the updated spot price of wstETH/ETH. The details of this calculation are discussed in Appendix A.

On the other hand, Aave's price of the collateral token (awstETH) and the debt token (variableDebtWethEth) are pegged 1:1 to their underlying assets. Therefore, the returns from lending and borrowing come from the growth of the respective token balances. To calculate the returns of the Aave tokens, we gather all the "ReserveDataUpdated" events for the above tokens. The details of this calculation are discussed in Appendix B.

Then, the timestamp of Lido's rebase event was utilized daily to perform the return calculation. The daily strategy PnL (in ETH) for date t is calculated as follows:

$$\text{PnL} = B_{wstETH} \cdot (p_{\text{t}} - p_{\text{t-1}}) + (p_t \cdot B_{\text{coll, t}} - p_{\text{t-1}} \cdot B_{\text{coll, t-1}}) - (B_{\text{debt, t}} - B_{\text{debt, t-1}}) \tag{11}$$

where p_{t} is the spot price of wstETH/ETH at time t,and B_{wstETH}, $B_{\text{coll, t}}$, $B_{\text{debt, t}}$ are the balance of wstETH, awstETH, variableDebtWethEth at date t respectively. Therefore, the daily return is given by:

$$R_t = \frac{PnL}{p_{\text{t-1}} \cdot (B_{wstETH} + B_{\text{coll, t-1}}) - B_{\text{debt, t}}} \tag{12}$$

Then, the APR/APY of the strategy is calculated by annualizing the daily returns:

$$\text{APR} = \frac{R_t}{\Delta_t} \cdot \text{SecondPerYear} \tag{13}$$

$$\text{APY} = \left(1 + \frac{R_t}{\Delta_t}\right)^{\text{SecondPerYear}} - 1 \tag{14}$$

where Δ_t is the time difference between date t and $t-1$ in seconds, and SecondPerYear is the number of seconds in a year.

To calculate the strategy's cumulative return, we use Eq.(12). However, instead of using the previous day $t-1$, we use the initial date of the backtest as a reference point:

$$R_t^{cum} = \frac{B_{wstETH} \cdot (p_t - p_0) + (p_t \cdot B_{\text{coll, t}} - p_0 \cdot B_{\text{coll, 0}}) - (B_{\text{debt, t}} - B_{\text{debt, 0}})}{p_0 \cdot (B_{wstETH} + B_{\text{coll, 0}}) - B_{\text{debt, 0}}} \tag{15}$$

5.2 Result and discussion

In Fig.1, the annualized daily return (APR) of the tETH strategy (black line) is presented over the past 12 months and compared with the Lido staking APR (dashed blue line). The figure illustrates that the tETH v1.0 strategy consistently outperforms Lido's, despite the high borrowing rate from June 2023 to November 2023. From November 2023 onwards, however, the borrowing rate decreased, leading to an even more significant outperformance of the tETH strategy over Lido's.

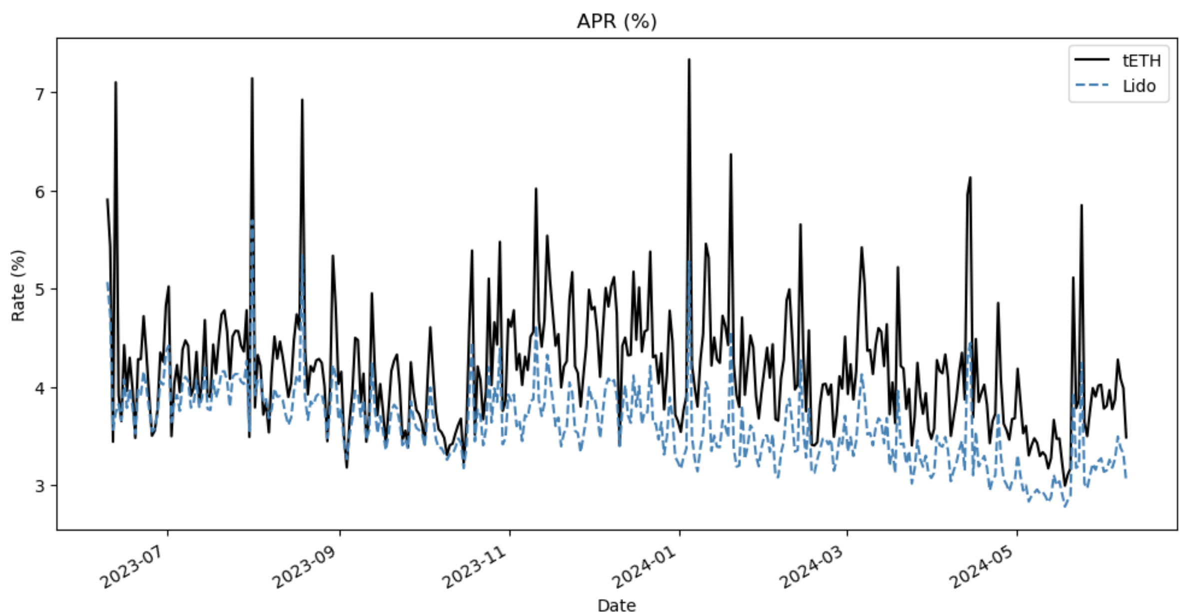

Figure 1: Backtested daily return of the tETH strategy over 12 months.

The same trend is observed in the cumulative return of the tETH strategy (black line) against Lido staking (dashed blue line) (Fig. 2). Over the course of the 1-year backtesting period, the tETH strategy has outperformed Lido staking by approximately 0.6%.

In Fig. 3, a breakdown of the tETH strategy's daily returns is provided against the Lido staking rate. The black line represents the difference between the tETH strategy and Lido staking APR. Specifically, Lido staking rate, Aave Supply APR, and Aave Borrow APR are represented by the blue, red, and green lines, respectively. The vertical grey bars indicate periods where the Lido staking APR is higher than the strategy's APR due to high borrowing costs from over-utilization of Aave's lending pool. Interestingly, not all days with high borrowing rates result in lower returns for the strategy as compared to the underlying LST. Although the LST supply

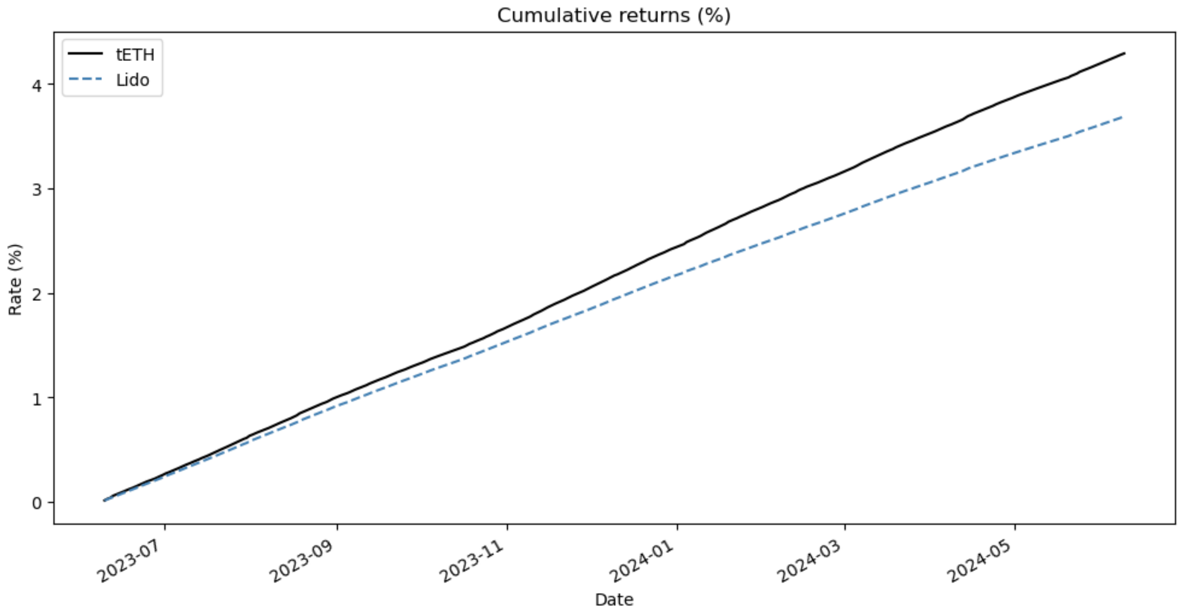

Figure 2: Backtested cumulative return of the tETH strategy over 12 months.

rate is generally negligible, historical instances show occasional spikes in the supply APR, resulting in extra income for the strategy. Further investigation reveals that the yield spike from the supply rate is not solely from regular borrowings but also from flash loan activities by arbitrageurs.

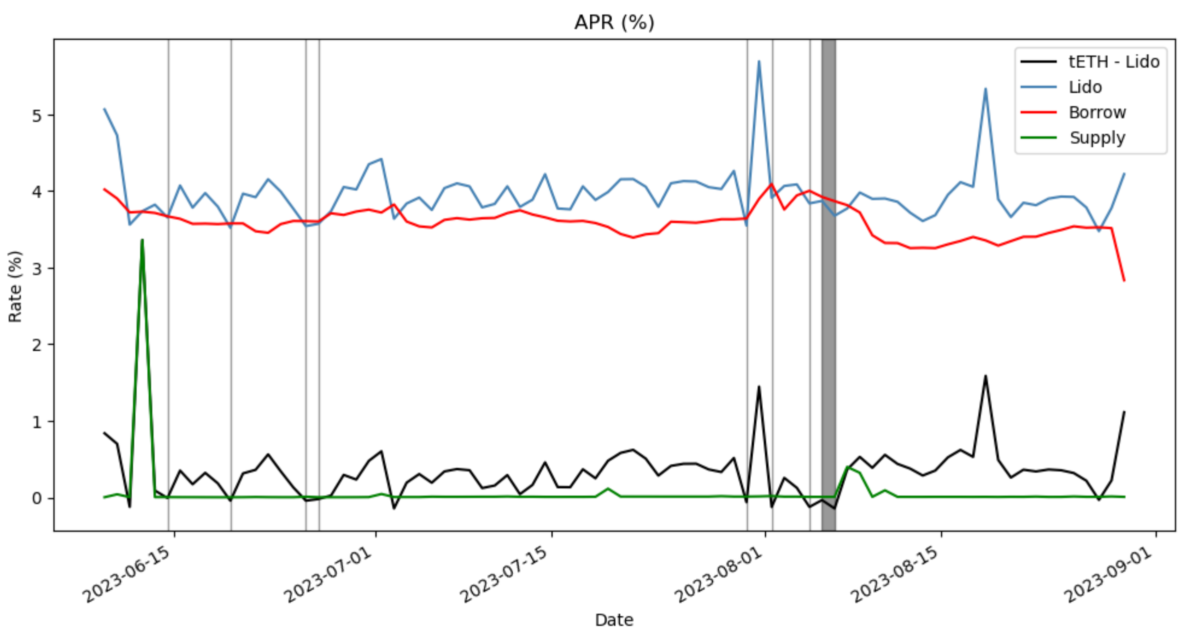

Figure 3: Breakdown of the tETH daily return against Lido staking, Aave supplying and borrowing .

6 Risk management

6.1 Depeg risks

The safe LTV ratio is defined as the the level at which the position's health factor stays at or above 1.0, even during the worst possible LST-ETH deppegging event based off historical data. With the tETH strategy, the health factor is defined as:

$$HF = \frac{A_{wstETH}^{\text{supply}} \cdot p_{wstETH} \cdot L_t}{A_{ETH}^{\text{borrowing}} \cdot p_{ETH}} \tag{16}$$

where p_{wstETH}, p_{ETH} are Aave's USD price of the tokens. L_t is the liquidation threshold. As such, Eq. (16) can be re-written as:

$$HF = \frac{A_{wstETH}^{\text{supply}} \cdot p_{wstETH/ETH} \cdot L_t}{A_{ETH}^{\text{borrowing}}} = \frac{L_t}{LTV} \tag{17}$$

where $p_{wstETH/ETH} = \frac{p_{wstETH}}{p_{ETH}}$ is the Aave's oracle spot price of wstETH/ETH.

In the event of an LST-ETH depeg, where the price of wstETH drops by a factor of x.

$$P'_{wstETH/ETH} = p_{wstETH/ETH} \cdot (1 - x) \tag{18}$$

From the Eq. (17) and definition of the safe LTV, it can be derived that:

$$1.0 \leq \frac{L_t \cdot (1 - x)}{LTV_{\text{safe}}} \Rightarrow LTV_{\text{safe}} \geq L_t \cdot (1 - x) \tag{19}$$

Using Eq. (19), the proposed tETH strategy is safe from a price drop of 15.79% with Aave's eMode enabled ($L_t = 0.95$), and the safe LTV set to 0.8. This level of LTV provides a sufficient buffer to respond to adverse market conditions and avoid potential losses from liquidations. For reference, Lido's historical data shows that the price of wstETH only dropped by approximately 6.7% during the worst depegging event in June 2022. However, this event occurred before Beacon Chain withdrawals were enabled through "The Shanghai Upgrade". With "The Shanghai Upgrade", arbitrageurs are able to profit by buying the depeg to unwrap to stETH and redeem stETH 1:1 with ETH, which creates even more resistance for any attackers attempting to create a depeg in the LST.

6.2 Interest rate risks by over-utilization of Aave lending pool

Utilization ratio is defined as the ratio between the amount being borrowed and supplied to a spcific pool within a lending protocol. Due to the interest rate model employed by most lending protocol, borrowing costs for all borrowers within a given pool surge significantly as the pool cross a certain utilization threshold.

In Aave, the interest rate model is defined as the following:

$$if\ U \leqslant U_{\text{optimal}} : R_t = R_0 + \frac{U_t}{U_{\text{optimal}}} \cdot R_{\text{slope1}} \tag{20}$$

$$if\ U > U_{\text{optimal}} : R_t = R_0 + R_{\text{slope1}} + \frac{U_t - U_{\text{optimal}}}{1 - U_{\text{optimal}}} \cdot R_{\text{slope2}} \tag{21}$$

where R_t is the interest rate, U is the utilization ratio, $U_{optimal}$ is the utilization ratio threshold that defines the inflection point between slope 1 and slope 2.

During the backtesting period, the borrowing rate exceeded the LST yield on eight occasions. Of these instances, seven lasted only one day due to the natural market forces of supply and demand reducing the utilization rate. Specifically, when interest rates increase because of over-utilization of the pool, external users are incentivized to supply funds to the pool to benefit from the high interest rates. Concurrently, existing borrowers are encouraged to repay their debts due to the increased costs. This dynamic restores the market to an equilibrium at the optimal utilization rate.

The only exception was when the borrowing rate was continuously high for 2 days from 04 Aug 2024 to 05 Aug 2024, when the strategy incurred a minor setback in the yield premium on top of stETH. The tETH safety mechanism was enacted on day 3 when the strategy vault repaid a portion of the debt to the strategy's "Internal Utilization Rate - Lower Bound" in order to optimize the realized yield for the vault investors. (For information on the tETH repayment strategy, refer to the tETH Official Doc.)

Specifically, this two-day event resulted in the strategy's underperformance of 0.0435 basis point when compared against stEH. However, this gap was quickly covered by the outperformance in the immediate next day, presenting an example for effective risk management practices employed by the protocol.

References

[Aave,] Aave. Aave Documentation. https://docs.aave.com/hub.

[Lido Finance,] Lido Finance. Lido Documentation. https://docs.lido.fi/.

[Treehouse,] Treehouse. Treehouse Documentation. https://docs.treehouse.finance/protocol.

Appendices

A Lido rebase

Every day, at around 12:25 UTC, the Lido stETH contract emits a rebase event that updates the total supply of stETH and wstETH. The rebase event includes the following information:

```
timeElapsed : 86400
preTotalShares : 6356881294769610780573341
preTotalEther : 7168342735897795185723748
postTotalShares : 6343229466385294913452552
postTotalEther : 7153750793235088775329935
sharesMintedAsFees : 790674638318786538 67
```

The price of wstETH/ETH is calculated as follow:

$$p_t = \frac{\text{postTotalEther}}{\text{postTotalShares}} \tag{22}$$

Lido APR:

$$\text{APR} = \frac{(\text{postShareRate} - \text{preShareRate}) \cdot \text{SecondPerYear}}{\text{timeElapsed} \cdot \text{preShareRate}} \tag{23}$$

where

$$\text{preShareRate} = \frac{\text{preTotalEther}}{\text{preTotalShares}} \tag{24}$$

$$\text{postShareRate} = \frac{\text{postTotalEther}}{\text{postTotalShares}} \tag{25}$$

B Aave interest rate model

B.1 Index

For Aave, the Liquidity Index and the Borrow Index are metrics to track the accumulation of interests over time. The Liquidity Index measures the growth of aTokens' supply (Aave's interest-bearing rebase tokens), reflecting the accrued interest since the last update and ensuring lenders receive their fair share of interests generated. Conversely, the Borrow Index tracks the accumulation of interest on borrowed funds, indicating the growth of the debt owed by borrowers. Together, these indices maintain a transparent system for both lenders and borrowers on the Aave platform.

At the inception of the pool, the Liquidity Index and Borrow Index are initialized to 1. As time passes and interest accrues, the index increases to reflect the growth of both supply and debt.

Let I_t^L, R_t^L be the Liquidity Index and the supply rate at time t respectively, and Δt be the elapsed time since $t-1$. The current liquidity index is calculated as:

$$I_t^L = I_{t-1}^L \cdot (1 + R_t^L \Delta t) \tag{26}$$

The Borrow index is updated in a similar fashion but with compounding interest instead:

$$I_t^B = I_{t-1}^B \cdot \left(1 + \frac{R_t^B}{\text{SecondPerYear}}\right)^{\Delta T} \tag{27}$$

B.2 Aave's scaled balance

Upon any deposits or borrowings from the Aave protocol, users receive aToken (in variableDebtToken or stableDebtToken), representing their share of the pool's liquidity, for the same amount of the deposited/borrowed tokens. Aave then uses a scaled balance system to calculate the interest accrued on these tokens. The scaled balance is the amount of the user's principal divided by the current liquidity or borrow index.

When the index has grown to a new value, the user balance is updated to reflect the accrued interest:

$$\text{User Balance} = \text{Scaled Balance} \cdot \text{Current Index} \tag{28}$$

For example, at time t_0, a user will receive 100 aWETH if he deposits 100 ETH into the Aave. Assuming the current liquidity index is at 1.1, the scale balance of the above deposit is:

$$\text{Scaled Balance} = \frac{100}{1.1} = 90.90909090909091$$

Assuming the liquidity index has grown to 1.2 at time t_1, the user balance is then updated to:

$$\text{User Balance} = 90.90909090909091 \cdot 1.2 = 109.0909090909091$$