Liquid Staking

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Proof of Stake

- Sept 2022 Ethereum blockchain changed to "proof of stake."
- Validators chosen to add blocks based on the amount of ETH they have locked up as collateral.
- Validators earn returns on their staked collateral.
- Originally, the staked ETH could not be withdrawn.
- Now, withdrawn after a waiting period.
- Waiting period important for consensus

ETH Staking

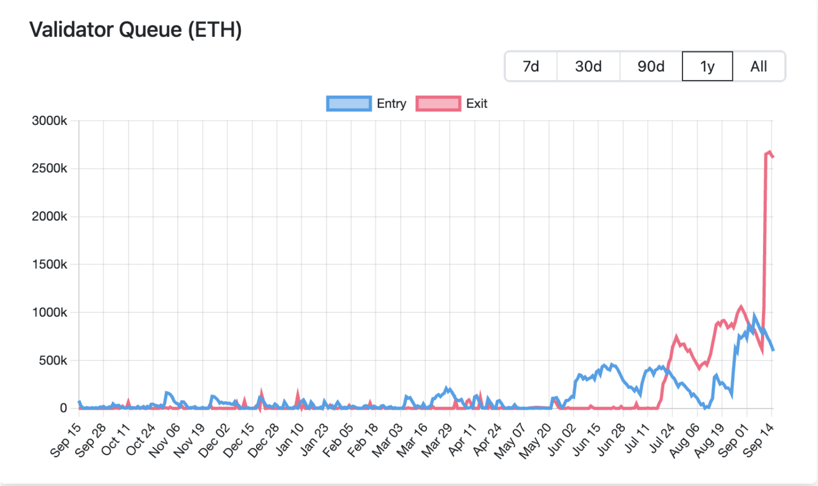


Figure: Network rate limit means excess are placed in the respective queue. Data from validatordata.com.

The Queue

- Queues are designed to protect the stability of Ethereum's proof of stake (PoS) consensus.
- After getting through the exit queue Eth it becomes withdrawable.
- The network cycles through withdrawable ETH to specified withdrawal addresses.
- The more ETH waiting, the longer it will take to cycle through withdrawals (currently 9 days).

Queue Wait time

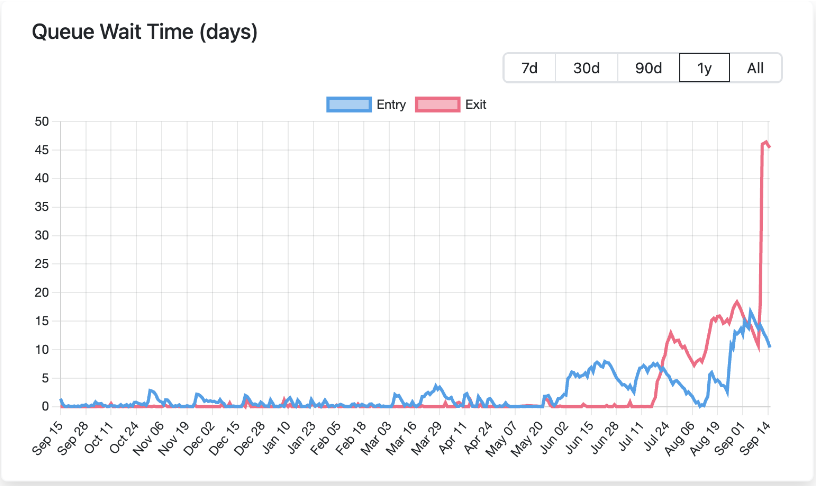
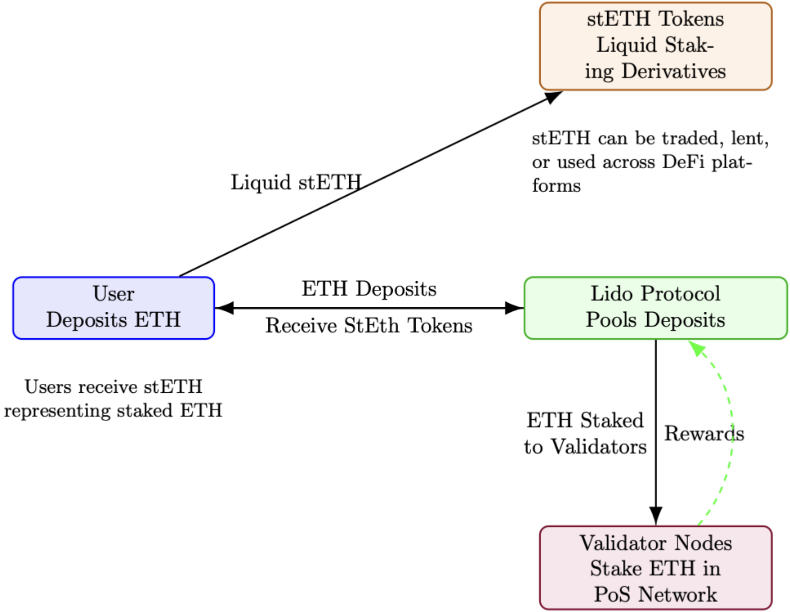


Figure: Data from validatordata.com.

Staking in Practice

- Random illiquidity (both in time and cost to withdraw)
- Minimum stake amount of 32 ETH
- Useful to have an intermediary to organize deposits and withdrawals.

What is liquid staking?



The Lido Protocol

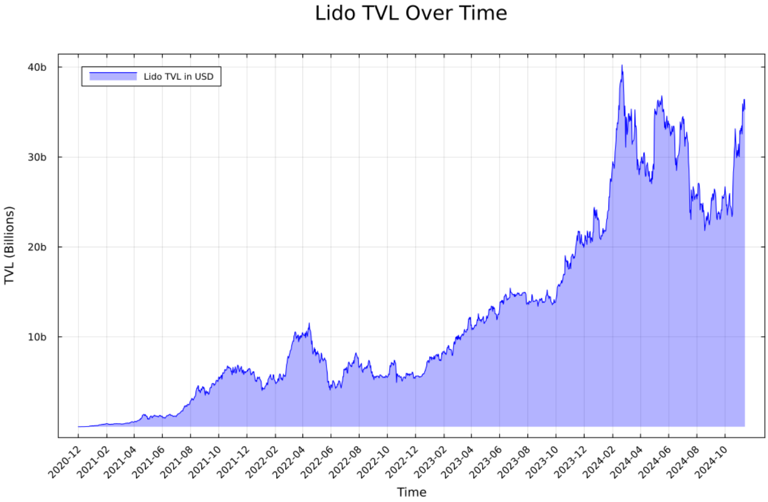


Figure: TVL measured in USD. Data provided by Dune API.

Economically relevant features
Similarity to Banks

1. Combine small stakes and commit to validators
   - Vet validators
2. Allow withdrawals
   - These are not “demand deposits”
   - Redemption queue: “sequential service constraint”
   - An informative signal
3. Market for Staked ETH against ETH
   - A way to convert or “withdraw”
   - An informative signal
4. Lido is not riskless
   - Slashing (low)
   - Operational Risk

Risks

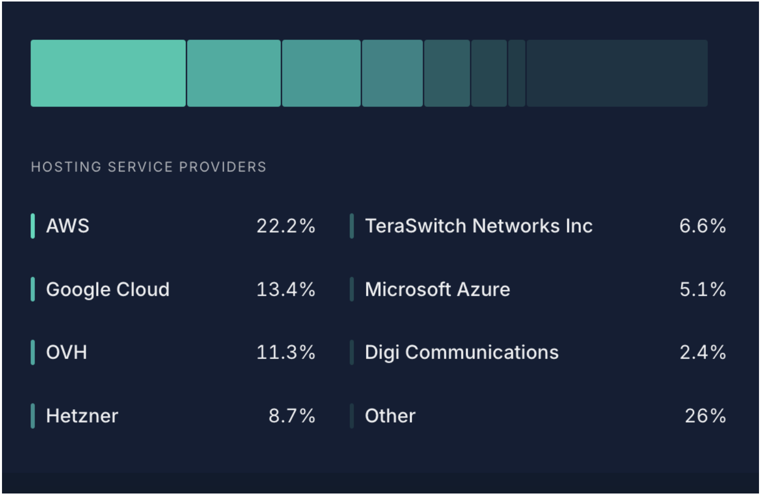


Figure: The distribution of Cloud Service Providers among the professional validators.

Application to Reality?

- Tokenized Deposits
  - Pilot programs through BIS
- Obvious benefits to programmable money but new regime.
- What effect will digital deposits have on bank stability?

Literature

- Diamond Dybvig (1983):
  - Demand deposit contracts can be optimal risk sharing contract.
  - Inefficient bankruns possible
- Green and Li (2003)
  - Dynamic DD with flexible contracts
- Goldstein and Pauzner
  - Global Game: bank run in response to fundamentals
  - Demand deposit with correct interest rate can be optimal risk sharing contract.

The Jacklin Critique

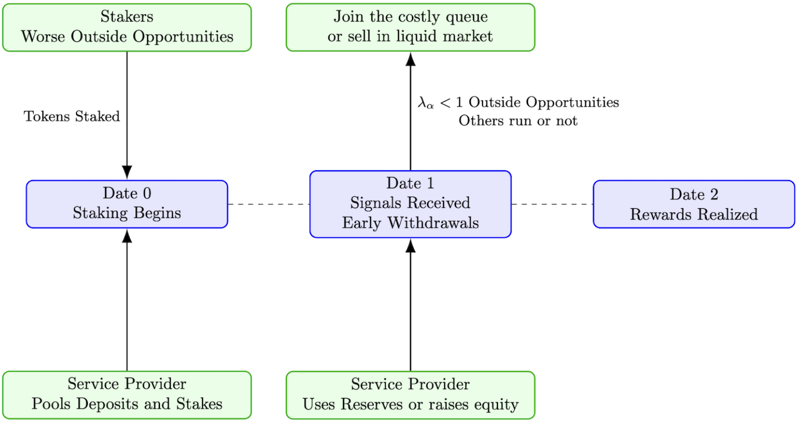
- Dividend paying equity claim is a better form of contract.
- Important there is a market for the ex dividend security

- For deposit taking institutions with uncertain fundamentals, what effect does a liquid market have on outcomes?

- Relevant question as we discuss tokenized deposits.

- Our paper: Use liquid staking as a laboratory.

The Model


Stakers
Worse Outside Opportunities
Tokens Staked
Join the costly queue
or sell in liquid market
$\lambda_\alpha < 1$ Outside Opportunities
Others run or not
Date 0
Staking Begins
Date 1
Signals Received
Early Withdrawals
Date 2
Rewards Realized
Service Provider
Pools Deposits and Stakes
Service Provider
Uses Reserves or raises equity

Players

- Staking service of random quality $\widetilde{\theta}$
    - $\widetilde{\theta} = \bar{\theta} + \sigma_\theta \widetilde{\epsilon}_\theta$
- Investors: receive a signal of outside opportunities – stake if preferred
    - Determines the size of the staking service.
- Another round of signals of outside opportunities
    - Some: λ_α withdraw
    - Ones who remain receive a private signal ($s_i = \widetilde{\theta} + \sigma_s \widetilde{\epsilon}_i$)
- Withdrawal either through a queue or market
    - Token market with informed liquidity providers.
    - Liquidity provider with a signal s_m

The Staking Service

- Retains a treasury of t
  - Tradeoff: The larger the treasury, the lower the amount to stake and payoff
  - Similar to a capital or liquidity requirement
- Retains a portion $(1-\alpha)$ of every dollar earned
- Can raise an additional ℓ externally
  - Trade with the liquidity suppliers
- Scale of the service I_α original investment (determined by outside opportunities)

Withdrawals

- Liquid Staking: issues depositors "receipt tokens" that they can use elsewhere or sell.
    1. Direct withdrawal: join a queue (waiting cost)
    2. Market sell for the numeraire (ETH)
- Costs associated with both $\implies$ price impact cost or waiting cost (η).
- Queuing cost: η,
- Market cost $1 - P$

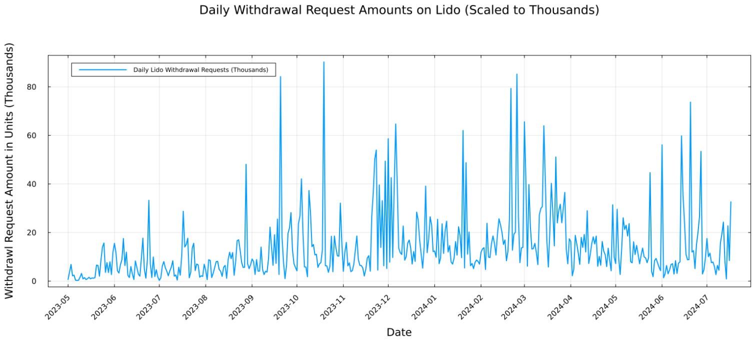


Figure: Daily withdrawal request amounts on Lido, scaled to thousands, over time. The x-axis represents the dates spanning from May 2023 to July 2024, while the y-axis denotes the daily withdrawal amounts in units of thousands. Data provided by Dune API.

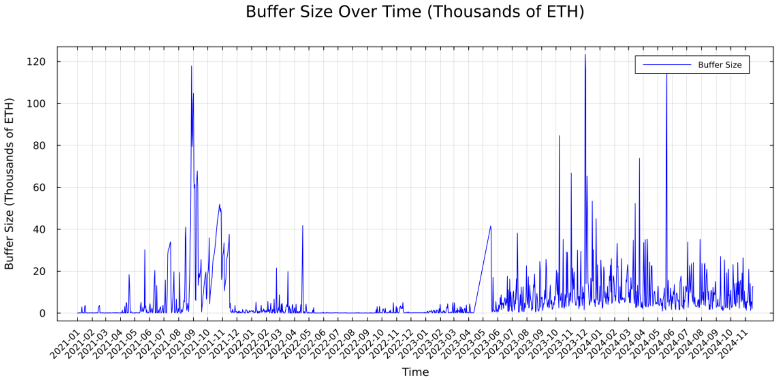


Figure: Daily buffer size on Lido over time, measured in units of ETH. The x-axis represents the time period spanning from 2021 to late 2024, and the y-axis represents the buffer size in ETH (in thousands). The blue line illustrates the variations in buffer size throughout this time frame. The data is raw except for the omission of outlier values around the Shapella upgrade.

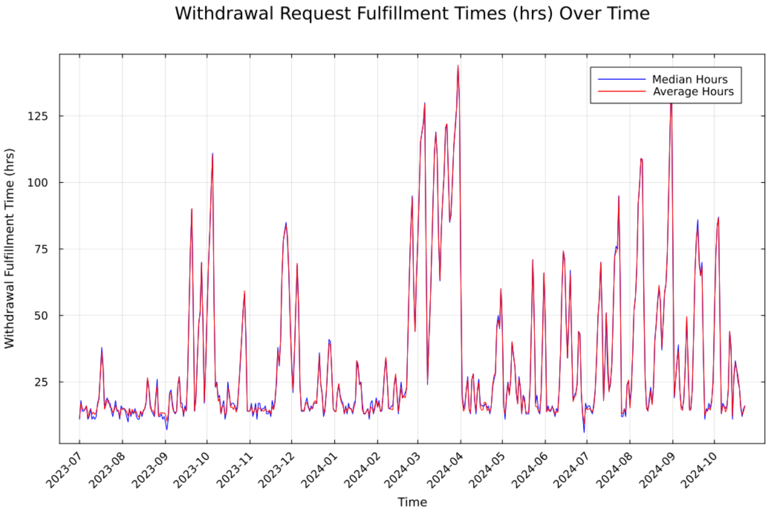


Figure: Withdrawal requests fulfillment times (in hours) over time, showing the median fulfillment times (blue line) and average fulfillment times (red line). Both median and average times generally follow a similar trend throughout the observed period. Data provided by Dune API.

Bad events

- We are interested in events when

$$\text{withdrawals} \geq \underbrace{\text{reserves on hand}}_{\text{treasury}=t} + \underbrace{\text{Staking Service Equity}}_{\ell}$$

- Withdrawals driven by outside investment opportunities
- Volume of redemptions determined by strategic stakers.

Strategic Stakers' Payoff

Early withdrawal

$$u_i(a_i = 1) = \begin{cases} 1 - \eta & \text{if Withdrawals} \leq \ell + t \\ \frac{\ell + t}{I_\alpha} & \text{otherwise} \end{cases} \tag{1}$$

Late withdrawal is:

$$u_i(a_i = 0) = \begin{cases} \frac{\alpha(I_\alpha - t)\tilde{\theta}}{I_\alpha} & \text{if Withdrawals} \leq \ell + t \\ \frac{\ell + t}{I_\alpha} - \psi & \text{otherwise} \end{cases} \tag{2}$$

- t Reserves
- η queueing costs
- ψ: late withdrawal penalty
- ℓ market value of service

Market for the Tokens

- Downward sloping demand curve

$$D(P \mid \mathcal{F}_m) = E[\alpha(I_\alpha - t)\widetilde{\theta} \mid \mathcal{F}_m] - \gamma P \tag{3}$$

- γ willingness to absorb supply
- Noisy Demand shock: $\sigma_\xi \tilde{\xi}$

- The price of the staked token is determined by market clearing, and we obtain

$$D(P|\mathcal{F}_m) + \sigma_\xi \tilde{\xi} = \text{Aggregate Sales} \tag{4}$$

Liquidity Providers' Information Set

- Liquidity providers observe a private signal $s_m = \widetilde{\theta} + \sigma_m \widetilde{\epsilon}_m$
  - ω of the people who want to redeem go to the market
  - $(1 - \omega)$ queue to redeem
- Market makers observe the size of the queue with noise
- Information set contains private signal, queue, price

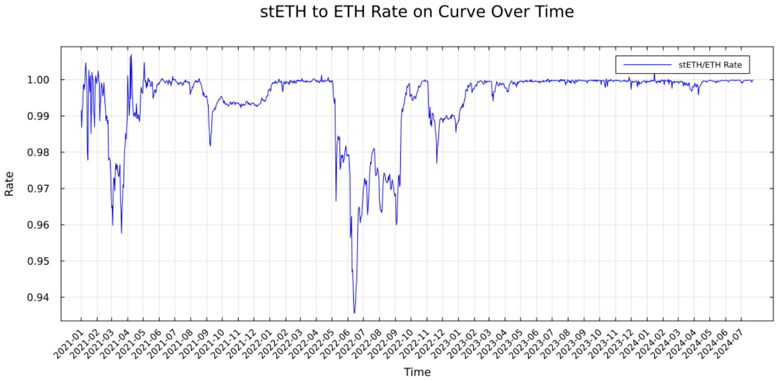


Figure: The stETH to ETH rate on Curve over time, illustrating the stability and deviations of the peg. Early periods show high volatility, with notable dips during periods of market stress or significant events affecting stETH liquidity. The rate stabilizes closer to 1.00 in later periods, reflecting improved liquidity and protocol optimizations. Data provided by Dune API.

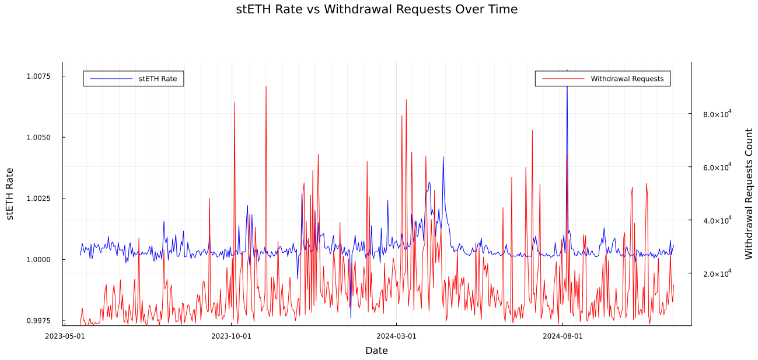


Figure: The graph shows the relationship between **stETH Rate** (left Y-axis, in blue) and **Withdrawal Requests Count** (right Y-axis, in red) over time. The X-axis represents the date spanning from May 2023 to late 2024.

Equity Value of Staking service

- Liquidity suppliers are also potential purchases of the protocol
- Use the market price to pin down equity value.
- Impose a haircut, β

$$\ell = \beta \frac{(1-\alpha)P}{\alpha}$$

Definition

An equilibrium consists of a price function, $P(\tilde{\theta}, \tilde{\epsilon}_i, \tilde{\epsilon}_m, \tilde{\xi})$, strategies, and the corresponding market demand curve, such that

i. Strategic depositor's withdrawal decision is optimal
ii. traders submit a demand curve given their information
iii. market clears
iv. ℓ, is determined
v. Beliefs are consistent

Equilibrium

Step 1: Assume a Monotone Strategy

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Step 2: Find Information Content

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Step 3: Use Information to Determine Market Price

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Step 4: Use Market Price in Strategic Stakers' Decision

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Step 5: Determine Equilibrium Run Probability and Indifferent Type

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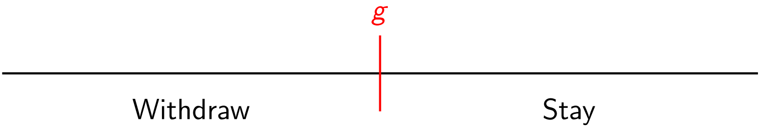
Step 6: Pin Down All the Parameters

Monotone Equilibrium

Definition

A monotone equilibrium is an equilibrium where a strategic token depositor withdraws if and only if a monotone increasing function of his private signal is below a cutoff g.



- Higher g, the more unstable the service

Solution

- A strategic staker will choose to hold the staked token if expected payoff difference between late and early withdrawal decisions based on his signals is weakly positive
- The marginal token holder would be indifferent between late and early withdrawal.

$$\Pr(\text{Succeed}|s_i = g)\left(\frac{\alpha(I_\alpha - t)}{I_\alpha} E[\theta \mid s_i](1-\eta)\right) - \Pr(\text{failure}|s_i = g)\psi = 0$$

Service Fails

Aggregate ETH withdrawal $\geq$ ETH value of all stakes

- Characterize as a function of the random variables
- Can determine this for a strategic staker that receives a signal s_i

Proposition

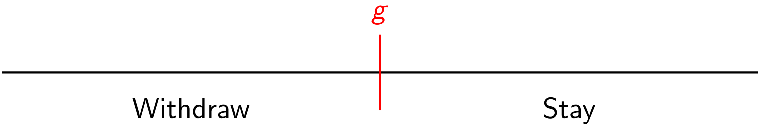
When $\sigma_s \to 0$, there exists a monotone equilibrium threshold characterized by a threshold signal for a staker to withdraw and a unique cutoff value for the staking service to fall.

$$\Phi\left(\frac{\alpha\gamma(\lambda_\alpha - t) + (\alpha a)(\omega\lambda_\alpha - \alpha(I_\alpha - t)g^*)}{\sqrt{(\alpha\gamma\kappa_\alpha + (\alpha a)\omega)^2 + (\alpha a))^2\sigma_\xi^2}}\right)\left[1 + \frac{\psi}{\alpha\frac{(I_\alpha - t)}{I_\alpha}g^* - (1-\eta)}\right] = 1$$

Effect of Market noise on runs

Market Noise can have a destabilizing effect on the protocol if
$\left(1+\beta\frac{(1-\alpha)}{\alpha}\omega+\gamma\right)\lambda_\alpha < t+\gamma(t-\lambda_\alpha)+(I_\alpha-t)g^*$

- Expect $t > \lambda_\alpha$
- More illiquid $\Longrightarrow$ more likely to be destabilizing



Market

- Market performs 3 roles
  1. Allows users to redeem ETH
  2. Provides information about the stability of the service
  3. Provides benchmark pricing for the amount of equity the service can raise
- Market noise can be destabilizing

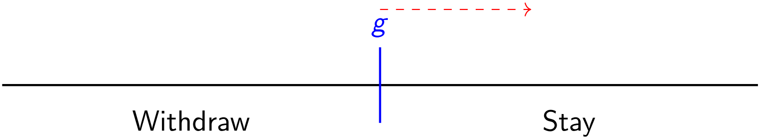
Effect of a Liquid Market

Tradeoff:

- Liquid market allows redemptions (like deposit insurance)
- Liquid market provides information that induces coordinated behavior.
- Liquid market adds noise that can lead to a run.

Effect of Treasury on Stability

- Threshold g, is increasing in the treasury.
- Higher $t \implies$ more likely to get paid out conditional on early withdrawal.
- Higher t, $\implies$ the lower the return on protocol which makes it easier to leave
- Net effect of treasury is to lead to more withdrawals



Liquid Staking

- Tokenized deposits that can be easily transferred
- Easily traded for the numeraire
- Liquid market can increase instability
- High Treasury can be destabilizing.