Vesta Finance: System Parameterization Analysis

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1 Overview

Between the dates of April 23rd 2022 and May 23rd 2022, Vesta Finance engages the Risk DAO to perform a system analysis for it's stable coin based lending platform. The goal of the analysis is to review the system parameters, and provide recommendations for design changes.

1.1 Introduction

Vesta Finance is a zero interest rate lending protocol. It allow users to borrow VST, a USD-pegged stable coin against a list of collateral assets. Similar to Liquity [10] it allows users to stake their VST into *stability pools*, which are used as the first liquidity source in times of liquidations. As another layer of protection, if the stability pool is empty, liquidations are executed by distributing the liquidated position collateral and debt among all other borrowers in the system. Finally, to make sure VST is traded with a value of at least $1, it allows redemption of VST in return of an underlying collateral.

Stability pool losses, liquidation distribution, and redemptions have severe consequences on the user experience, however the ultimate risk of any lending platform is insolvency. Hence, in this report, we focus on the analysis of system insolvency. Some other aspects, e.g., stability pool PnL were previously analyzed by us in previous work [8], and other aspects are left for future works.

While the current implementation of the Vesta Finance is inspired by Liquity design, the team expressed their desire to pivot into a more standard parameterized model. Hence, we recommended to adapt the standard Compound [11] and Aave [1] set of parameters. Hence, we analyze Vesta as a Compound compatible lending market, augmented with a stability pool, and we analyze the likelihood of bad debt incidents under different sets of parameters. The reader should note that not every bad debt would lead to system insolvency, as in Vesta failed liquidations are distributed among other borrowers. However avoiding bad debt as a main goal is a sound and conservative research goal. Both because it achieves the real goal, which is to prevent system insolvency, and also because minimizing other borrowers loss is important for their user experience.

1.2 Compound compatible lending market parameters.

DeFi lending markets manage billions of user funds, with the top 2 platforms, namely, Compound [11] and Aave [1] holding over $20B of crypto-assets. At their core, they allow *suppliers* to deposit a set of assets, and *borrowers* to borrow them. The permissionless nature allows anyone to be a supplier and enjoy a supplier interest rate, however it also dictates that a borrower could only borrow against a collateral, and the platform becomes (partially) insolvent when a user debt exceeds his or her collateral. An insolvency event generates bad debt which comes at the expense of supplier deposits. It is the market's admin responsibility, typically a DAO, to set *risk parameters* to mitigate the likelihood of insolvency events.

Liquidations. Similar to foreclosure of real world loans, liquidators can repay the outstanding debt of a risky loan and seize the borrower collateral with a discount. This process is also permissionless, and it is practically the only barrier towards an insolvency event. After seizing the collateral, liquidators will typically try to lock their profits by selling it in the open market as quickly as possible. To date most of liquidations are done by flash bots who liquidate and sell the seized collateral in the same transaction, while facing zero price risk. This process is bounded by the *available* DeFi liquidity, and for this purpose Liquity [10], and B.Protocol [8], independently introduced the notion of *stability pool*, and *backstop pool*, which is effectively an automated stability pool.

Similar to Liquity, Vesta Finance is also using stability pools, and lets its users to automate their stability pool deposits with B.Protocol.

Risk parameters. To prevent insolvency, the market admin should set parameters that encourage successful liquidations, and reduce the insolvency risk when a liquidation process prolongs. Different platforms may offer different configurable parameters. In this work, we follow the standard that was set by Compound, and is widely adopted among other lending platforms, e.g., see [15, 13, 3, 12, 2] and for a comprehensive list see [5]. Compound standard defines three parameters, namely, *liquidation incentive*, *Collateral factor* (a.k.a loan-to-value), and *close factor.*

- *Liquidation incentive.* Liquidators are assumed to be greedy, and they will only execute a liquidation when they believe it is profitable. For this purpose a liquidation incentive is given, in the form of a discount over the seized collateral. For example, with a liquidation incentive of 5%, repaying an outstanding debt of 1000 VST will seize a collateral worth $1050.

  Higher liquidation incentive makes the liquidation more appealing, and in particular makes it easier for the DeFi market to liquidate it. Indeed, if the discount on the collateral is bigger, then bigger collateral quantity can be sold with the same profit, as the higher sell slippage is compensated by the higher liquidation incentive.

  On the negative side, higher liquidation incentive is less appealing to users who stand to lose more as their position becomes undercollateralized.

- *Collateral factor.* If liquidations were guaranteed to be executed immediately, then the needed over-collateralization would be the size of the liquidation incentive. In practice however, liquidity crises and blockchain congestion might delay the execution of the liquidations. Lending platforms are required to maintain higher safety margins, as higher over-collateralization ratio compensates for the risk of default in the presence of execution latency. The collateral factor specifies a borrower's minimum collateral requirement w.r.t her outstanding debt.

  On the negative side, lower collateral factors increase the capital requirements for the borrowers, and facilitate lower leverage.

- *Close factor.* The close factor determines the % of debt that can be liquidated when the borrower does not meet the over-collateralization requirements. By definition, higher closing factors reduce the platform risk, as it enables liquidators to close bigger portions of the borrower position. On the other hand borrowers would find lower closing factors more appealing.

1.3 Additional market parameters.

- *Debt ceiling.* Vesta Finance controls the maximum amount of VST that can be borrowed against every type of collateral asset. This can be used both to mitigate systemic risks (e.g., bug in the collateral smart contract), and quantitative risks (e.g., set parameters to fit current market liquidity)

- *VST liquidity.* While the redemption mechanism guarantees a lower bound for the value of VST, the price might de-peg and VST could be traded with value of over $1 in times of liquidity crisis. This directly affects the incentive of the liquidator, as the liquidation incentive assumes that 1 VST = $1. Vesta Finance does not directly control the size of VST liquidity, currently mostly on curve.fi, however it can control the incentives for the liquidity providers. In addition, it can adjust other risk parameters it does control to the current amount of VST liquidity.

- *Stability pool size.* Bigger stability pool sizes contribute to a smoother liquidation process. While Vesta Finance does not directly control the sizes of the stability pool, it can control the incentives for the stability pool stakers. In addition, it can adjust other risk parameters it does control to the current size of the stability pool.

- *Stability pool recovery speed.* We analyze the affect of the stability pool recovery speed on the risk of the platform in Section 3. The faster seized collateral is sold to VST and deposited back to the pool, the faster future liquidations could be executed. Empirical results suggest that retail users takes quite long to recover, and Vesta Finance can help speed the recovery by making solutions such as B.Protocol more accessible to its users.

1.4 Goals of the analysis.

Using the quantitative simulation technique we developed in [4], and with a novel stability pool simulation technique we developed for this report, we aim to answer on what would be the best values for the above parameters.

In addition, we also survey known qualitative analysis best practices, that give general risk score for the assets in question.

2 The Quantitative Risk Assessment Model

Similar to [7, 9], we aim to construct a formal model that can simulate the behavior of a lending market, and assess if the market's risk parameters are safe. A single simulation is composed of:

- A sequence of liquidations with time and sizes. I.e., when each liquidation happened, and what was each liquidation volume.
- Price trajectory of the collateral asset for every point in time.
- The available market liquidity for selling the collateral. Throughout our model we assume that liquidators will only use DeFi markets to sell the seized collateral, and hence focus on simulating only DeFi liquidity.

Our system can model lending markets with and without a stability pool. When such stability pool exist, then the simulation also consist of:

- The available liquidity of the stability pool at any point in time.

Having a model for the above, we execute a sequence of liquidations and analyze the lending market state. For simplicity we assume that an execution is successful if it does not have an insolvency event. However, the model can also embed other definitions, e.g., insolvency of at least 1% of the market size.

Our model differs from the one in ([7, 9]) as it removes the need to simulate individual user accounts. All previous works developed ad-hoc heuristics to simulate individual account behavior for given price trajectories. Those heuristics were necessary in order to simulate liquidation events. We take a different approach, by taking real world liquidation events from centralized futures exchange, and adjust their sizes to fit the expected size of the lending market. With this approach fewer core assumptions about user behavior are needed. Avoiding assumptions on user behavior is particularly important for markets who offer new assets and to markets that are deployed on new blockchains.

Given the above components, we get a full simulation of the amount of collateral that is subject to liquidation, the time the liquidation will take place, and the price during and after the liquidation. See Figure 1 for an example of a single simulation run. We assume that an actual (possibly partial) liquidation takes place only when the market liquidity is enough to absorb it, with slippage lower than the liquidation incentive, or alternatively if the backstop has enough liquidity. An insolvency event is when a debt liquidation did not complete before the collateral price decreased by more than its collateral factor.

In the remainder of the section we explain the first three components of the model, namely, liquidation events, price trajectories, and market liquidity. In the next section we explain the backstop concept and how we add it to the model.

2.1 Modeling liquidation events

We take liquidation events from real world data, namely, from Binance Futures exchange. We take the most popular asset that has a similar volatility as the asset we wish to simulate. In this work, we define similar as at least x0.2 and at most x5 times the volatility, and we defer the formal definition of volatility

Figure 1: A simulation run. The price trajectory is in green. The orange plot illustrate the balance of the stability pool. The red line shows the market available liquidity for 10% trading slippage. The yellow line shows the amount of open liquidations.

to the next subsection. We denote this sequence of liquidations as the *reference liquidations*, and the liquidation asset as the *reference asset*.

To choose the sequence of *simulated liquidation events* we ignore the volatility of the reference asset and simulated asset. Instead we fix the monthly liquidation volume, by setting a *simulation liquidation factor*, denoted by **slf**, and multiplying the liquidation volume of all reference liquidations by this factor.

When stress testing the market, we find two metrics to be relevant for deciding the **slf**:

1. Fix the maximal daily liquidation volume, and derive a **slf** to support it. This approach is useful when trying to reason about an absolute volume of daily liquidations the market could handle safely.

2. Fix the monthly liquidation volume as a percentage of the total market collateral. This is useful for conservative approaches, where, e.g., the market admin assumes that every deposited $1 will not get liquidated more than once or twice a month [1]. This approach is also useful when analyzing the effect of a stability pool.

We note that a simulated liquidation of volume v at time t means that there is a user position with collateral v at time t that is not sufficiently overcollateralized. The exact time in which the liquidation will take place is subject to the simulated market liquidity (and backstop if applicable).

[1] These numbers are very aggressive for most DeFi platforms.

2.2 Modeling price trajectory

In the work, we use price trajectories only to simulate the platform insolvency (and not to decide if liquidation will occur). Hence, we are mostly interested in how the price behaves between the time a user position is subject to liquidation (as described in the previous subsection) and the time the full liquidation is completed (as described in the next subsection). For this purpose we try to have a price simulation that is approximating short time frames. For a time duration of T minutes, we define the T *price average volatility* as the average T minutes price standard deviation, and denote it for an asset a by $\mathbf{vol(a)_T}$. Further, we define the *STD ratio* as the ratio $\frac{\mathbf{vol(sa)_T}}{\mathbf{vol(ra)_T}}$, where sa (respectively ra) is the simulated (resp. reference) asset. For example if the average volatility of SPELL is x2.8 higher than the one of ETH, then the corresponding STD ratio is 2.8.

Having the STD ratio in hand, we amplify, in every minute, the price change by that ratio. In our example, if between time t and $t+1$, the ETH price changed (either up or down) by 0.1%, then the simulated SPELL price will change by 0.28%. Our numerical results show that if the STD ratio is under 5, then the simulated asset average volatility corresponds to its real world average volatility.

The intention of this process is not to simulate the long term price trajectory of the asset. But rather to sync the expected price changes along with the expected liquidations. In other words, we want that after every simulated liquidation the simulated price will behave similarly to the one of the reference asset after a reference liquidation. In Figure 2 we illustrate the short term simulated price for five different STD ratios. It shows that the price decreases are amplified when the ratio increases. The price increases are also amplified, however, as depicted in Figure 3, higher STD ratio skew the trajectory downwards. This stems from the fact that if one asset price movement is $(-5\%, +5\%)$, and a second asset price movement is $(-10\%, +10\%)$, then the second asset total price decrease is bigger. Overall the bias towards price decreases makes our simulation more conservative, and as depicted in Table 2.2 achieves our main goal, which is to create a simulated asset with the same average volatility.

STD ratio	30 minutes average volatility
0.5	0.499
1	1.000
1.5	1.500
2	2.0003
2.5	2.50007
3	3.001
4	4.004

2.3 Modeling market liquidity

In our current analysis we focus on Arbitrum liquidity, where most of the DeFi liquidity resides in constant product automated market makers (e.g., Sushiswap [14]).

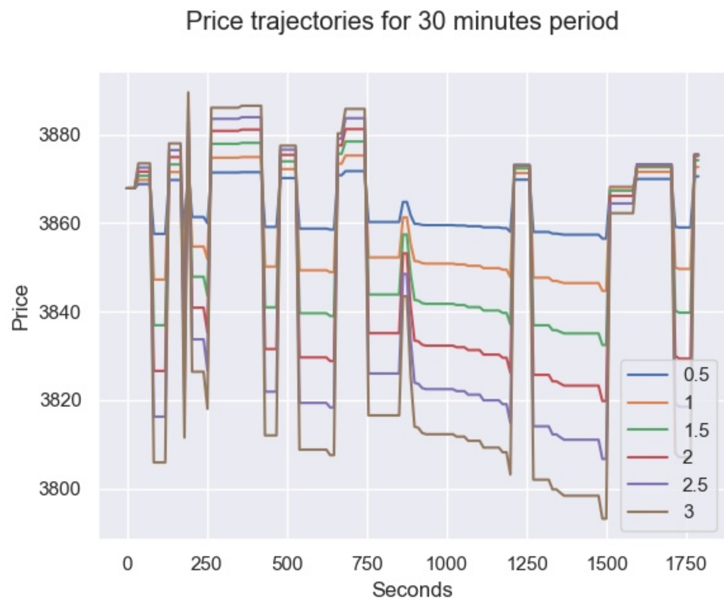

Figure 2: Simulated price trajectories for different STD ratio that range between 0.5 and 3.

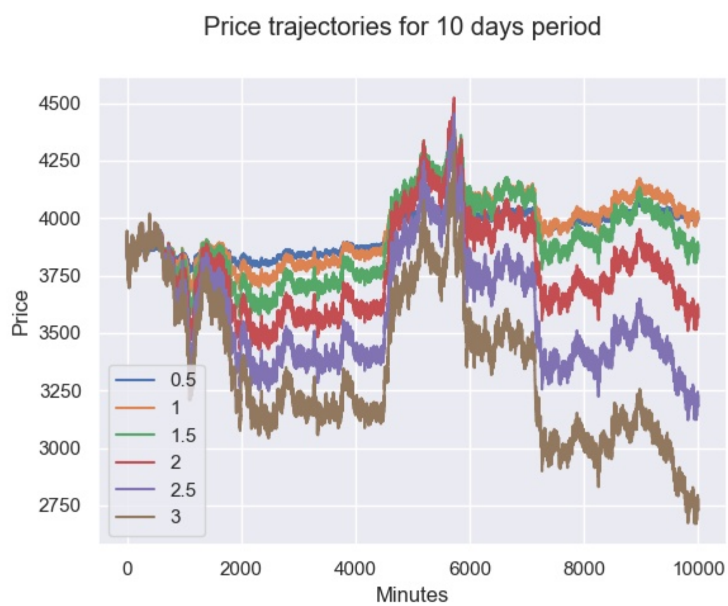

Figure 3: Simulated price trajectories for different STD ratio that range between 0.5 and 3.

Constant product AMMs have relatively sticky liquidity, and as opposed to orderbook exchanges tend to remain stagnant even during extreme market conditions. The $x \cdot y = k$ invariant provides a well defined slippage function for every volume size. To simulate the effect of the liquidations on the market, we fix a time parameter T and assume that the market price converges to the price trajectory every T minutes. During the T minutes interval, we accumulate the total liquidation volume that was executed in the interval, and compose the corresponding slippage over the current simulated price trajectory. For example, if the current price trajectory (i.e., market price) is \$7, \$1M of liquidations were executed in the last T minutes, and the slippage for \$1M quantity is 10%, then we assume that \$1M quantity can be sold in the DeFi market for price \$6.3.

The value of T depends on how long it is expected for liquidity to flow from its main venue, e.g., from a centralized exchange to Ethereum, or from Ethereum to an L2 or other L1. We note that in particular we assume the liquidations do not affect the overall price trajectory. This assumption is easy to justify in multichain markets, where most of the asset liquidity is outside the blockchain of the lending market.

We note that even in markets that are fully on Arbitrum, such as DPX, there is an inherent delay in the liquidity, as the price oracle is based on a TWAP algorithm, which lags over real market price. Hence, it will take some time until the oracle price, according to which the liquidation is executed, will converge to the actual market price. And during this time, liquidation arbitrages cannot be executed.

2.4 Modeling the price impact of liquidations

While the price trajectory of ETH/USD already embeds the effect of liquidation events that happened in the corresponding futures market, special handling is required in the cases where we expect Vesta Finance liquidations to have significant effect on the underlying price of the collateral asset.

Our market liquidity model already give us the recipe to simulate the price impact of a given liquidation on the market price. After selling the seized collateral, the price will inevitably decrease, and we use an exponential decay model to simulate how the price impact will decay over time.

In mathematics, exponential decay describes the process of reducing an amount by a consistent percentage rate over a period of time. Formally, if liquidation $\mathcal{L}_0$ at time t_0 decreased the price by a factor of f, then at time t we multiply the price trajectory value by $f + (1-f) \cdot (1 - e^{-\lambda \cdot (t-t_0)})$. For a fixed λ parameter, we denote the value T, such that $e^{-\lambda \cdot T} = \frac{1}{2}$, as the *half life recovery time*.

For example, assume a certain liquidation at time t_0 decreased the price by 15%, then we set $f = 0.85$. Further, assume the half life recovery time is 2 hours, then we set $\lambda = -\frac{\ln(0.5)}{120} = 0.0057762265$, and the price factor after t minutes is $0.85 + 0.15 \cdot (1 - e^{-0.0057762265t})$. The adjusted price trajectory is depicted in Figure 4.

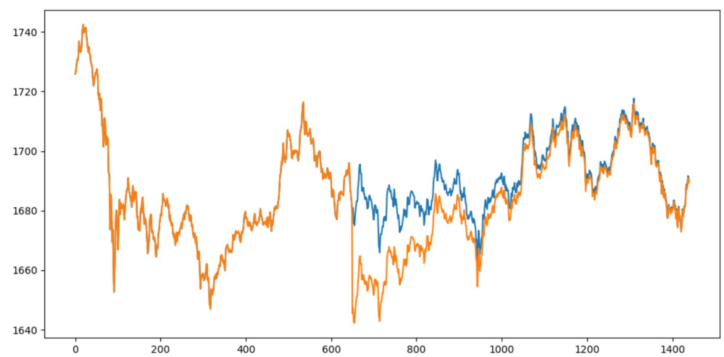

Figure 4: Adjusted price trajectory. Around minute 600 a liquidation event triggered a 15% drop in the price. From this point on-wards, the adjusted trajectory (in orange) slowly converges back to the original trajectory, with a half-life time period of 120 hours.

Naturally, a simulation consists of more than just a single liquidation, and in this case we just separately multiply the price trajectory by the price impact of every single liquidation.

3 Stability Pool

A stability pool as used by lending protocols like Liquity or Vesta serves as an instant reserve of stable-coins to liquidate *bad* loans. This allows for faster liquidation and hence lower collateralization requirements. Anyone can stake the pool's stablecoin (e.g. LUSD, VST) into the stability pool. When the stability pool liquidates loans these depositors lose some of their stablecoin balances (to pay off the debt) but get the collateral (from the loan) in exchange. In such case, the depositor has the following options:

- *No action.* i.e. their stablecoin balance in the stability pool is reduced and they have an additional amount of collateral that they can withdraw from the stability pool
- *Rebalance/withdraw.* i.e. swap the received collateral back to the stablecoin and stake that amount to the stability pool, such that their balance is the same as to prior the liquidation event.

Typically, depositors of the stability pool receive more value in collateral than what was deducted in stablecoin balance (since the liquidation threshold is >1). This is why in principle a staker of the stability could even stake more stablecoins back into the stability pool. Conversely, they could also decide to provide less back into the pool or even withdraw additional balances from their stake of the stability pool.

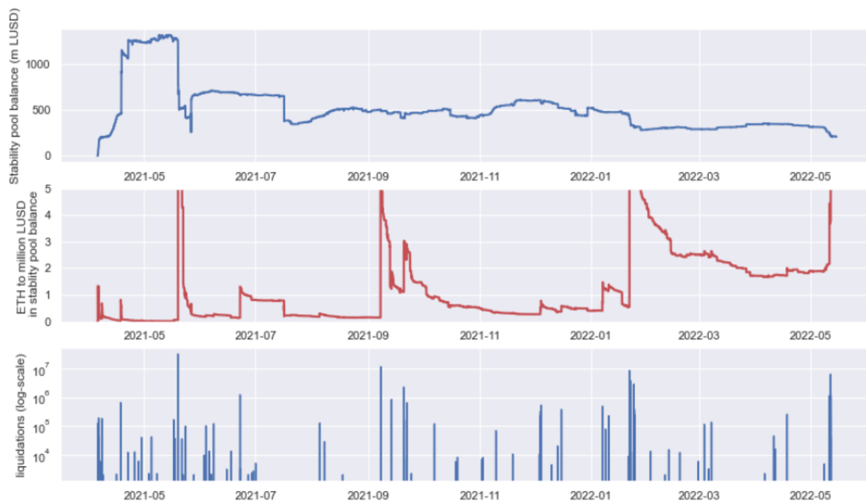

Figure 5: From top to bottom: Stability pool balance (M), ratio of ETH to million LUSD in the stability pool, liquidations.

As Vesta Finance is still an early stage platform, we query empirical results from Liquity protocol.

Figure 5 shows, on a minute basis, Liquity's stability pool balance (upper chart), the liquidations (bottom chart) and the ratio of ETH to LUSD in the stability pool (LUSD scaled by millions, middle chart), i.e. this red line in the middle chart shows if depositors rebalance/withdraw the collateral and how quickly (as then that ratio approaches 0 again).

As staking rewards decreased since the start of the stability pool in May 2021, it does not surprise that the total balance of the stability pool decreases as well. Noteworthy though is the drop in balance of over 500m LUSD mid May 2021 following several larger liquidation events [2]. This is one example for the second option mentioned above, where stakers withdraw the ETH they received from the liquidations (and hence the red line in the middle chart goes down), but they withdraw additional funds from the stability pool (i.e. whilst almost 100m LUSD was used for liquidations on May 19th, the stability pool balance dropped by over 500m LUSD).

There are also points where the stability pool balance of the upper chart makes a step-move down without major liquidation, e.g. mid/end July 2021 are examples where stakers withdraw.

We capped that middle chart as there are four days with major liquidation events [3] where the ratio goes all the way to 40, i.e. for every million LUSD in

[2]The largest spike in the bottom liquidation chart on May 19th represents ∼30m LUSD, i.e. ∼30m LUSD have been liquidated within a minute.

[3]Mid May 2021, early September 2021, mid January 2022 and early May 2022

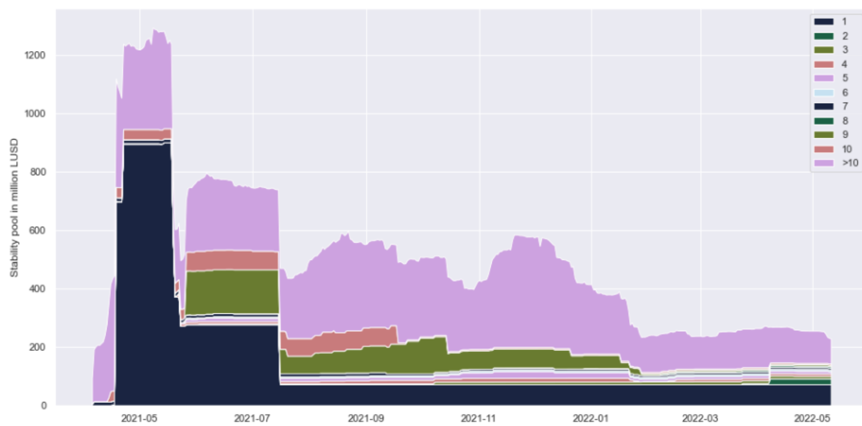

Figure 6: Liquidity stability pool stakers over time, ranked by current deposit value.

the stability pool there was 40 ETH from liquidations. The sharp spikes show that typically stability pool depositors quickly rebalance or withdraw the ETH received from liquidations. However, it is not going back to 0 right away, but decaying exponentially over time. After the larger liquidations in January 2022 quite some share of ETH wasn't even withdrawn, i.e. the ratio stayed at an elevated level of 2 ETH per million LUSD in the stability pool.

To model these dynamics it is also worth looking into the depositor structure. Figure 6 shows the wallets that staked LUSD into Liquity's stability pool. The current top 10 wallets are shown separately, the rest is aggregated (labeled as '>10').

There are $\sim$ 2.5k wallets staking over 10 LUSD. Concentration is quite high, i.e. the largest staker has 30%, top 10 stakers shown above make $\sim$ 60% and top 100 exceed 90%. The normalized Gini coefficient is 0.98.

3.1 Modeling approach

In order to model the above dynamics, we make some simplifying assumptions:

- The volume of the stability pool only changes in the course of liquidation events, i.e. there are no additional deposits and/or withdrawals (those dynamics can be modeled separately in relation to the staking incentives for the stability pool).
- Stakers always rebalance, i.e. the red line in the middle chart representing the ETH to LUSD ratio of balances in the stability pool approaches 0 after a liquidation happened (and does not stay at some elevated level as seen in the past months for Liquity).

Clearly, the first assumption is a big simplification given those steep, step-function like decreases of the stability pool balances seen in Liquity's history so far. The second assumption allows us to use an exponential decay function to describe the rebalancing after a liquidation as

$$b_\lambda(t - t_l) = L_{t_l} \cdot e^{-\lambda \cdot (t - t_l)}$$

where t_l is the time of liquidation, t the current time and L_{t_l} the amount of stability pool reserves used for that liquidation. Hence, $b_\lambda(t - t_l)$ describes the stablecoin balance at time t that still needs to be re-balanced (swapping the received collateral back into the stablecoin) in order to get the stability pool back to where it was prior t_l. λ is a parameter that defines how quickly stakers rebalance. We use the notion of a half life time here, i.e. use a time T at which half of L was repaid (and consequently $\frac{3}{4}$ of L repaid after $2T$, $\frac{7}{8}$ after $3T$ etc.). When T is fixed, we get $\lambda = \frac{\ln(2)}{T}$. With that our decay function given the half life time T is $b_T(t - t_l) = L_{t_l} \cdot e^{-\frac{\ln(2)}{T} \cdot (t - t_l)}$.

For our simulation we also want to add the impact of adding a (or even multiple) backstop protocol(s) like B.Protocol [8] that has automated processes in place to sell the liquidated collateral to replenish their position in the stability pool. In this case, the share X of the total stability pool is managed by such protocol(s) and (1-X) by the group of retail stakers. Model-wise that means we have:

- *Retail stakers*, that behave as seen in Liquity's stability pool and hence can be modeled with the above, with the adjustment that they recover $(1 - X)$ of the liquidated amount

  $$b^S_T(t - t_l) = (1 - X) \cdot L_{t_l} \cdot e^{-\frac{\ln(2)}{T} \cdot (t - t_l)}$$

- *Protocols*, for which we assume a constant recovery volume R in given time-steps (recovery intervals t_R) where they swap the collateral from the liquidation for the stablecoin until they fully recovered their original balance of the stability pool:

  $$b^P_{R,t_R}(t - t_l) = X \cdot L_{t_l} - \frac{(t - t_l) \cdot R}{t_R}$$

  The balance b that still needs to be repaid after time t is the initially used amount $X \cdot L_{t_l}$ minus what has been repaid. Every time-step t_R these protocols manage to repay R, hence they rebalanced $(t - t_l) \cdot \frac{R}{t_R}$.

3.2 Parameter selection

The half life recovery time T depends on user behavior, and the recovery interval t_R depends on market liquidity. In order to asses historical values for T we generate multiple simulation for different values of T, plot a curve on how the stability pool ETH to LUSD ratio would behave with a given value for T, and find the T values that minimize the Euclidean distance from the historical ETH to LUSD curve. Naturally this value is expected to change over time, and thus

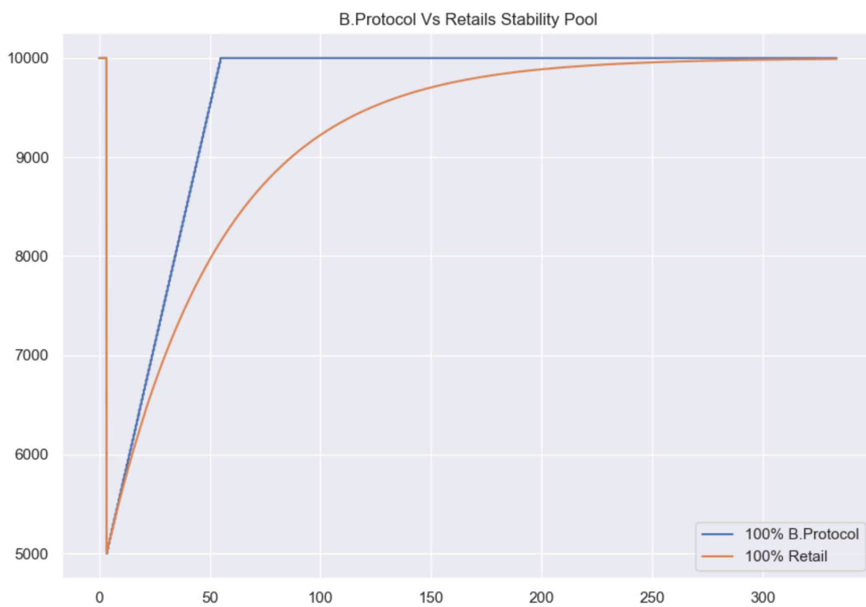

Figure 7: Simulated stability pool balance recovery. The orange plot describes a pool with $X = 0$ and $T = 36$ hours. The blue line depict a pool with $X = 1$ and $R = 50$ ETH per half hour.

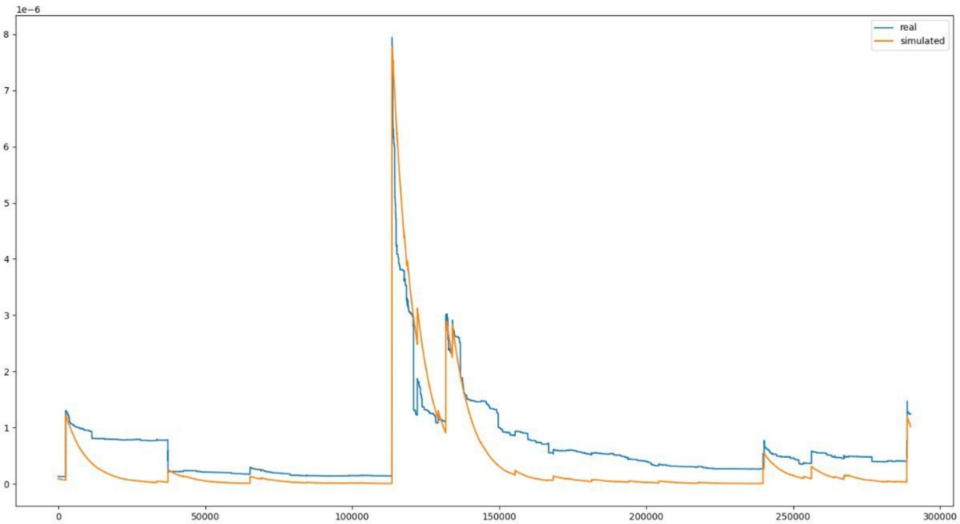

Figure 8: Simulated stability pool ETH to LUSD ratio, according to $T = 81$ hours, and the actual ratio (in blue).

we only aim to get reasonable boundaries for expected T values. Two such curves are depicted in Figure 8.

The value of t_R corresponds to the amount of liquidity that the market can digest with B.Protocol maximum rebalance discount (which typically amounts to the liquidation incentive of the lending platform).

4 Simulation results

4.1 Simulated assets

4.1.1 ETH

Ethereum is a decentralized, open-source blockchain with smart contract functionality. Ether (ETH) is the native cryptocurrency of the platform, as well as the native token of the Arbitrum L2. Among cryptocurrencies, Ether is second only to Bitcoin in market capitalization.

Measuring Price Volatility. As the reference price trajectory is ETH vs USD, no adjustments are needed. The price trajectory is depicted in Figure 9.

Measuring Market Liquidity. ETH is traded vs stable coins on Sushiswap, Uniswap and Curve Finance. To assess the market liquidity we take a conservative approach and take into account only the available liquidity in Sushiswap vs USDC. At the time we ran the simulation, it was possible to sell 800 ETH with 10% slippage in Sushiswap (over Arbitrum). The price slippage is displayed in

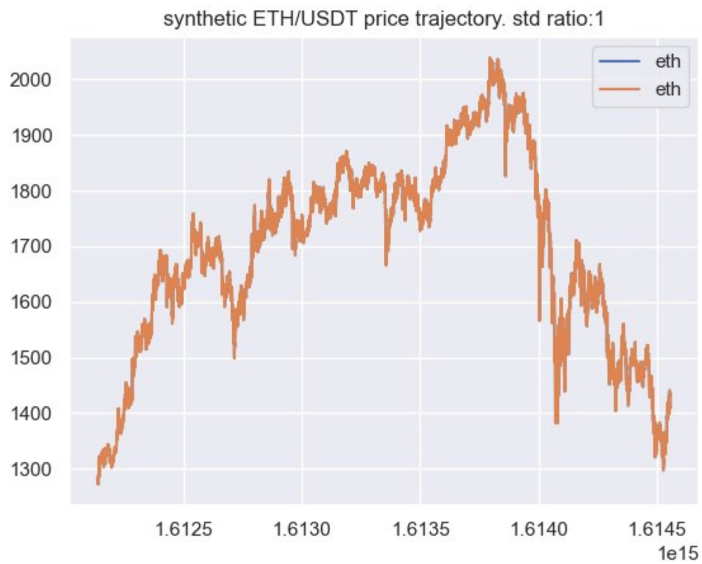

Figure 9: ETH price trajectory.

Figure 10

Simulation results. We ran 16,800 different simulations, with the following parameter ranges:

- Debt ceiling of \$5M, \$10M, \$15M, and \$30M.
- Monthly liquidation volume that is between 0.5 to 6 times the debt ceiling.
- With its current size, we do not expect that ETH liquidations on Vesta Finance would have a bigger effect on ETH price than the effect of Binance futures liquidations, which are already embedded in the price trajectory. Hence, we set the price recovery time to 0.
- Stability pool size which is between 0.1 and 0.5 of the total debt ceiling.
- Between 0.0% to 50% of the stability pool is managed by B.Protocol.
- Half life recovery time for the stability pool of 1-10 days.
- ETH/USD liquidity debt of 400-800 ETH.

The full results can be viewed with the HTML tool we developed. In Figure 11 we present the results that best fit the current state of the ETH collateral in Vesta, namely, a stability pool that is 0.25 of the total debt, B.Protocol deposits that are 10% of the total stability pool, and stability pool half time recovery time of 10 days.

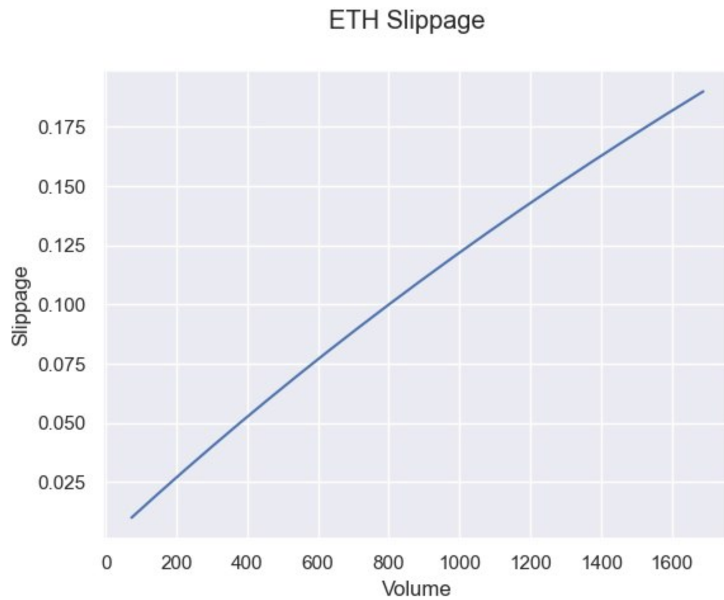

Figure 10: Price slippage of ETH token vs USDC (Volume in ETH).

Currently Vesta does not have any debt ceiling on for the ETH collateral, however the current VST debt that is backed by ETH amounts is $2.7M. We recommend the collateral factor to be the average of the simulation results for factors 0.5-2 minus the liquidation penalty. Hence, for a debt ceiling of up to $5M, a collateral factor of 90%, with 10% liquidation incentive, which fits the current Vesta configuration is valid.

4.1.2 renBTC

The RenVM bridges BTC to Ethereum, and from there to the Arbitrum L2, via a semi-centeralized bridge. The minting process generates 1 renBTC for every BTC that is sent, and the process is also reversable. Hence, as long as the bridge remains in tact, renBTC is expected to be traded for the same value as BTC.
Price Trajectory. The STD ratio of BTC is 0.78 (lower than the STD of ETH), and thus we set the same value also for renBTC.

The price trajectory is depicted in Figure 12.
Market liquidity. The only liquidity source for renBTC on Arbitrum is curve Finance, where it is traded vs WBTC. Curve consists of over $30m of liquidity which are available for sell for almost zero slippage. Hence the renBTC/USDC liquidity is dictated by the WBTC/USDC liquidity. WBTC is traded vs stable coins on Sushiswap, Uniswap and Curve Finance. To assess the market liquidity we take a conservative approach and take into account only the available liquid-

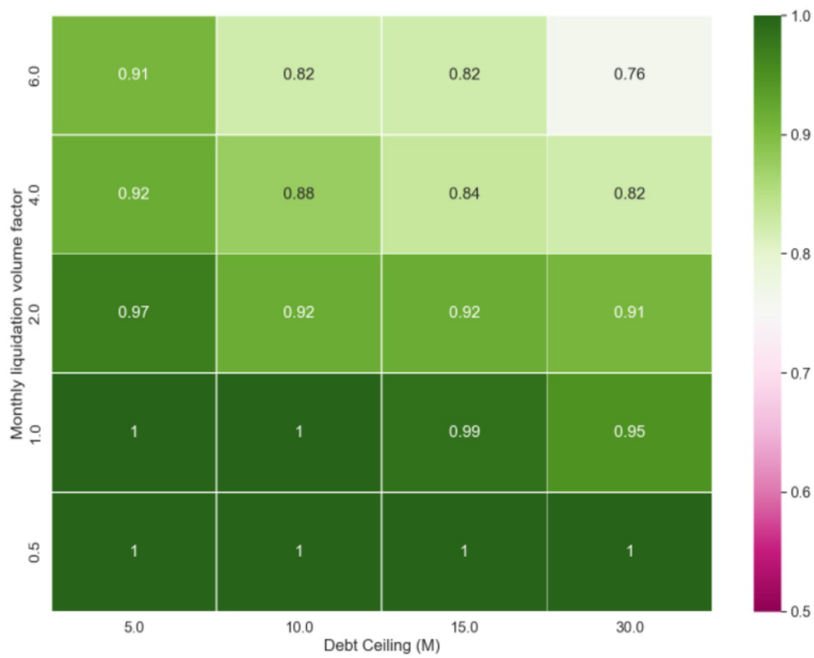

Figure 11: Simulation results for ETH collateral with current system params. Each cube represents 1 - max loss.

Figure 12: renBTC price trajectory.

ity in Sushiswap vs USDC. At the time we ran the simulation, it was possible to sell an equivalent amount of 500 ETH worth of WBTC with 10% slippage in Sushiswap (over Arbitrum).

The price slippage for renBTC displayed in Figure 13.

Simulation results. We ran 16,800 different simulations, with the following parameter ranges:

- Debt ceiling of \$5M, \$10M, \$15M, and \$30M.
- Monthly liquidation volume that is between 0.5 to 6 times the debt ceiling.
- With its current size, we do not expect that renBTC liquidations on Vesta Finance would have a bigger effect on renBTC price than the effect of Binance futures liquidations on ETH, which are already embedded in the price trajectory. Hence, we set the price recovery time to 0.
- Stability pool size which is between 0.1 and 0.5 of the total debt ceiling.
- Between 0.0% to 50% of the stability pool is managed by B.Protocol.
- Half life recovery time for the stability pool of 1-10 days.
- ETH/USD liquidity debt of 250-500 ETH.

The full results can be viewed with the HTML tool we developed. In Figure 14 we present the results that best fit the current state of the renBTC collateral in

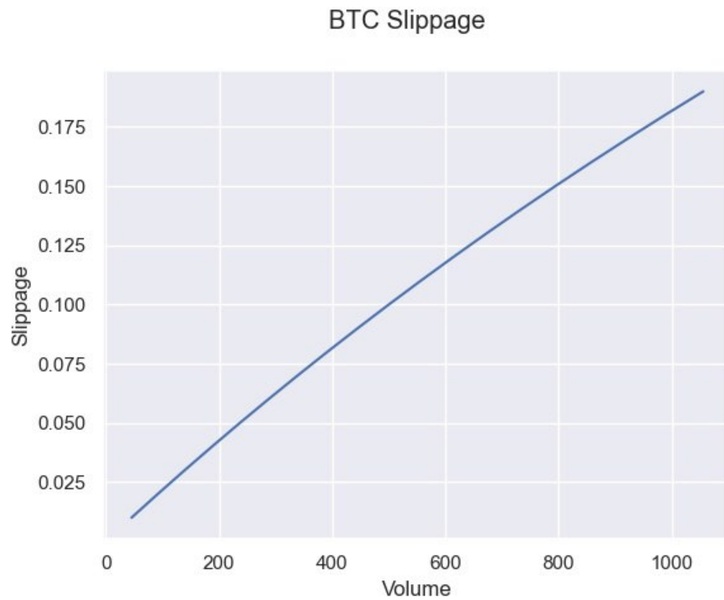

Figure 13: Price slippage of BTC (volume in ETH).

Vesta, namely, a stability pool that is below 10% of the total debt, B.Protocol deposits that are 0% of the total stability pool, and stability pool half time recovery time of 10 days.

Currently Vesta does not have any debt ceiling on for the renBTC collateral, however the current VST debt that is backed by renBTC is \$0.6M. We recommend the collateral factor to be the average of the simulation results for factors 0.5-2 minus the liquidation penalty. Hence, for a debt ceiling of up to \$5M, a collateral factor of 90%, with 10% liquidation incentive, which fits the current Vesta configuration is valid. We note however, that without increasing the size of the stability pool, it might not be safe to support \$10M debt ceiling with the current parameters.

4.1.3 TriCrypto

TriCrypto is an LP token for automatic market-making with dynamic peg by Curve Finance. In stable state, the LP token is composed with equal holdings of USDT, WBTC and ETH. Over time the LP token accumulate trading fees, however in the short term the amount of fees are negligable, and therefor we ignore them in our analysis.

Price Trajectory. The STD ratio of the asset is 0.66 (lower than the STD of ETH, and of the one of WBTC, as it is composed of 33% of USDT).

The price trajectory is depicted in Figure 15.

Market liquidity. 3\$ worth of TriCrypto are redeemable for \$1 worth of

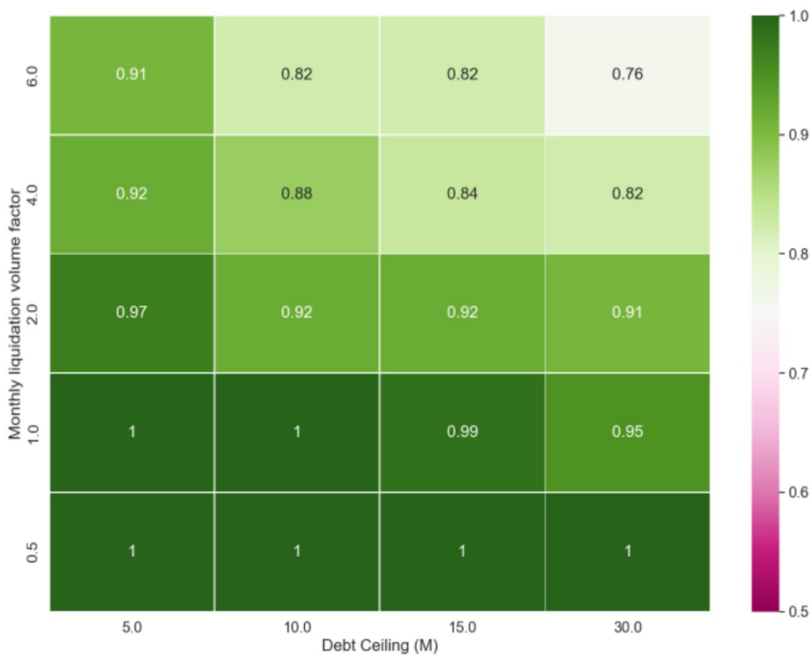

Figure 14: Simulation results for renBTC collateral with current system params. Each cube represents 1 - max loss.

Figure 15: TriCrypto price trajectory.

USDT, \$1 worth of WBTC, and \$1 worth of ETH. As the USDT to VST slippage is effectively zero for any reasonable amount, and as the ETH liquidity is higher than the WBTC liquidity, the bottleneck is WBTC liquidity. In the previous section, we assumed that 500 ETH worth of WBTC can be sold for 10% slippage. Hence for TriCrypto we assume that x3 of that amount can be sold, namely 1500 ETH.

The price slippage for TriCrypto displayed in Figure 16.

Simulation results. We ran 16,800 different simulations, with the following parameter ranges:

- Debt ceiling of \$5M, \$10M, \$15M, and \$30M.
- Monthly liquidation volume that is between 0.5 to 6 times the debt ceiling.
- With its current size, we do not expect that TriCrypto liquidations on Vesta Finance would have a bigger effect on TriCrypto price than the effect of Binance futures liquidations on ETH, which are already embedded in the price trajectory. Hence, we set the price recovery time to 0.
- Stability pool size which is between 0.1 and 0.5 of the total debt ceiling.
- Between 0.0% to 50% of the stability pool is managed by B.Protocol.
- Half life recovery time for the stability pool of 1-10 days.
- TriCrypto/USD liquidity debt of 750-1500 ETH.

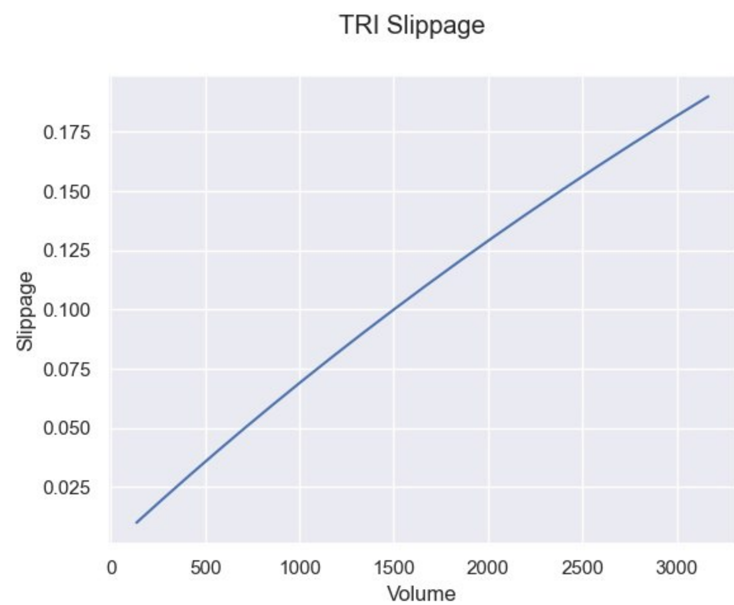

Figure 16: Price slippage of TriCrypto (volume in ETH).

Currently Vesta does not support this asset, however the simulation results in Figure 17 suggest that it could quite easily support 90% collateral factor, with 10% liquidation penalty, up to $30M debt ceiling if it will have similar stability pool ratio as it has in ETH.

4.1.4 gOHM

Olympus is an algorithmic currency protocol with the goal of becoming a stable crypto-native currency. Though sometimes called an algorithmic stablecoin, Olympus is more akin to a central bank since it uses reserve assets like DAI to manage its price. gOHM is the on-chain governance token of Olympus. It has a static balance and increasing redemption value.

Price Trajectory. The STD ratio of OHM is 1.15. The price of gOHM equals the price of OHM multiplied by a rebase index. For short time durations the index does not change, hence we measure the OHM price movements, instead of the less liquid gOHM movements. Hence, we set an STD ratio of 1.15 also to gOHM.

The price trajectory is depicted in Figure 18.

Market liquidity. At the time of writing, it is possible to sell 40 ETH worth of gOHM with 10% slippage in Sushiswap over Arbitrum.

The price slippage for gOHM displayed in Figure 19.

Simulation results. We ran 16,800 different simulations, with the following parameter ranges:

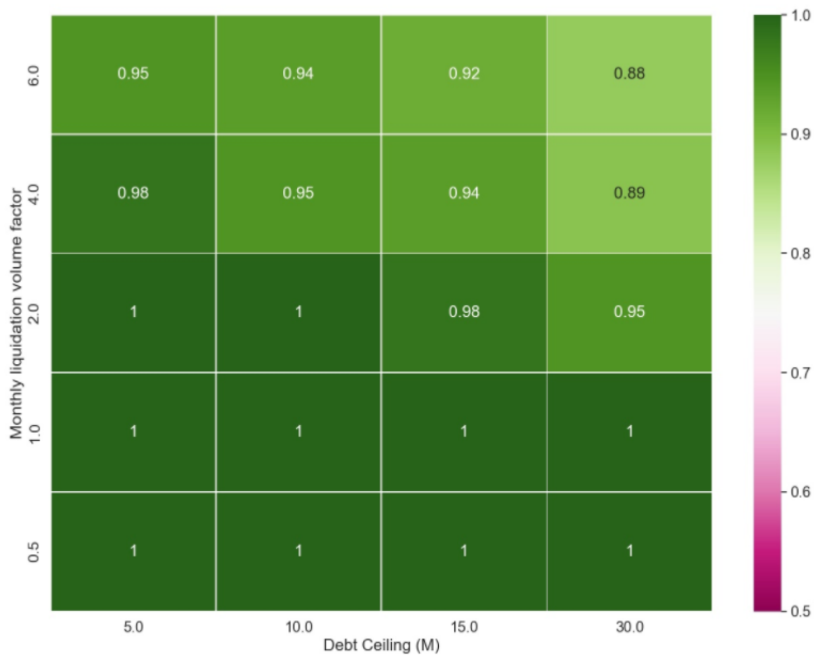

Figure 17: Simulation results for TriCrypto collateral with current system params. Each cube represents 1 - max loss.

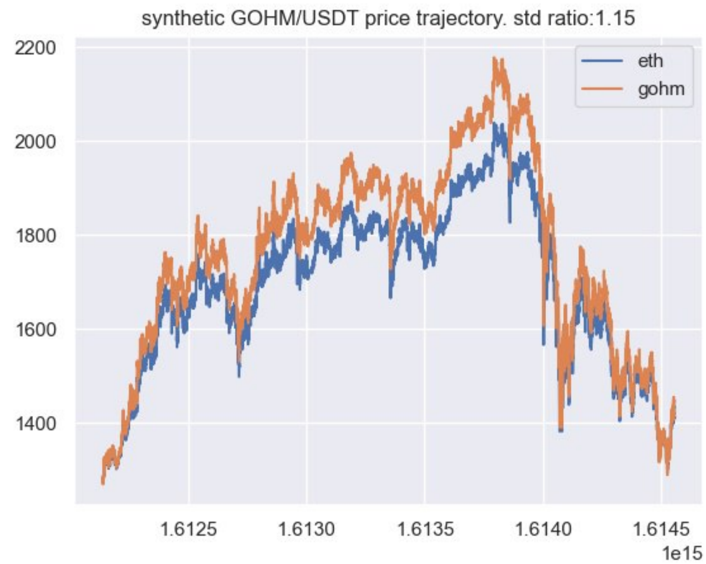

Figure 18: gOHM price trajectory.

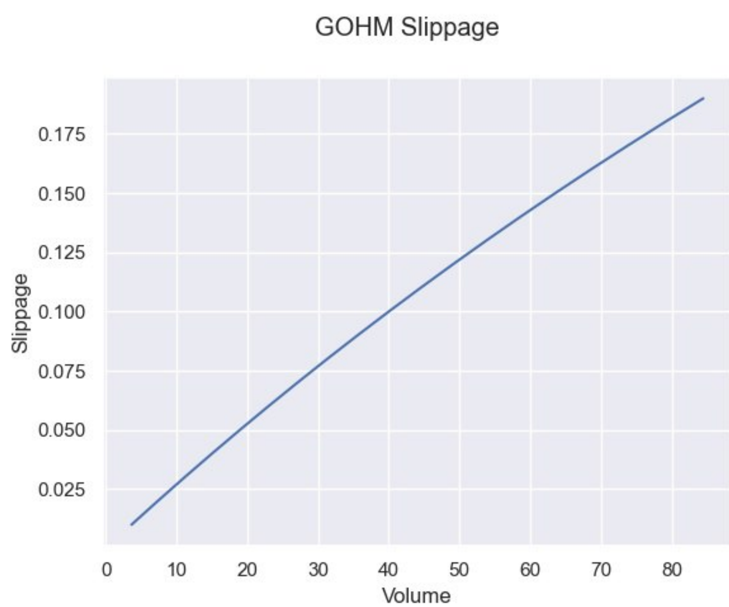

Figure 19: Price slippage of gOHM (volume in ETH).

- Debt ceiling of \$2M, \$4M, \$8M, and \$16M.
- Monthly liquidation volume that is between 0.5 to 6 times the debt ceiling.
- With its current size, we do not expect that gOHM liquidations on Vesta Finance would have a bigger effect on gOHM price than the effect of Binance futures liquidations on ETH, which are already embedded in the price trajectory. Hence, we set the price recovery time to 0.
- Stability pool size which is between 0.1 and 0.5 of the total debt ceiling.
- Between 0.0% to 50% of the stability pool is managed by B.Protocol.
- Half life recovery time for the stability pool of 1-10 days.
- gOHM/USD liquidity debt of 20-40 ETH.

The full results can be viewed with the HTML tool we developed. In Figure 20 we present the results that best fit the current state of the gOHM collateral in Vesta, namely, a stability pool that is below 10% of the total debt, B.Protocol deposits that are 0% of the total stability pool, and stability pool half time recovery time of 10 days.

Currently Vesta has a debt ceiling of \$2M, with stability pool size of roughly 10%, of which 25% is deposited in B.Protocol. As DEX liquidity for the asset is relatively low, a bigger liquidation incentive might be needed to encourage stability pool deposits. With a liquidity incentive of 15%, the simulation suggests that a collateral factor of 0.75 could be supported for \$2M debt ceiling. However for higher debt ceiling, more conservative numbers are required.

4.1.5 GMX

GMX is a decentralized spot and perpetual exchange that supports low swap fees and zero price impact trades. Trading is supported by a unique multi-asset pool that earns liquidity providers fees from market making, swap fees and leverage trading. GMX is the platform's utility and governance token, holding the token unlocks a variety of benefits.

Price Trajectory. The STD ratio of GMX is 2.84. The price trajectory is depicted in Figure 21.

Market liquidity. At the time of writing, it is possible to sell 300 ETH worth of GMX with 10% slippage in Uniswap over Arbitrum.

The price slippage for GMX displayed in Figure 22.

Simulation results. We ran 86,400 different simulations, with the following parameter ranges:

- Debt ceiling of \$2M, \$4M, \$8M, and \$16M.
- Monthly liquidation volume that is between 0.5 to 6 times the debt ceiling.
- Half life price recovery time of 1-10 days.

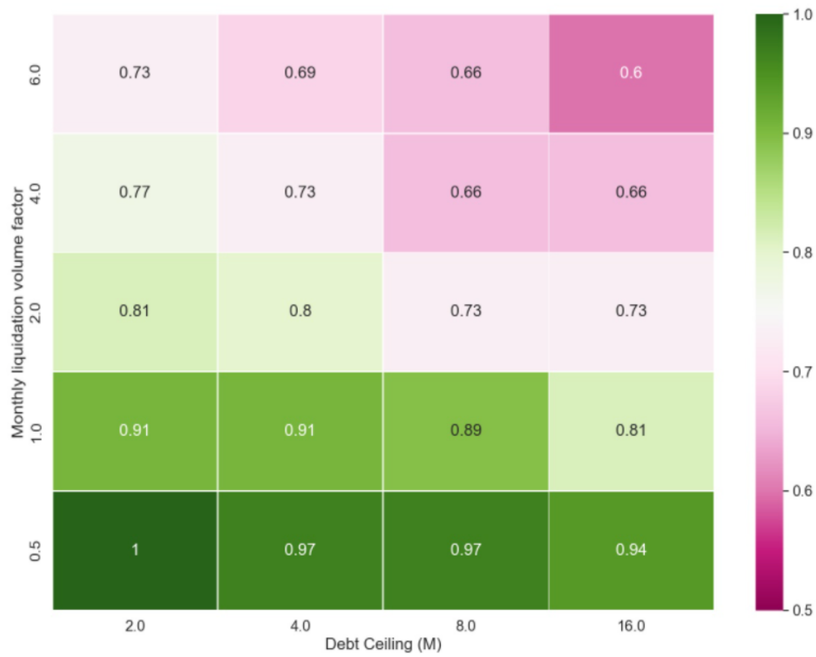

Figure 20: Simulation results for gOHM collateral with current system params. Each cube represents 1 - max loss.

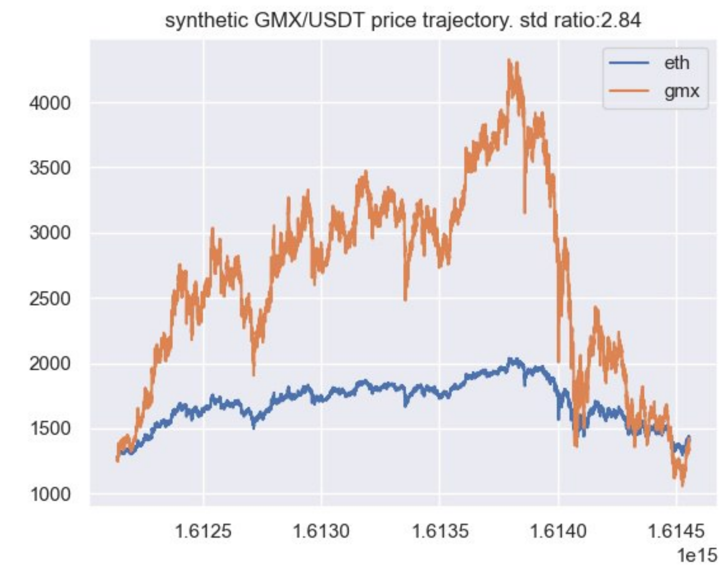

Figure 21: GMX price trajectory.

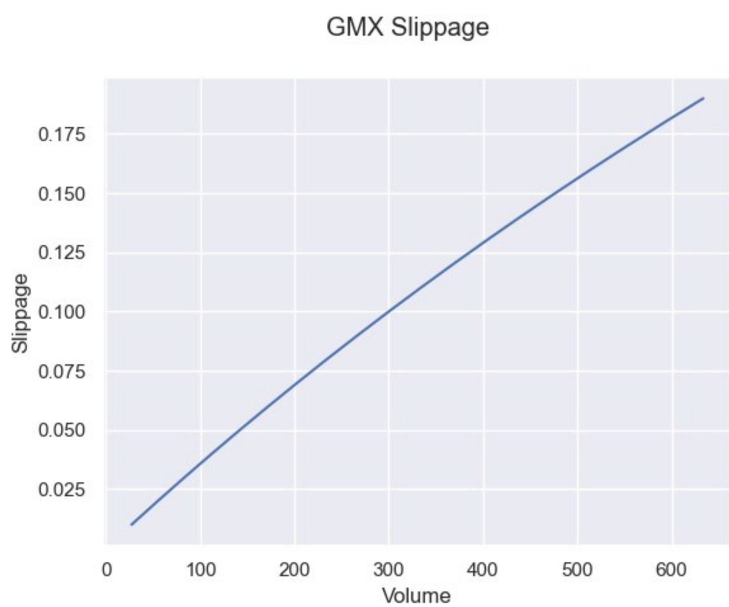

Figure 22: Price slippage of GMX (volume in ETH).

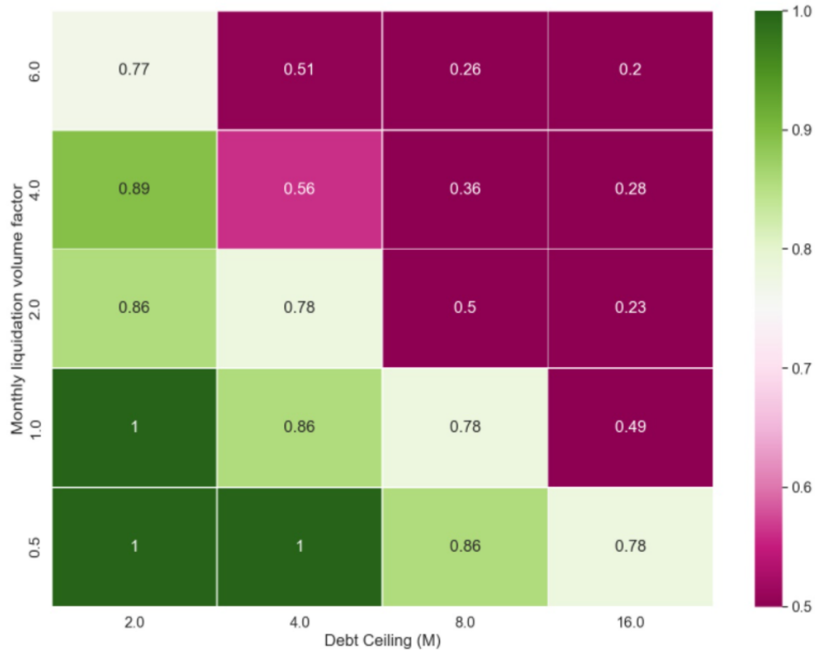

Figure 23: Simulation results for GMX collateral with current system params. Each cube represents 1 - max loss.

- Stability pool size which is between 0.1 and 0.5 of the total debt ceiling.
- Between 0.0% to 50% of the stability pool is managed by B.Protocol.
- Half life recovery time for the stability pool of 1-10 days.
- GMX/USD liquidity debt of 75-150 ETH.

The full results can be viewed with the HTML tool we developed. In Figure 23 we present the results that best fit the current state of the GMX collateral in Vesta, namely, a stability pool that is below 10% of the total debt, B.Protocol deposits that are 0% of the total stability pool, and stability pool half time recovery time of 10 days.

Currently Vesta has a debt ceiling of $1M, with stability pool size of roughly 10%, of which 0% is deposited in B.Protocol. As TWAP oracle is used, a bigger liquidation incentive might be needed to compensate for the feed update delays. With a liquidity incentive of 15%, the simulation suggests that a collateral factor of 0.75 could be supported for $2M debt ceiling. However for higher debt ceiling, more conservative numbers are required.

Figure 24: DPX price trajectory.

4.1.6 DPX

Dopex is a decentralized options protocol which aims to maximize liquidity, minimize losses for option writers and maximize gains for option buyers - all in a passive manner for liquidity contributing participants. DPX is a vanilla governance and protocol fee accrual token.

Price Trajectory. The STD ratio of DPX is 2.64. The price trajectory is depicted in Figure 24.

Market liquidity. At the time of writing, it is possible to sell 700 ETH worth of DPX with 10% slippage in Sushiswap over Arbitrum.

The price slippage for DPX displayed in Figure 25.

Simulation results. We ran 86,400 different simulations, with the following parameter ranges:

- Debt ceiling of \$2M, \$4M, \$8M, and \$16M.
- Monthly liquidation volume that is between 0.5 to 6 times the debt ceiling.
- Half life price recovery time of 1-10 days.
- Stability pool size which is between 0.1 and 0.5 of the total debt ceiling.
- Between 0.0% to 50% of the stability pool is managed by B.Protocol.
- Half life recovery time for the stability pool of 1-10 days.

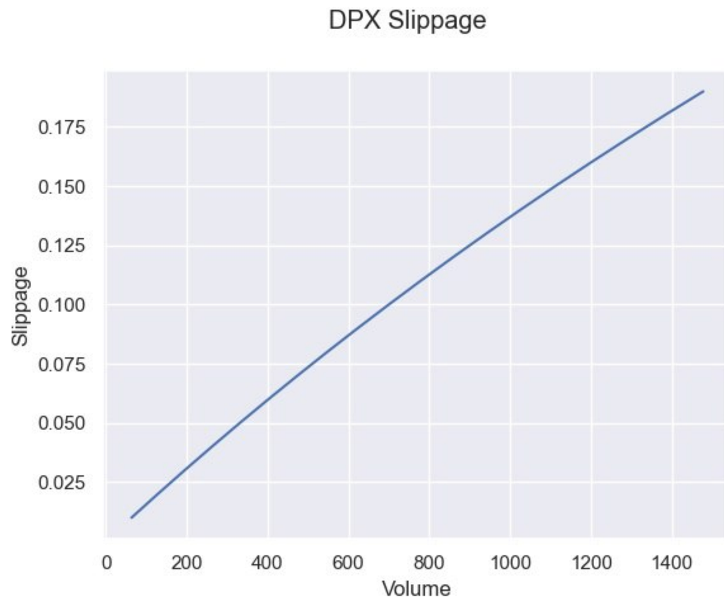

Figure 25: Price slippage of DPX (volume in ETH).

- DPX/USD liquidity debt of 350-700 ETH.

The full results can be viewed with the HTML tool we developed. In Figure 26 we present the results that best fit the current state of the DPX collateral in Vesta, namely, a stability pool that is around 10% of the total debt, B.Protocol deposits that are 0% of the total stability pool, and stability pool half time recovery time of 10 days.

Currently Vesta has a debt ceiling of $3M, with stability pool size of roughly 10%, of which 0% is deposited in B.Protocol. As TWAP oracle is used, a bigger liquidation incentive might be needed to compensate for the feed update delays. With a liquidity incentive of 15%, the simulation suggests that a collateral factor of 0.85 could be supported for $2M debt ceiling. However for higher debt ceiling, more conservative numbers are required.

5 Qualitative Analysis and Best Practices

Vesta Finance, and the entire Arbitrum L2 ecosystem, are both at early stage in their life cycle. As such, there are a lot of uncertainty and potential issues that mathematical models cannot quantify. Some potential issues, such as smart contract bugs or rug pulls are better mitigated by placing a debt ceiling to cap the worst case scenarios. Other issues, such as a lagged oracle price can be mitigating by reducing the collateral factor.

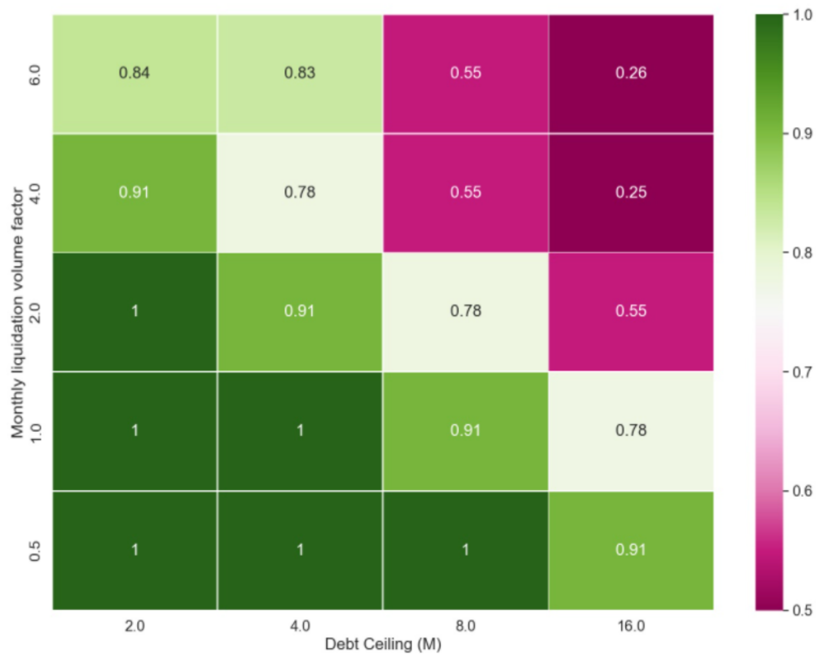

Figure 26: Simulation results for DPX collateral with current system params. Each cube represents 1 - max loss.

5.1 Price Oracle

When assessing the integrity of the price oracle we consider the following:

1. Does the price provided by a reputable entity? Chainlink is one example for a reputable vendor. Uniswap and Sushiswap TWAP oracles are also supplied by reputable entities, albeit having other issues.

2. Does the oracle have sanity backup checks? A good practice is to compare the price of the main oracle to other sources.

3. Does the oracle directly price the underlying asset? An ETH/USD price feed directly price the value of ETH vs USD, while BTC/USD price feed indirectly give the price of wBTC vs USD.

4. The price oracle update rate: Chainlink price feeds typically being updated quickly when there is a price change, while Uniswap TWAP oracles take time to update.

5.1.1 ETH

Chainlink price oracle is used. To the best of our knowledge, without sanity checks with other oracles.

5.1.2 renBTC

Chainlink BTC price oracle is used. To the best of our knowledge, without sanity checks with other oracles. It should be noted that the oracle provide price feed for BTC and not renBTC.

5.1.3 TriCrypto

A price feed of the LP token can be composed out of three chainlink price feeds, namely, USDT to USD, BTC to USD, and ETH to USD. It should be noted that BTC price is taken for WBTC, though they might diverge in theory.

5.1.4 gOHM

The price is composed out of two Chainlink price feeds, namely, the Index price feed and the OHM price feed. To the best of our knowledge, without sanity checks with other oracles.

5.1.5 GMX

A 30 minutes TWAP Uniswap V3 oracle is used. Such oracle is by design lagging over the real market price. Further, arguably DEX TWAP oracles are more vulnerable for price manipulation attacks.

5.1.6 DPX

A 30 minutes TWAP oracle, operated by the team, is used. Such oracle is by design lagging over the real market price, and require full trust in the team that operates it.

5.2 On-chain liquidity stickiness

The on-chain liquidity depth is already modeled in our quantitative simulation, however it cannot accurately predict how liquidity providers would behave in times of big market movement. Some of the uncertainty is mitigated by taking into account only constant product AMMs, which historically tend to act passively over short time frames. However, for the medium term, changes in the liquidity depth will force changing some of the risk parameters. Hence, it is better to try and asses the likelihood for changes in advance.

Liquidity contributor distribution. Having more individual liquidity providers over multiple DEXes would reduce the odds for liquidity crisis in times of liquidations. On the other hand, having liquidity provided only by few requires trust that the liquidity providers will not withdraw when the market moves.

Incentivised liquidity. A liquidity that is based on liquidity mining program for the liquidity providers is more likely to shrink during bear markets, and in these markets liquidations are most needed.

Historical liquidity amount volatility. The more volatile the liquidity amount is, higher safety margins are required.

5.2.1 ETH

Decent amount of liquidity is offered in multiple venues, including Sushiswap, Uniswap V3, and Curve finance.

5.2.2 renBTC

renBTC liquidity is offered only vs WBTC on curvfi. At the time of writing it has around 200 liquidity contributors. The liquidity is somewhat incentives by CRV rewards, however these rewards are not (directly) affected by the value of renBTC.

Overall the renBTC vs WBTC liquidity quality is of higher quality than the one of VST itself, and thus it is not expected to be a bottleneck in the liquidation process.

For WBTC, decent amount of liquidity is offered in multiple venues, including Sushiswap, Uniswap V3, and Curve finance.

5.2.3 TriCrypto

The TriCrypto liquidity is a composition of USDT, ETH and WBTC liquidity. All with high quality liquidity in Sushiswap, Uniswap V3 and Curve Finance itself.

The liquidity is somewhat incentives by CRV rewards, however these rewards are not (directly) affected by the value of TriCrypto token.

5.2.4 gOHM

gOHM liquidity is available only in Sushiswap, and with relatively small amounts. Moreover, recently the liquidity shrank by almost 66%. Further, the liquidity is not organic, and it is incenvised with a liquidity mining rewards.

5.2.5 GMX

All of GMX liquidity is controlled by the GMX team.

5.2.6 DPX

DPX liquidity is offered only in Sushiswap. Incentivised by a liquidity mining program, and recently suffered from a contraction of over 70%.

5.3 Other Systemic risk

Other systemic risks include complex smart contract implementation, control by a centeralized entity, upgradable token contracts and mintable token contracts.

5.3.1 ETH

No additional risk.

5.3.2 renBTC

renBTC is controlled by a centralized entity, and malfunctions in the BTC custody would result in systemic risk. However, so far renBTC has mostly positive reputation, and thus the additional systemic risk currently seems to be low.

5.3.3 TriCrypto

The TriCrypto LP token is based on a one year old implementation of a relatively complex AMM algorithm [6]. In addition, the LP token is composed out of WBTC and USDT, both controlled by centralized entities.

However, by now the TriCrypto smart contract is relatively battle tested, and both WBTC and USDT proved resilience in tough market conditions. Hence, the additional systemic risk is relatively low.

Asset	Price Oracle	Liquidity	Additional risks	Score
ETH	Almost perfect	Very stable	None	A
renBTC	Very good	Stable	Low	B+
TriCrypto	Very good	Very stable	Low	A-
gOHM	Very good	Unstable	Governance risks	B-
GMX	Medium	Owned by the team	Governance risks	C
DPX	Owned by the team	Unstable	Governance risks	C

Figure 27: Qualitative analysis summary.

5.3.4 gOHM

The gOHM token is fully controlled by the Olympus Treasury multisig, who is currently governed by a 4 out of 8 multisig, without any execution delay.

Given the project is battle tested and operated for over a year, we classify the additional risk as medium.

5.3.5 GMX

The token smart contract allows the governance to mint additional tokens. Given the project is still at an early stage, the additional risk is high.

5.3.6 DPX

The token smart contract is non upgradable, however the team still holds around 50% of the total supply in a 2 out of 4 multisig. Given the project is still at an early stage, the additional risk is high.

5.4 Summary

We summarize the results of the qualitative analysis in Table 27, and propose to cap the debt ceiling of the assets as follows:

- Assets with score A could potentially be uncapped, however to mitigate price oracle attacks and other potential glitches, we recommend to cap it by 2 times the amount of VST DEX liquidity (on Curve Finance).
- Assets of class B should be capped to at most 20-30% of the entire VST target supply (*).
- Assets of class C should be capped to at most 10% of the entire VST target supply (*).

(*) *Target supply:* Given the early stage of Vesta Finance, the target supply need not be the current VST supply, as otherwise it would lift heavy restrictions on risky assets.

5.5 Best practices

5.5.1 Debt Ceiling.

Have debt ceiling for all assets. Use the quantitative and qualitative analysis to decide the max ceiling, but start with a lower ceiling and increase it gradually as it becomes more utilized. Such approach helps in mitigating systemic risks that stems from smart contract and price oracle bugs.

5.5.2 VST liquidity

Our quantitative simulation relies on the assumption that USDC can be instantly swapped to VST with relatively low slippage. This is possible due to the FRAX/VST liquidity provided on Curve Finance. As it is only possible to redeem VST to $1, and not the other way around, it is of paramount importance to make sure the VST liquidity is well maintained. Further, the currently VST liquidity structure heavily relies on FRAX, which could impose a systemic threat if FRAX gets de-peg.

It is a best practice to encourage additional sources of stable coin liquidity. Further, given the existing dependency in FRAX, the team should consider having a PSM module, which allows users to mint [4] and redeem 1 VST for 1 FRAX, up to a certain minting bound. While this is a common practice in leading stablecoins (e.g., DAI and FEI), it is somewhat controversial, and reasonable bounds should be set to mitigate systemic risks.

5.5.3 Stability pool

- *Unified stability pool liquidity.* Having one stability pool liquidity for all assets, or alternatively allowing different pools to backup each other in times of need, would help in mitigating bad debt.
- *Sticky deposits.* Introducing a delay in withdrawals of stability pool deposits could give some long term guarantees on its size. For the long run, the deposits are incentivised with liquidity mining program, but in times of crisis, e.g., when price oracle is lagging, rational depositors might decide to temporarily withdraw, and would not help to prevent bad debt.
- *Backup stability pool liquidity with a flashloan liquidation bot.* When the stability pool is empty, Vesta Finance mechanism allows it to distribute the underwater borrower debt among other borrowers in the system. While this provides nice security guarantees, it give rise to a complicated user experience for the borrowers. A way to mitigate it is to prepare a flashloan liquidation bot which will take a FRAX loan, convert it to VST, deposit it to the stability pool, and then arbitrage its liquidation reward, when possible. Naturally this would help only in part of the cases, and does not

[4] Potentially only in emergency mode and only for liquidations

constitute a replacement for the stability pool mechanism, as the flash-arbitrage liquidity is limited. However it could sometime mitigate the debt distribution to other borrowers.

5.5.4 Execution of partial liquidations

It is crucial to allow liquidators to liquidate user debt in chunks. In the current implementation, if a user has $1m debt, and the stability pool has smaller inventory, then it will not be able to even partially liquidates him. Further, if the user debt is $5m, a liquidator will have to liquidate the entire $5m in a single tx, which makes it impossible to instantly flash arb the seized collateral.

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