CHAOS LABS

Nexus Mutual V2 Mechanism Design Audit and Recommendations

A rigorous analysis of Nexus Mutual V2, focusing on market risk, protocol mechanism design, and risk parameter analysis.

Nexus Mutual

November 5th, 2023

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November 2023

Abstract

Nexus Mutual, a pioneering entity in decentralized insurance solutions, has identified a need for a comprehensive review and enhancement of its current tokenomic mechanisms. Recognizing the expertise of Chaos Labs in research and mechanism design, Nexus Mutual sought a collaboration to validate and potentially refine its protocol rigorously. This partnership aims to harness advanced research methodologies and intricate simulations to yield insights into risk parameters, financial robustness, and strategic optimizations.

Nexus Mutual, operating on the Ethereum blockchain, offers a wide spectrum of cover products, addressing various risk categories, and facilitates risk underwriting, claim evaluations, cover acquisitions, and the foundation of risk management entities.

A notable challenge that has emerged is the restricted exit options for members through Mutual's existing NXM token bonding curve mechanism. This limitation has been further exacerbated by the price disparity observed between the NXM token and its wrapped counterpart, wNXM, in secondary markets.

To address these challenges, Nexus Mutual envisions a protocol upgrade with specific goals:

- Harmonizing the price dynamics of NXM and wNXM.
- Ensuring members have a direct and equitable exit route from the protocol.
- Strategically capturing capital during member influxes.
- Augmenting book value for members with a long-term perspective.

Chaos Labs, in response, is poised to:

- Conduct a meticulous analysis and stress-testing of Nexus Mutual's Mechanism Design, assessing the protocol's performance across standard and extreme market scenarios.
- Fine-tune RAMM trading parameters, encompassing aspects like Target Liquidity, MCR Floor, ratchet velocity, oracle buffer, and TWAP duration.
- Formulate robust defenses against potential market manipulations.

This report is meticulously crafted as an independent document, offering a comprehensive backdrop for the ensuing recommendations. The report is systematically segmented into four pivotal sections:

1. A detailed exposition of Nexus Mutual's Mechanism Design and its overarching objectives.
2. A comprehensive delineation of the research methodology, accompanied by the structural framework of the agent-based simulations.
3. An analytical deep-dive into the outcomes derived from the Monte Carlo Agent-Based Simulations.

4. Recommendations, providing an exhaustive discourse on parameter suggestions underpinned by the rigorous research methodology and results interpretation.

Our collaborative research examines the nuances of high and low capitalization scenarios, each presenting challenges and implications. This document focuses on high-capitalization zones.

While we delve deeply into the V2 Nexus Mutual Mechanism Design, this paper is not intended as the definitive reference guide or specification. For a more comprehensive understanding of the mechanism, we direct readers to the whitepaper and technical specifications provided after this article. It is advisable to peruse those documents for a thorough grasp.

Contents

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Chapter 1

Nexus Mutual V2 Mechanism Design

1 Introduction

Nexus Mutual's extant bonding curve mechanism, employed for direct token transactions on its platform, has exhibited limitations, notably in facilitating member exits directly via the protocol. Concurrently, a discernible price disparity has emerged between the native token (NXM) and its wrapped counterpart (wNXM) in secondary markets.

2 Proposed Augmentation

The envisaged enhancement to the Nexus Mutual Protocol aims to:

1. Realign the price dynamics between NXM and wNXM.
2. Facilitate direct member exits from the protocol at equitable valuations.
3. Strategically capture capital during member influxes.
4. Augment book value, thereby benefiting long-term, aligned members.

The implementation is structured in a bifurcated approach:

1. Addresses scenarios where the Mutual is robustly capitalized.
2. Introduces functionalities tailored for scenarios of diminished capitalization, particularly as the Capital Pool nears the Minimum Capital Requirement (MCR).

2.1 Operation Dynamics

The refined mechanism concerns pricing NXM relative to the book value and market demand.

It's worth noting that the book value is different from market value. Market value reflects what investors will pay for the company in the open market.

In the context of Nexus Mutual, the term "Book Value" pertains to one NXM and is calculated as the total assets in the capital pool divided by the overall circulating supply of NXM tokens.

The operation dynamics are delineated as follows:

- The static Minimum Capital Requirement (MCR) floor is replaced, with MCR now contingent upon the Cover Amount.
- NXM price increases with each purchase and a decrement with each sale, orchestrated via internal Automated Market Makers (AMMs). Notably, Mutual emerges as the sole automated liquidity provider.
- NXM acquisitions from the protocol are inhibited below the Book Value to prevent member dilution. Consequently, the 'Above' pool predominantly functions within the range $(\textit{Book Value} \times (1 + \textit{oracle buffer}), \infty)$.
- Conversely, NXM sales to the protocol are curtailed above the Book Value. The 'Below' pool thus operates within the range $(0, \textit{Book Value} \times (1 - \textit{oracle buffer}))$.
- A 'ratchet' mechanism facilitates price discovery, progressively adjusting the NXM price towards a target.
- Liquidity adjustments within the AMM pools are automated, contingent upon predefined target liquidity thresholds and the Capital Pool's status vis-à-vis the MCR.
- For non-trading interactions, an internal price metric is employed, derived from the Time-Weighted Average Prices (TWAPs) of both pools.
- A circumscribed buffer around the Book Value is maintained to mitigate potential oracle-induced arbitrage scenarios.

2.2 Advantages of the Refined System

- Enhanced asset backing per token resultant from each transaction.
- Strategic capital capture above the Book Value and its release below.
- Introduction of an efficient buyback mechanism for value-accretive NXM burning.
- Decoupling of market dynamics from the Mutual's risk management, ensuring price stability.
- Facilitation of arbitrage opportunities between wNXM and NXM, thereby reconciling price disparities.
- Through adept parameter adjustments, diverse long-term outcomes can be realized, aligning with market valuations or establishing the Mutual as a price determinant.

2.3 Potential Limitations

- Cognitive fixation on the Book Value, particularly concerning the downward ratchet in scenarios where NXM price surpasses the Book Value.
- The intricate parameter matrix might engender complexity, rendering outcomes unpredictable, especially post-launch.
- The ultimate system behavior remains intrinsically tethered to market dynamics.

2.4 V2 Mechanism Objectives and Considerations

1. Ensuring Growth and Sustainability of the Mutual
   - It is imperative for the mutual's growth that new capital can seamlessly integrate into the system.
   - Upon entry, such capital must be retained within the mutual, ensuring a balance where the captured capital is at least equivalent to the released amount, given a symmetrical transactional pressure.
2. Safety and Claims Management
   - The mutual must be able to honor its claims, even under the most adverse conditions.
3. Technical Feasibility and Adaptability
   - The system's architecture should prioritize gas efficiency and predominantly operate on-chain.
   - Post-deployment, there should be flexibility to refine and iterate the mechanism as needed.
4. Liquidity on Exit
   - Members should be allowed to liquidate their holdings within a reasonable timeframe.
   - Departing members should not be forced to transact at values substantially below the Book Value of their tokens.
5. Value Proposition for Members
   - Members should witness tangible benefits from favorable profit and loss outcomes.
   - In scenarios where the mutual prospers, value should be channeled to NXM holders, with a particular emphasis on active participants.

2.5 Potential Pitfalls to Circumvent

1. Extractive Arbitrage
   - The entry and exit mechanisms should be fortified against exploitative strategies. Users should only be able to siphon value from the system with proportionate contributions, ensuring the mutual's overall well-being remains uncompromised.
2. Interest Misalignment
   - No member, especially those contributing value, should find themselves at a disadvantage due to the implementation of the new tokenomic framework.
3. Price Disparity Concerns (wNXM gap)
   - A minimal variance should exist between the open market price of wNXM and the Mutual's valuation of NXM. Exceptions can be made only to safeguard against potential adversarial strategies.

4. Dilution Safeguards
    - The mutual should exercise caution against undue dilution of existing members. Any action, such as minting or burning of NXM, that potentially diminishes the Book Value for current members should be overwhelmingly in the mutual's broader interest or be offset by a corresponding action that enhances the book value.
5. Equitable Exit Strategy
    - In situations characterized by a mass exodus of capital, the system should ensure that early exits do not disproportionately benefit at the expense of those who exit later.

3 The Ratcheting Automated Market Maker (RAMM)

3.1 Modification of the MCR Floor

The MCR floor parameter, previously set at 162,425 ETH, is recommended to be adjusted to 0 ETH. After this implementation, the MCR will be defined as:

$$MCR = \frac{TotalActiveCoverAmount}{4.8}$$

3.2 Introduction of Dual RAMM Pools

We advocate for the replacement of the existing Bonding Curve with two distinct RAMM pools:

Above Pool This pool is responsible for minting NXM tokens in exchange for ETH.

- Accepts ETH deposits and disburses NXM.
- Establishes an NXM price floor, calculated as:

$$NXM_{floorPrice} = (1 + OracleBuffer) \times BookValue$$

- This ensures no NXM minting from the protocol below this threshold.
- Price is instantaneously driven upwards by user NXM purchases and gradually reduced towards the price floor via the ratchet mechanism.
- ETH liquidity in the pool augments with user deposits and is automatically reduced when necessary.

Below Pool
This pool oversees the burning of NXM tokens in return for ETH.

- Accepts NXM and disburses ETH.
- Sets an NXM price ceiling, calculated as:

$$NXM_{ceilPrice} = (1 - OracleBuffer) \times BookValue$$

- This ensures no NXM redemption from the protocol above this threshold.
- Price is instantaneously driven downwards by user NXM sales and gradually increases towards the price ceiling via the ratchet mechanism.
- ETH liquidity in the pool diminishes with user withdrawals and is automatically supplemented, contingent on the Capital Pool exceeding the sum of the Minimum Capital Requirement (MCR) and the target liquidity for the below pool.

3.3 Parameter Definitions and Exemplary Values

Parameter	Description
$oracle\_buffer$	Margin to allow for Oracle lag when calculating Book Value in ETH. Secondary function - create spread.
liq	ETH liquidity in the pools
liq_NXM_a	Notional NXM reserve in the Above Pool
liq_NXM_b	Notional NXM reserve in the Below Pool
$target\_liq$	Target ETH liquidity in the pools
liq_speed_a	Max amount of ETH that is removed from the Above Pool daily
liq_speed_b	Max amount of ETH that is added to the Below Pool daily
$ratchet\_target$	Value towards which the spot_prices move
$ratchet\_speed\_a$	Daily decrease in spot_price_a price when above the target value
$ratchet\_speed\_b$	The daily increase in spot_price_b price when below target value

3.4 RAMM Pools Mechanisms

The RAMM pools' operational intricacies are delineated below, supplemented with hypothetical scenarios for clarity:

Below Pool Initialization
An initial liquidity, $open\_liq_b$, is provisioned to the pool. This is likely to differ from $target\_liq_b$. The NXM amount within the pool is determined using an opening price, which is set to be 90% of the wNXM price at launch, ensuring that:

$$liq\_NXM_b = \frac{liq_b}{spot\_price_b}$$

This assumes that the wNXM price remains below the Book Value at launch. Adhering to the Uniswap formula, the trade invariant is established as:

$$liq_b \times liq\_NXM_b = k_b$$

Below Pool Ratchet Up

The ratchet mechanism ensures that the NXM price within the pool gravitates towards a predetermined maximum price, $ratchet\_target_b = (1 - OracleBuffer) \times book\_value$, over time. This mechanism is proposed to be a daily price increase, expressed as a percentage of the Book Value.

Below Pool Liquidity Injection

The system periodically assesses whether the ETH liquidity in the pool, liq_b, deviates from the target liquidity, $target\_liq_b$. If a deficit is detected, the system prompts a liquidity augmentation process contingent on certain conditions.

Above Pool Initialization

An upfront liquidity, denoted as liq_a, is provisioned to the pool. The NXM value within the pool is initially ascertained using an opening price, calculated so that the internal price ip is equal to the latest Bonding Curve price at launch:

$$ip = ip_a + ip_b - BV$$

At initialization the internal prices of the pools equal their opening prices: $ip_a = spot\_price_a$, $ip_b = spot_price_b = 90\%$of wNXM price and the internal price should equal the Bonding Curve price $ip =$ Bonding Curve price. Therefore it follows for the opening price of the Above Pool:

$$spot\_price_a = ip - spot\_price_b + BV$$

This aims for the wNXM price to remain below the Book Value at launch.

The NXM amount in the pool, liq_NXM_a, is then derived as:

$$liq\_NXM_a = \frac{liq_a}{spot\_price_a}$$

Adhering to the Uniswap formula, the trade invariant is established as:

$$liq\_NXM_a \times liq_a = k_a$$

Above Pool Ratchet Down

The ratchet mechanism ensures that the NXM price within the pool gravitates towards a predetermined minimum price, $ratchet\_target_a = (1 + OracleBuffer) \times book\_value$, over time. This mechanism is proposed to be a daily price increase, expressed as a percentage of the Book Value.

Above Pool Liquidity Removal

The system periodically assesses whether the ETH liquidity in the pool, liq_a, deviates from the target liquidity, $target\_liq_a$. If an excess is detected, the system prompts a liquidity reduction process.

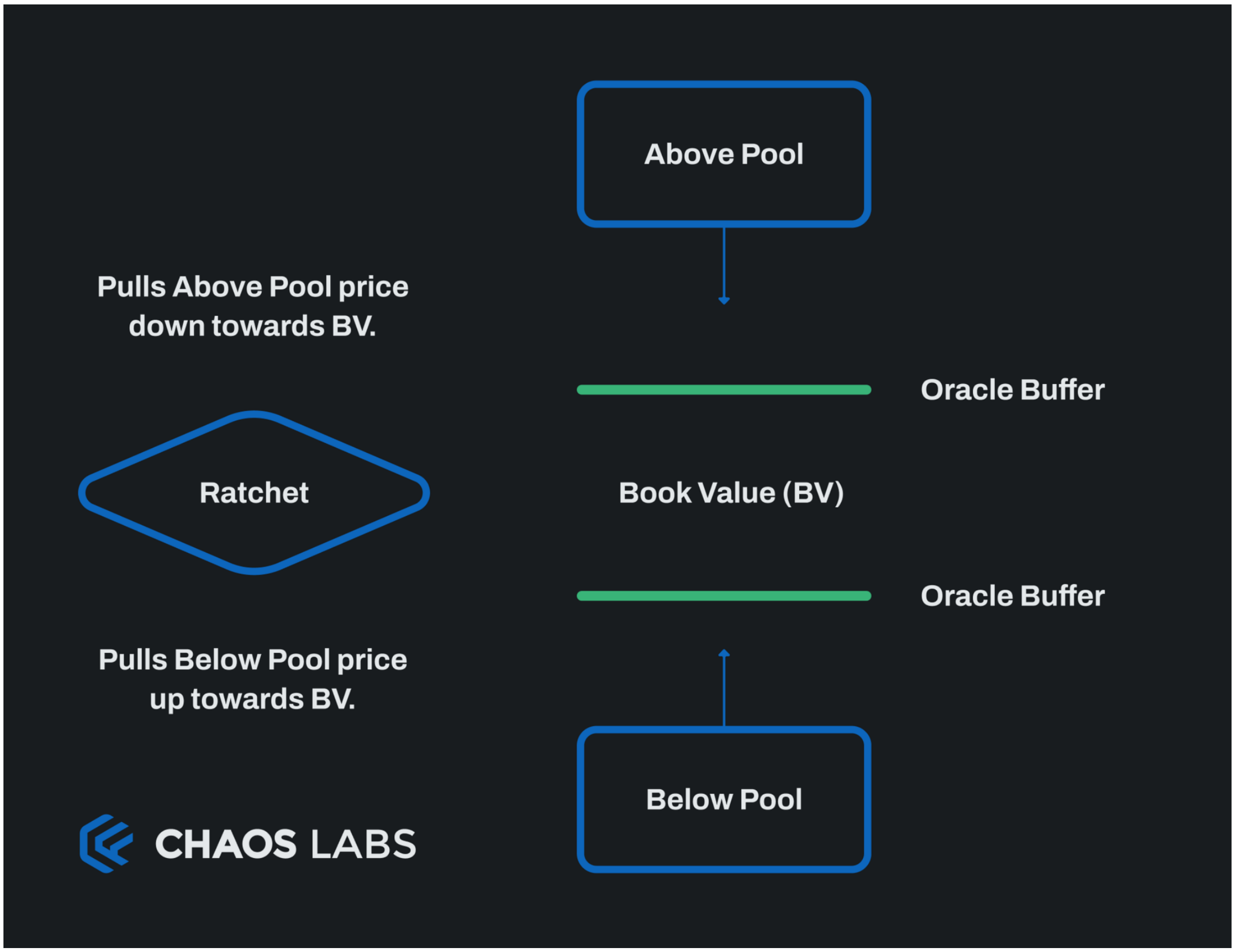

Figure 1.1: Source: Nexus Mutual V2 Tokenomics

Chapter 2

Agent-Based Monte Carlo Simulations Architecture

1 Simulations for Dynamic Systems

1.1 Introduction to Simulations

Simulations serve as a bridge between theoretical models and real-world applications, particularly in blockchain. They either interface directly with blockchain applications or emulate on-chain protocols. These simulations are grounded in mathematical assumptions, which are derived from the interplay between protocol parameters and exogenous variables. Collectively, these assumptions form a model, facilitating a deeper comprehension of the protocol's operational dynamics.

1.2 The Rationale Behind Simulations

Analytical solutions, which employ closed-form mathematical methods or equations, are apt for models with straightforward relationships. However, the intricate nature of most real-world systems often renders such solutions impractical. In these instances, simulations emerge as the preferred tool. Through simulations, a computer numerically evaluates a model, approximating the desired real-world characteristics of the model.

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1.4 Challenges in Simulation

Despite their evident utility, simulations are not ubiquitously employed. The primary deterrent is the intricacy involved in crafting high-fidelity simulations. This complexity is accentuated in the domain of Decentralized Finance (DeFi) due to its nascent stage, limited historical data, and evolving dynamics. Broadly, the challenges in simulation can be categorized into two domains: precision in modeling and scalability. The subsequent sections elucidate the system we've devised to address these challenges, particularly on scalability.

1.5 Chaos EVM Simulations

The Chaos simulation environment is a testament to our innovative approach. This python-based, agent-centric simulation environment commences each simulation with a data synchronization phase. This phase entails the extraction and assimilation of both contemporary and historical mainnet data, agent elasticity, protocol liquidity, and risk parameters. Notably, Chaos simulations have demonstrated a remarkable performance, boasting a 250-fold enhancement in latency and CPU efficiency compared to on-chain simulations.

1.6 Agent-Based Simulation: A Deep Dive

In the simulation landscape, an agent is conceptualized as an autonomous entity capable of perceiving its environment and making informed decisions. These agents, over time, can adapt and refine their behaviors. Within the DeFi simulation framework, agents mimic users, encompassing roles such as traders, arbitrageurs, and liquidity providers. The essence of agent-based simulation lies in the dynamic interactions between these agents, shaped by the ever-evolving environment.

1.7 Monte Carlo Simulations

Monte Carlo simulations adopt a probabilistic approach. For variables with inherent uncertainty, the simulation assigns a spectrum of random values, computes results for each, and subsequently aggregates these results to deduce an estimate. In the context of DeFi platforms like Nexus Mutual, each simulation iteration employs a unique, randomly generated price trajectory, with agent-based models simulating the reactions from protocol agents and secondary markets.

1.8 The Merits of Agent-Based Monte Carlo Simulations

While conventional financial models might solely rely on price dynamics, our focus extends to simulating potential protocol losses. These losses are contingent not just on price fluctuations but also on the intricate interactions between agents. By updating the actions of these entities in real time during simulations, we can approximate the expected value of protocol losses. The subsequent sections delve deeper into the methodologies underpinning our Monte Carlo agent-based simulations and the statistical framework that ascertains the value at risk for specific parameter configurations.

1.9 Nexus Mutual Simulation Environment

As the launch of the RAMM nears, it becomes paramount to gauge its efficacy, particularly within high liquidity zones. To this end, we embarked on a series of simulations, each tailored to simulate specific scenarios the protocol might confront.

1.10 Simulation Catalog

Simulations, in their essence, are composed of agents and scenarios. Each agent, with its unique attributes and behaviors, interacts within a predefined scenario, leading to many outcomes. Below, we delve into the catalogs of both agents and scenarios.

1.11 Simulation Scenarios

Our simulations were concentrated around three pivotal scenarios:

Liquidity Exiting at Launch

The team possesses insights into the anticipated volume of NXM that will be offloaded to the protocol upon its inauguration. This is termed as the “Exiting Liquidity”. The preliminary phase is characterized by an augmented liquidity of 43,835 ETH, supplemented by a daily injection of 1500 ETH per day, a ratchet speed of 50%, and a projected exodus of roughly 2 million NXM.

Large Book Value Price Drop Extrinsic to the RAMM

This scenario envisions the ramifications of an impending claim. Here, agents are equipped with foreknowledge about imminent fluctuations in the book value, typically a week or two in advance.

Upside Scenarios in the Above Pool

This scenario probes the system’s robustness when there’s a surge in participation. The crux is balancing capital assimilation and price escalation, contingent on diverse liquidity withdrawal and downward ratchet velocities. In scenarios marked by pronounced upside tendencies (i.e., a significant influx of ETH into the above pool), two primary outcomes are discerned:

1. An escalation in the Price ($spot\_a$).
2. Enhanced capital assimilation by the mutual.

If we predicate that participants are predisposed to invest in ETH irrespective of its price, then from a capital capture vantage point, the entirety of the ETH will be seamlessly integrated into the pool. Conversely, if a price threshold exists, beyond which participants exhibit reluctance, the protocol might grapple with capital deficits, especially if the price experiences an abrupt surge.

1.12 Agent Catalog

Agent Role	Description
NXM Holders seeking exit liquidity	Agents that hold NXM and are looking to sell it but haven't done so until now because of lack of liquidity
Arbitrageurs	Members of the protocol that mint/redeem NXM from the RAMM based on secondary market prices. When $p\_spot > p\_a$, arbitrageurs mint NXM from the above pool and sell them in spot markets. When p_spot < p_b, arbitrageurs buy NXM from spot markets and sell them in the below pool.
Liquidity Providers	Agents that provide wNXM liquidity in secondary markets like Uniswap LPs.
Informed Traders	Traders who may have information on events that have an impact on the Book Value, like upcoming claims

Figure 2.1: Source: Chaos Labs Agents Catalog

1.13 Simulation Examples

Let's delve into a couple of specific examples that were executed. These examples will provide a clearer understanding of how different parameters and assumptions can lead to varied outcomes.

1.14 Example 1: Ratchet Speed Dynamics

Objective

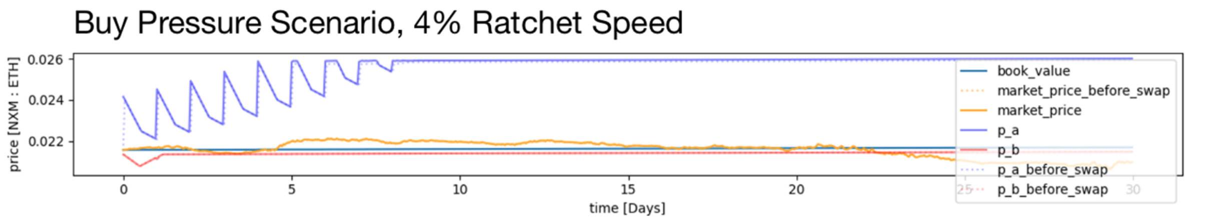
To understand the impact of different ratchet speeds on the capital captured by the capital pool.

Parameters & Assumptions

- Daily ETH inflow: 250 ETH (as long as the price remains below 1.2x BV)
- Ratchet speeds tested: 10% vs. 4%

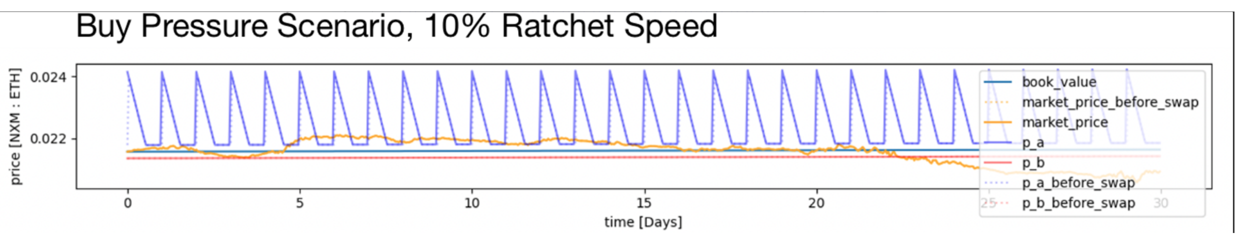
4% Ratchet Speed

With a slow ratchet speed, the asset's price remains high for a longer period. This rapid adjustment could deter some participants from entering, as the price might surpass their acceptable threshold sooner. As a result, the capital pool might capture less ETH over the 30 days.



10% Ratchet Speed

A faster ratchet speed means the price adjusts more quickly towards the target. This could attract more participants to contribute ETH, as the above pool price drops very quickly below their threshold, and more liquidity is available. Consequently, the capital pool might capture a more substantial amount of ETH over the same 30 days.



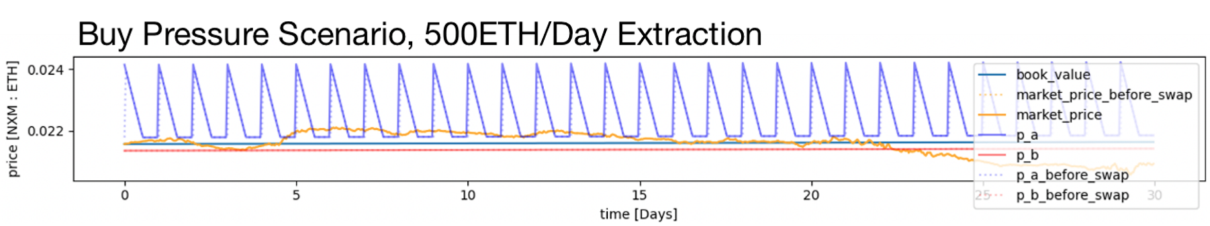
1.15 Example 2: Liquidity Removal Dynamics

Objective

To analyze the effects of liquidity removal rates on price dampening and capital capture.

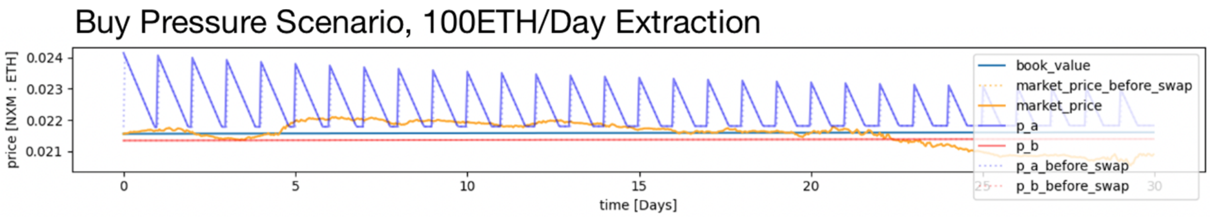
Parameters & Assumptions

- Daily ETH inflow: 250 ETH (as long as the price remains below 1.2x BV)
- ETH Extraction Rates: 100ETH vs. 500ETH



Faster Liquidity Removal

When liquidity is removed from the pools at a rate faster than its inflow, the dampening effect on the price is minimal. This means the price can experience more volatility, potentially leading to less capital being captured as the price might move beyond participants' acceptable range.



Slower Liquidity Removal

Conversely, if liquidity is removed more slowly than it enters the pools, the price experiences a dampening effect. This stability can attract participants, allowing the mutual to capture more capital as the price remains within a more acceptable range for a longer duration.

Conclusion

These examples underscore the importance of carefully calibrating protocol parameters. Even slight adjustments can lead to vastly different outcomes, emphasizing the need for thorough simulations before implementing changes in a real-world setting.

Chapter 3

Simulations Results and Analysis

1 Elaborating on the Simulation Environment

1.1 Simulation Assumption: Convergence of wNXM and NXM Prices

Premise

The simulation operates on the foundational belief that the prices of wNXM (Wrapped Nexus Mutual) and NXM (Nexus Mutual) will, over an extended period, gravitate towards one another and eventually align.

Underlying Factors

1. **Deep Liquidity Around Book Value** - The RAMM (Ratchet Automated Market Maker) mechanism ensures a consistent and profound liquidity pool centered around the book value. This deep liquidity acts as a magnet, pulling the prices of both wNXM and NXM towards the book value.
2. **Arbitrage Opportunities** - Any significant divergence between the prices of wNXM and NXM will create arbitrage opportunities. Efficient market participants will capitalize on these price discrepancies, buying the undervalued token and selling the overvalued one, pushing the prices toward convergence.
3. **RAMM's Role** - The RAMM, by design, facilitates a stable and predictable liquidity environment. Its automated mechanisms, such as the ratchet function, ensure that liquidity is maintained around the book value, further reinforcing the convergence of wNXM and NXM prices.

Implication

This convergence assumption is crucial for the simulation as it provides a stable foundation upon which other variables and parameters can be tested. It ensures that the simulation results are grounded in a realistic market behavior expectation, where the two tokens' prices do not diverge significantly for extended periods.

In our exploration of volatility, we initially dissect three distinct scenarios:

1. **Launch Dynamics** - Encompassing NXM sales ranging from 10-50% of the circulating supply.

2. **Book Value Fluctuations** - Analyzing the implications of sudden decreases in Book Value.

3. **Buy Pressure** - Investigating the impact of strong buy pressure on the Capital Pool and NXM price.

Additionally, we've constructed a model to identify parameters that will ensure the internal TWAP remains impervious to potential market manipulations. Let's proceed by delving deeper into each of these simulations.

2 Simulation: Launch Scenario with Secondary Market Dynamics

Initial Conditions

- **Secondary Market Price** - Set at 0.018 ETH, reflecting the current Uniswap rate. The liquidity positions are asymmetrical, mirroring the present Uniswap liquidity profile.
- **Book Value** - Established at 0.021 ETH
- **Initial Pool Prices** - The starting prices for the above and below pools are determined in relation to the internal price.
- **Initial ETH Budget** - Set at 43,800 with a rapid ratchet speed of 50% and a swift liquidity injection of 1500 ETH/day. Post this phase, the ratchet speed and liquidity injection will adhere to the parameters defined in the sweep (default settings: 4% ratchet speed, 100 ETH/day liquidity injection).
- **Time Frame** - Every run simulates 365 days

Secondary Market Liquidity Profile During Launch

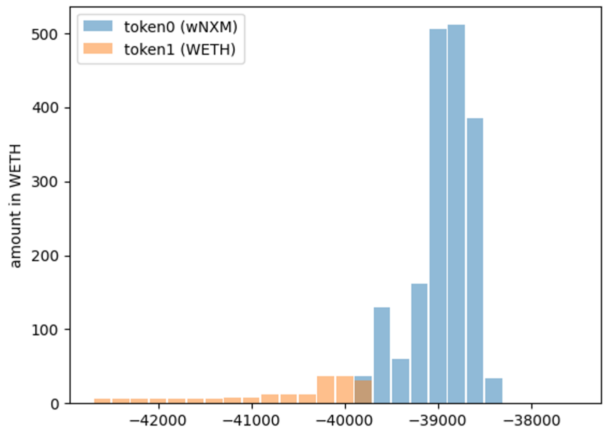


Figure 3.1: Initial Liquidity Configuration at Launch. Note the delta between WETH and wNXM liquidity.

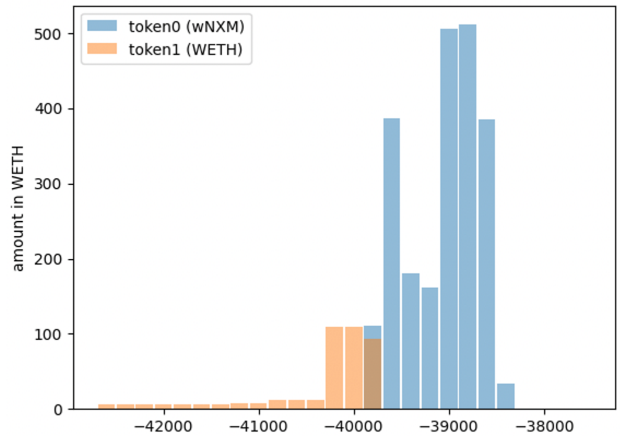


Figure 3.2: The LP agent has augmented liquidity near the prevailing price to accommodate for arbitrage with Centralized Exchanges.

Parameters under examination include:

- **Minimum Sell Price Percentage** - We assume NXM holders will sell their NXM tokens only at prices close enough to the current Book Value. The minimum price range as a percentage of the Book Value that was tested is from 86% to 98%.
- **NXM Sale Volume** - This is the amount of NXM tokens that will be sold by NXM holders immediately after launch, spanning from 10% to 50% of the circulating supply.
- **Key Heatmaps** - Duration until the completion of NXM sales.
- **Price Convergence Rate** - This is the daily rate at which secondary market prices move towards the Book Value. We examined convergence rates of 2% and 5% (applied if the secondary market is utilized). We also tested the case of full price convergence immediately with RAMM launch, i.e., 100% convergence rate.

A Note about the Activity Intervals, an Incremental Analysis

The daily volume that can be swapped in the RAMM depends on the time between the swaps and how much time the RAMM mechanisms have to pull it back toward the target price and liquidity.

For example, if there is a swap in daily increments, each day, we assessed the alterations induced by the ratchet and liquidity injection on the RAMM pool and the volume of NXM that could be sold into the below pool for a better price than 95% of the book value. This methodology allowed for selling approximately 200 ETH worth of NXM daily. Subsequently, we would inject 200 ETH/day into the RAMM to restore the target liquidity (L_{target}) to 5000 ETH.

However, what if we were to assess the system in smaller time increments? By checking hourly, we can sell roughly 62 ETH worth of NXM. Repeating this process 24 times a day results in a total daily sale of 1488 ETH. This discrepancy arises because when attempting to sell daily, the gap between the ratchet price and the optimal sell price is more pronounced. However, due to the AMM's constant product curve, the volume we can sell doesn't increase linearly.

In contrast, when assessing every hour, the ratchet still endeavors to align the below pool price with the target price. As a result, we can sell a reduced amount (62 ETH as opposed to 200 ETH). Simulations below were carried out with one-hour intervals, as this granularity provides an accurate approximation of continuous RAMM and agent activity and allows running full-year simulations.

2.1 Selling 2M NXM at a Minimum of 95% of Book Value into RAMM only without Arbitrage - Completed the sale in 27 days

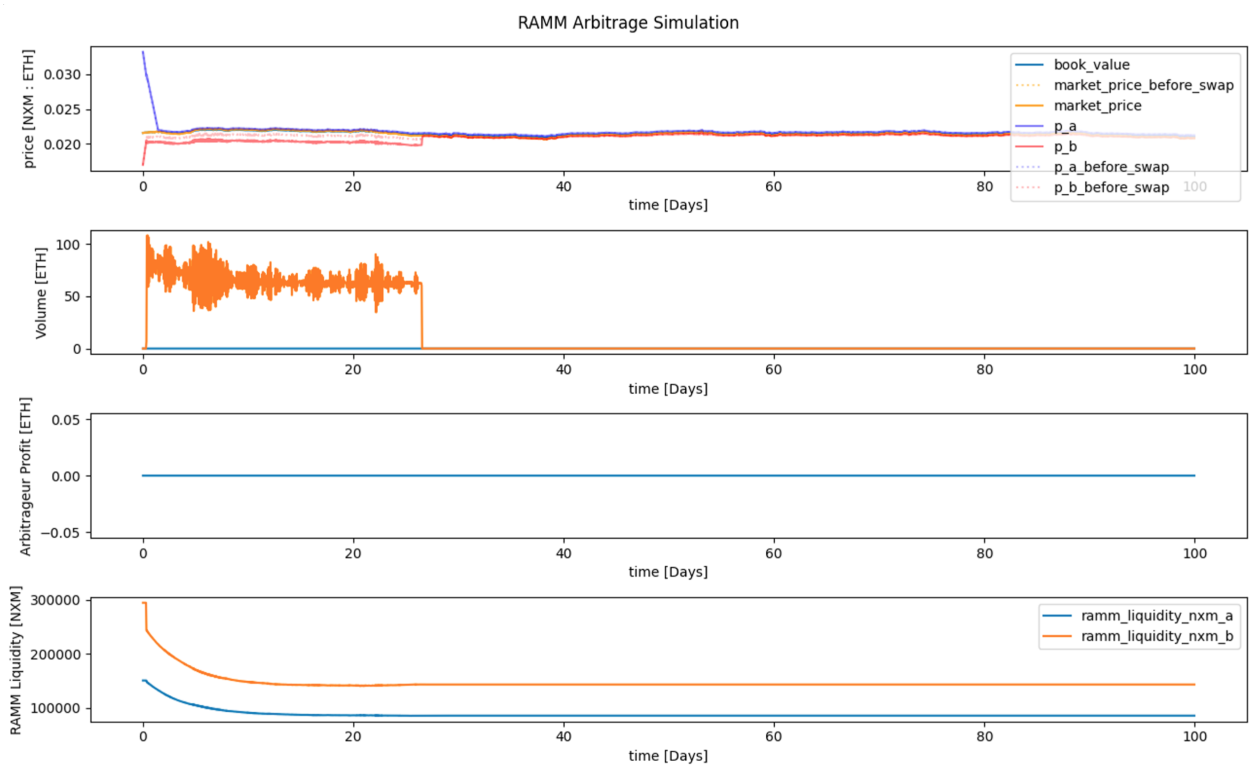


Figure 3.3: A single scenario shows the activity in the RAMM. NXM Exit Liquidity is sold directly to the RAMM for at least 95% of the Book Value when the secondary market price equals the Book Value and no arbitrage trading can be made. We can see that after 27 days, the whole NXM amount is sold when the trading volume drops to zero, and the below pool price remains at BV-Buffer.

2.2 Selling 2M NXM at a Minimum of 95% of Book Value with Arbitrage - Completed the sale in 68 days

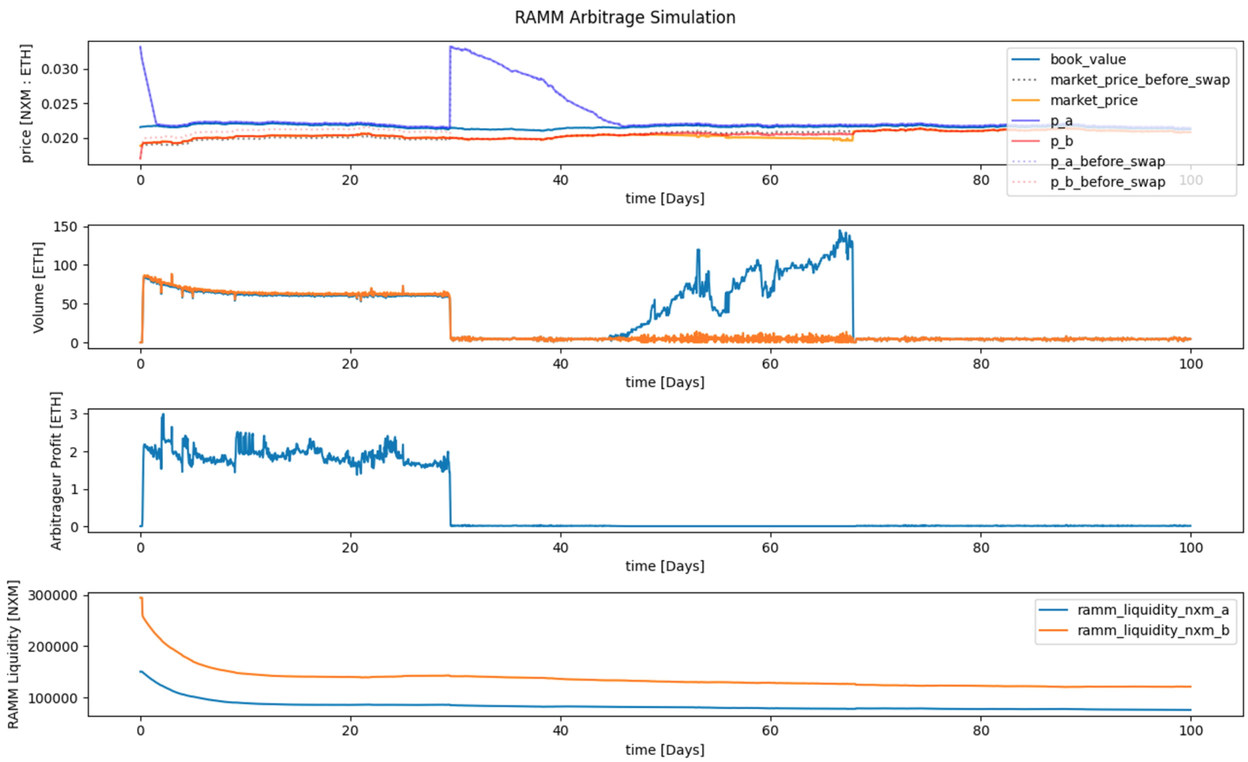


Figure 3.4: A single scenario shows the activity in RAMM and the secondary market if NXM Exit Liquidity is sold directly to the RAMM or the secondary market for at least 95% of the Book Value when the secondary market price is initially below the Book Value so that arbitrage trading can be made. Only starting at day 45 can NXM be sold into the RAMM and Secondary Market; before that, the Arbitrage pulled the below pool price and secondary market price below 95% of Book Value, and the NXM Seller was not willing to sell. Over time, a higher volume of NXM can be sold into the Secondary Market (blue line in volume plot) because the price gap between the converged secondary market price and the minimum sell price is bigger. We can see that after 68 days, the whole NXM amount is sold when the trading volume drops to zero, and the below pool price remains at BV-Buffer. By approximately day 30, the initial ETH budget is exhausted, and the liquidity injection and the ratchet speed parameters change to their default settings.

2.3 Selling 2M NXM at a Minimum of 85% of Book Value with Arbitrage - Completed the sale in 10 days

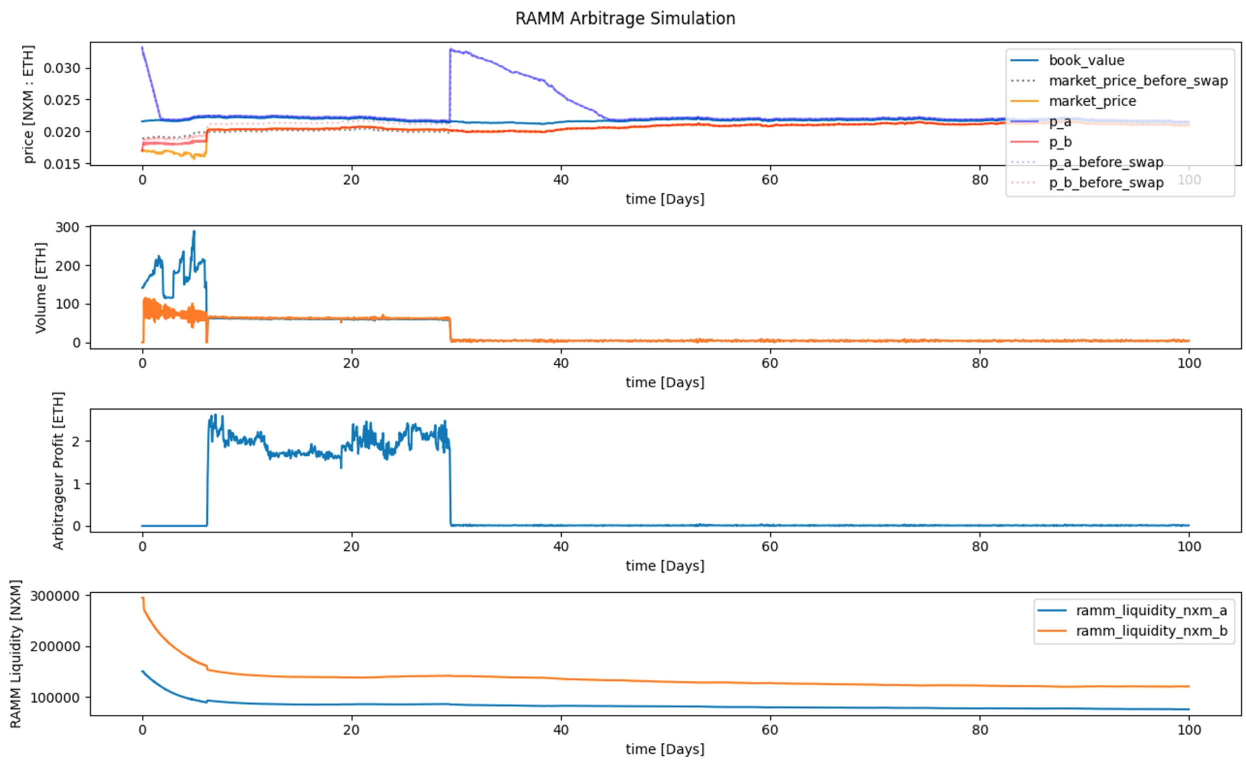


Figure 3.5: A single scenario shows the activity in RAMM and the secondary market if NXM Exit Liquidity is sold directly to the RAMM or the secondary market for at least 85% of the Book Value when the secondary market price is initially below the Book Value so that arbitrage trading can be made. After the Arbitrageur closes the price gap between the below pool and the Secondary Market, their prices are still above the minimum sell price, and NXM can still be sold into both. We can see that after ten days, the whole NXM amount is sold when the trading volume in the RAMM (blue line) drops to the same level as in the secondary market (orange). By approximately day 30, the initial ETH budget is exhausted, and the liquidity injection and the ratchet speed parameters change to their default settings.

2.4 100% convergence from secondary market price to book value

The heatmap below represents a sweep on the following parameters:

- Minimum Sell Price Percentage - Ranges from 86% to 98% of Book Value.
- NXM Sale Volume - Ranges from 10% to 50% of the circulating supply.
- Daily Price Convergence Rate - 2%, 5% and 100%.

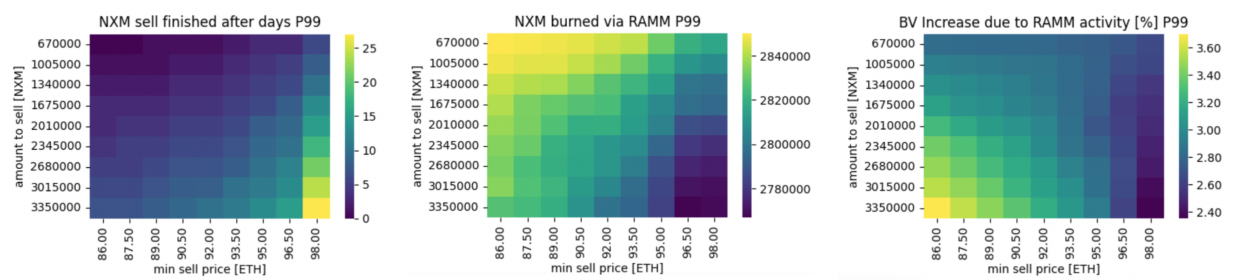


Figure 3.6: The above heatmaps show measurements of key metrics for different assumptions in the minimum sell price as % of Book Value and the total amount of NXM tokens sold, all assuming that secondary wNXM and NXM prices converge at launch. Within the ranges scanned, we can see that: 1. The number of days it takes for the entire Exit Liquidity to be absorbed by the RAMM is sensitive to both the minimum price NXM holders are willing to sell and the amount of NXM tokens that will be sold at launch 2. Under the most extreme assumptions of 50% of the circulating supply being sold to the NXM at 98% of the Book Value, the total amount of NXM can be absorbed by the RAMM within 25 days. In the vast majority of the scenarios, the full amount can be absorbed by the RAMM under 15 days. 3. The increase in Book Value as a result of the liquidity exiting is between 2.4%-3.6%

2.5 5% convergence from secondary market price to book value

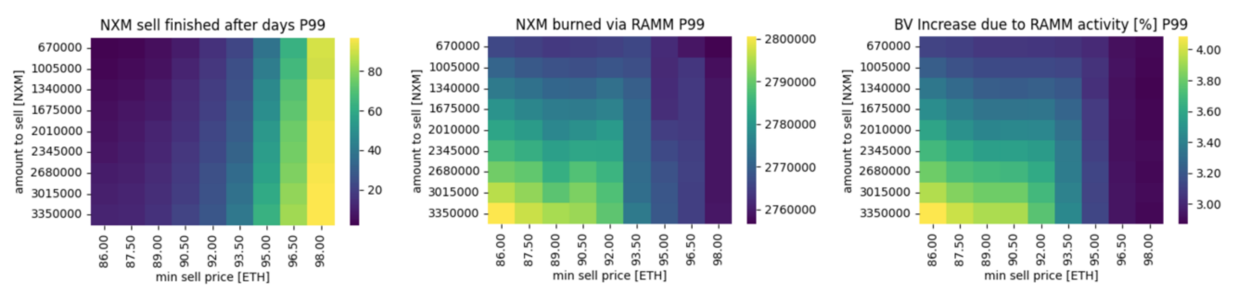


Figure 3.7: The above heatmaps show measurements of key metrics for different assumptions in the minimum sell price as a percent of Book Value and the total amount of NXM tokens sold, all under the assumption of a daily increase in secondary market price at 5% of Book Value. Within the ranges scanned, we can see that: 1. The number of days it takes for the entire Exit Liquidity to be absorbed by the RAMM is very sensitive to the minimum price NXM holders are willing to sell at, but not so much sensitive to the amount of NXM tokens that will be sold at launch 2. Under the most extreme assumptions of 50% of the circulating supply being sold to the NXM at 98% of the Book Value, the total amount of NXM can be absorbed by the RAMM within 100 days 3. The increase in Book Value as a result of the liquidity exiting is between 3%-4%

2.6 2% convergence from secondary market price to book value

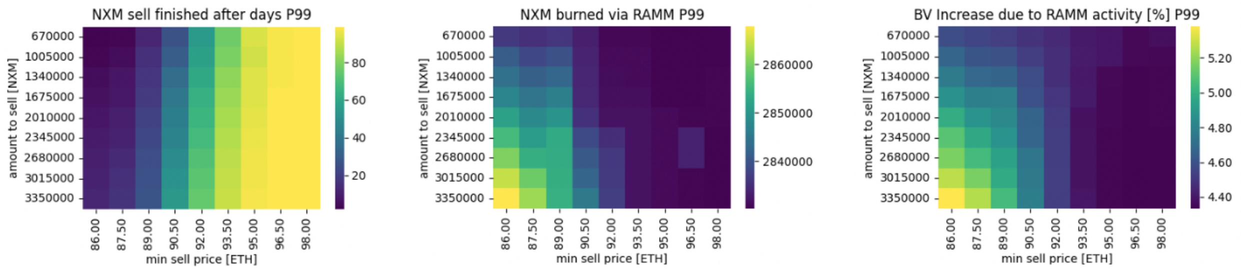


Figure 3.8: The above heatmaps show measurements of key metrics for different assumptions in the minimum sell price as a percent of Book Value and the total amount of NXM tokens sold, all under the assumption of a daily increase in secondary market price at 2% of Book Value. The main observations: 1. As the daily convergence is slower than the previous scenario of a 5% daily price convergence rate, arbitrageurs take a larger part of the trading volume, and so, the time it takes for liquidity to exit is typically longer, and more NXM tokens are burned. 2. The worst-case scenario of selling the entire Exit Liquidity is still 100 days, and the increase in the amount of NXM burned under such assumptions is only around 3% higher than under the assumption of a 5% daily price convergence rate

3 Simulation: Book Value Drop Scenarios

To analyze the behavior of the RAMM under scenarios of claims leading to Book Value drops, we have examined three possible impact levels on the Book Value - 2%, 5%, and 20%. The first two are likely scenarios in cases of significant claims, and the latter is considered a doomsday scenario. While the existence of claims is public knowledge, we also examined specific cases where an informed trader holds information not known to others about an expected Book Value drop. The main difference between the two scenarios is that when there is a publicly known event that will cause a decrease in book value, secondary market prices are expected to reflect the discounted value immediately. In cases where only the informed trader knows an upcoming event, secondary markets will reflect the full book value price until the event occurs. We used ten days as the canonical period between the knowledge of an upcoming event and the event when the Book Value drops.

3.1 Book Value Drop with Secondary Market Arbitrage

Objective

To simulate the market's response when it's aware of an impending drop in BV, creating an arbitrage opportunity between the secondary market and the RAMM.

Key Points

- **Anticipated Behavior** - Arbitrageurs exploit the price discrepancy between the secondary market and the RAMM.
- **Arbitrage Loop** - The user buys wNXM from the secondary market at a lower price and sells it into the Below Pool at a higher price.

- **Secondary Market Dynamics** - The liquidity profile in the secondary market is assumed to be symmetrical around the projected Book Value price.
- **Parameters to Explore** - Liquidity injection, ratchet speed, and their effects on ETH lost due to the upcoming BV change.

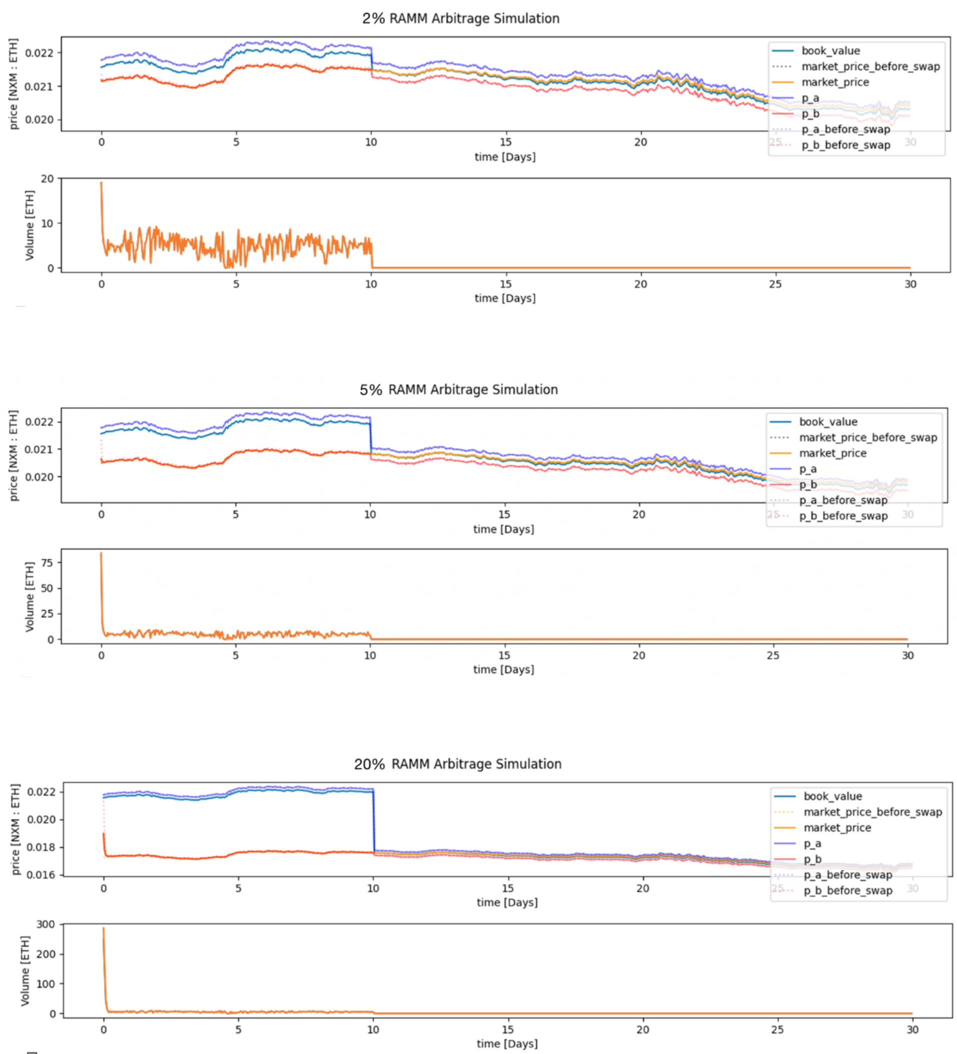


Figure 3.9: A single scenario showing the activity in RAMM and the secondary market if arbitrageurs act based on knowledge of an upcoming 2%, 5%, and 20% drop in the Book Value. In the first graph, we can see the below pool price is pushed below the Book Value before the price drops and remains at that price level. As can be seen on the graphs showing the traded volume, the majority of the arbitrage volume is traded immediately with the knowledge of the upcoming claim. It is evident that as the expected price drop is bigger, more arbitrage volume is traded throughout the ten days between the knowledge of the upcoming claim and the Book Value drop. The reason lies in the price convexity of the constant product price function of the RAMM.

ETH lost due to upcoming BV change Sweeps: total loss within ten days

- **ETH Lost heatmap** - Shows the extent of ETH loss resulting from arbitrage activities within the ten days leading up to the market drop.
- **Capital Pool ETH Captured heatmap** - Shows how much ETH is gained by the RAMM through buy-arbitrage opportunities with the Above Pool. These opportunities primarily occur after the Book Value drop.
- **Capital Pool ETH Removed heatmap** - Shows how much ETH is removed from the RAMM through sell-arbitrage opportunities with the Below Pool. For the ten days before the Book Value drop, the system is in a state that allows significant sell-arbitrage opportunities.

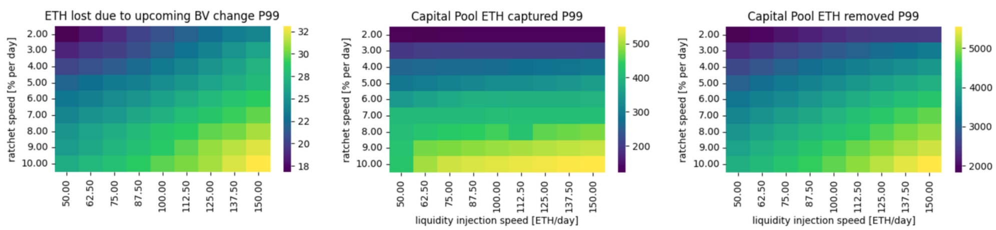


Figure 3.10: The impact of arbitrageurs acting on knowledge of an upcoming 2% Book Value drop translates into a net loss to the capital pool between 18ETH-32ETH across the tested ranges of liquidity injection speed and ratchet speed.

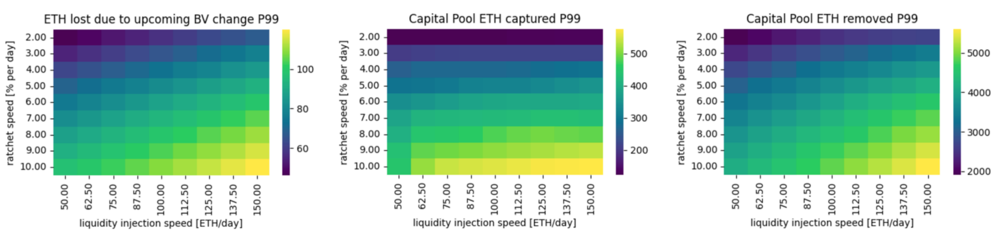


Figure 3.11: The impact of arbitrageurs acting on knowledge of an upcoming 5% Book Value drop translates into a net loss to the capital pool between 50ETH-120ETH across the tested ranges of liquidity injection speed and ratchet speed.

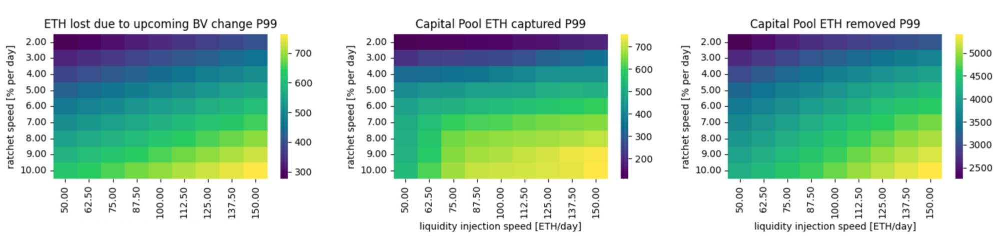


Figure 3.12: The impact of arbitrageurs acting on knowledge of an upcoming 20% Book Value drop translates into a net loss to the capital pool between 300ETH-750ETH across the tested ranges of liquidity injection speed and ratchet speed. In all value drop scenarios, we can see that the amount of lost ETH is sensitive to the liquidity injection rate and the ratchet speed in the tested range.

3.2 Book Value Drop with NXM Sell Informed Trader

Objective

To understand the behavior of an informed trader who anticipates a drop in the BV (Book Value) due to an impending claim or event.

Key Points

1. **Anticipated Behavior** - The informed trader sells NXM before the anticipated drop and buys back at the decreased prices.
2. **Liquidity Search** - The trader sells only into the Below Pool, as we are interested in the maximal loss of the protocol.
3. **Parameters to Explore** - Liquidity injection, ratchet speed, and their effects on ETH lost due to the upcoming BV change.

20% Book Value Drop Scenario

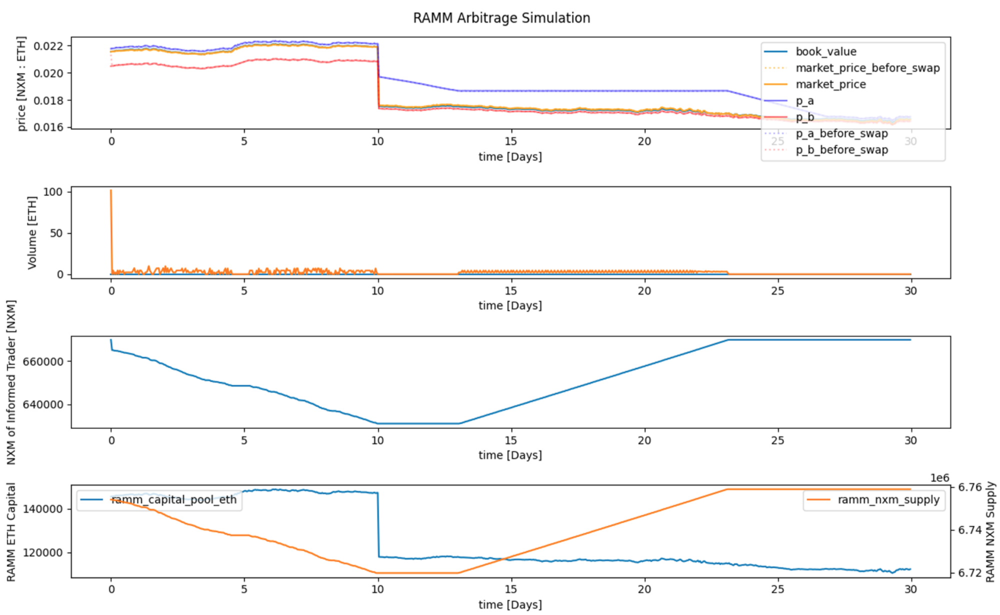


Figure 3.13: A single scenario shows the activity in the RAMM if an informed trader acts based on knowledge of an upcoming 20% drop in the Book Value. In the first graph, we see the below price pushed below the market price before the price drops and the above pull trending above book value when the trader buys back the NXM tokens after the price drops. As seen in the third graph, the trader sells a large amount of NXM at a high price and then buys back the same amount at a lower price after the price drops.

The heatmap below represents a sweep on the following parameters:

- Liquidity Injection speed - between 50ETH and 150ETH per day
- Ratchet speed - between 2% and 10% per day

- **ETH Lost heatmap** - Shows the extent of ETH lost due to the informed trader's activity. The value represents the ETH gain an informed trader made when he sold his NXM for a higher price before the Book Value drop and bought back the same amount of NXM after the drop for a lower price.
- **Capital Pool ETH Captured heatmap** - Shows how much ETH is gained by the RAMM by the informed trader buying back the NXM after the Book Value drop.
- **Capital Pool ETH Removed heatmap** - Shows how much ETH is removed from the RAMM by the informed trader selling NXM before the Book Value drop.

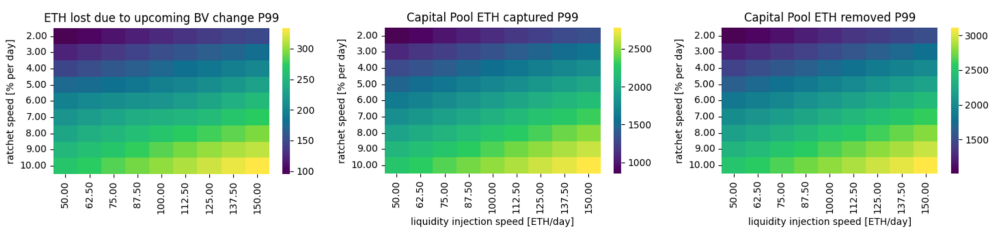


Figure 3.14: The impact of an informed trader acting on knowledge of an upcoming 20% Book Value drop translates into a net loss to the capital pool between 100ETH-350ETH across the tested ranges of liquidity injection speed and ratchet speed. The amount of lost ETH is sensitive to the liquidity injection rate and the ratchet speed in the tested range. Because we assume the informed trader sells the NXM tokens to buy them back at a lower price, the trader also returns some of the ETH removed from the pool; therefore, the lost ETH in such a scenario is smaller than in the case of arbitrage.

4 Simulation: Buy Pressure

Objective

To simulate the behavior of an NXM buy agent who is attempting to mint NXM daily, with a willingness to pay a premium over the book value.

Key Points

- Minting Behavior - The NXM buy agent is trying to mint NXM tokens at a fixed amount of ETH daily.
- Price Tolerance - The agent is willing to pay a premium, ranging between 20% to 50% above the book value, to mint NXM.
- Liquidity Dynamics - The simulation focuses solely on the RAMM, excluding secondary market activities and arbitrageurs. The underlying assumption is that the market prices NXM above its Book Value, and therefore, this premium is also reflected in secondary markets.

Setup Details

- **Book Value** - Set at 0.021 for the simulation.

- **Pool Prices** - Both the above and below pools are set at their target prices, which are 1% above and below the BV, respectively.
- **NXM Buy Agent Behavior** - The agent aims to mint NXM equivalent to 250 ETH daily. The agent will only mint through RAMM and not engage in secondary market activities.
- **Price Tolerance** - The agent is willing to pay a maximum of 20% or 50% above the BV to mint NXM.

Sweep Parameters

- **Ratchet Speed** - The simulation will explore a range of ratchet speeds from 1% to 10%.
- **Liquidity Extraction** - The simulation will test varying liquidity withdrawals from 50 to 500 ETH.
- **NXM amount to mint** - Fix the liquidity extraction to a value above the maximum mint per day, simulating an "infinite extraction", and sweep over the ETH Value of NXM bought daily.

Expected Outcomes

The simulation will provide insights into how the system behaves when there's a consistent demand to mint NXM at a premium over the book value. The results will be crucial for understanding the liquidity dynamics, the impact on the book value due to RAMM activity, and the amount of ETH captured in the capital pool under different scenarios.

4.1 Buyers are willing to pay 20% above Book Value

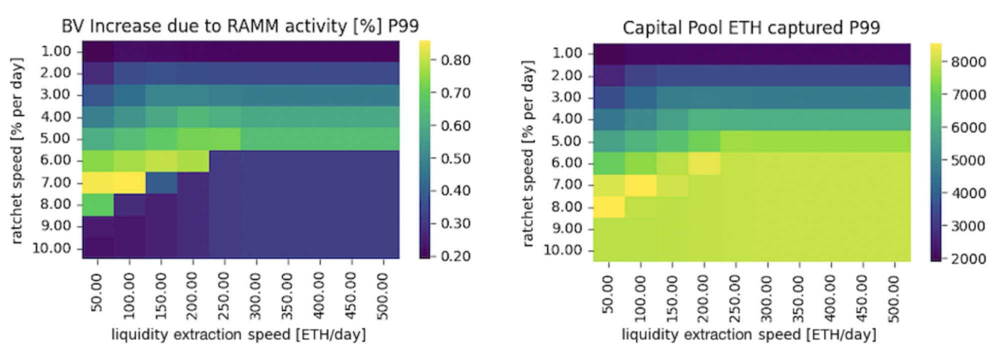


Figure 3.15: Mint 250 ETH worth of NXM per day, sweep over ratchet speed and liquidity extraction.

Sensitivity to daily buy pressure amount when buyers are willing to pay 20% above Book Value

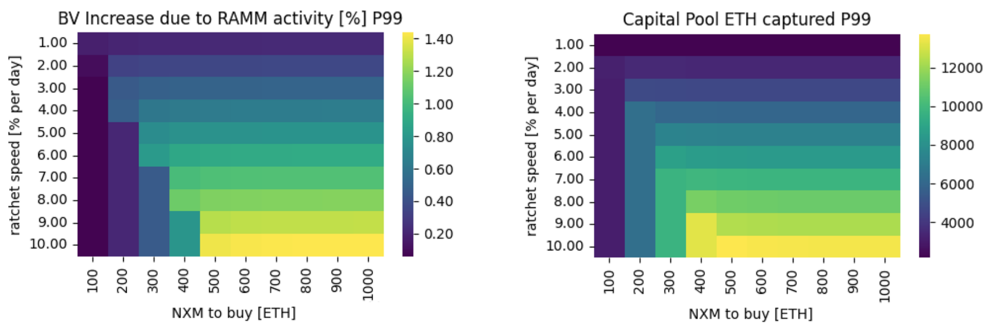


Figure 3.16: Sweep over ratchet speed and NXM amount to by in ETH, fixed liquidity extraction of 1200 ETH per day.

4.2 Buyers are willing to pay 50% above Book Value

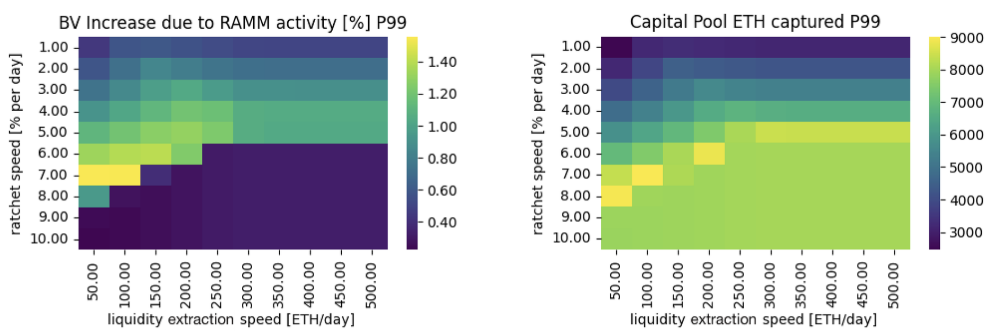


Figure 3.17: Mint 250 ETH worth of NXM per day, sweep over ratchet speed and liquidity extraction.

Sensitivity to daily buy pressure amount when buyers are willing to pay 50% above Book Value

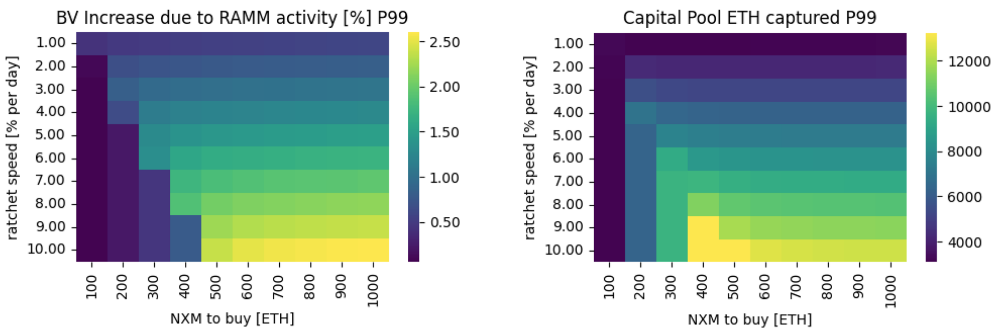


Figure 3.18: Sweep over ratchet speed and NXM amount to by in ETH, fixed liquidity extraction of 1200 ETH per day.

Key Insights

1. **NXM Purchase Dynamics** - The system exhibits a consistent behavior where, as long as the agent doesn't manage to buy the entire daily quota of NXM, the outcomes are more influenced by the ratchet speed than the liquidity extraction.
2. **Ratchet Speed Sensitivity** - The system's response to the agent's buying behavior is highly sensitive to changes in ratchet speed. Beyond a certain threshold of ratchet speed, the agent can consistently buy 250 ETH worth of NXM daily. Further increases in ratchet speed beyond this point don't significantly alter this outcome.
3. **Liquidity Extraction Impact** - As the liquidity extraction rate increases and surpasses the 250 ETH/day mark, the amount of NXM in the pools remains relatively stable, indicating that the system has reached an equilibrium state with respect to the agent's buying behavior and available liquidity.

Conclusion

The simulation suggests that for an NXM buy agent willing to pay a 20%-50% premium over the BV, the system's behavior is predominantly influenced by the ratchet speed. Once the system reaches a certain ratchet speed, it can consistently cater to the agent's daily NXM buying needs. Furthermore, when the liquidity extraction surpasses the agent's daily buying capacity, the system achieves a stable state with no significant fluctuations in the NXM pool.

Graphs showing the RAMM action during the buy pressure scenario under different settings

- Ratchet 4%, Liquidity extraction 100 ETH: 5078 ETH captured in the capital pool, Book Value increases by 0.53%
- Ratchet 4%, Liquidity extraction 500 ETH: 6048 ETH captured in the capital pool, Book Value increases by 0.59%
- Ratchet 10%, Liquidity extraction 100 ETH: 7866 ETH captured in the capital pool, Book Value increases by 0.24%
- Ratchet 10%, Liquidity extraction 500 ETH: 7991 ETH captured in the capital pool, Book Value increases by 0.32%

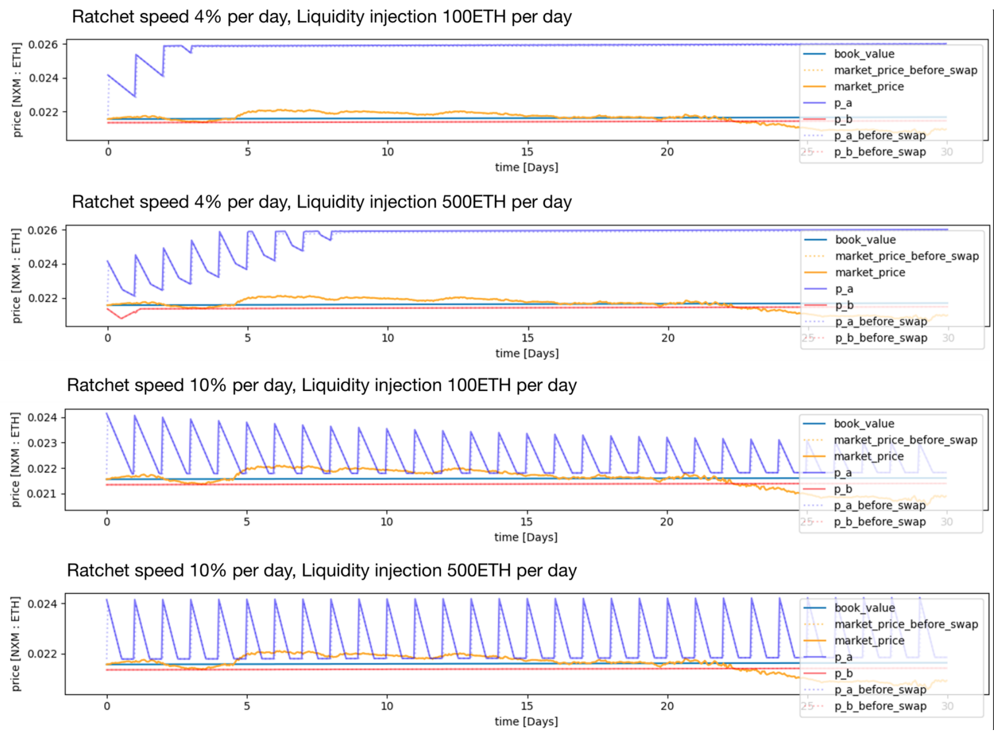


Figure 3.19: Below we provide the analysis and setting for each time series.

- When the ratchet speed is 4%, the RAMM does not react quickly enough to provide liquidity to satisfy the demand of 250 ETH per day. The above pool price reaches the buyers' target price and remains as the ratchet is slower than the demand flow.
- When the ratchet speed is 10%, the RAMM brings the above pool price down quickly enough to provide liquidity that satisfies the demand of 250 ETH per day. It is visible that the above pool price reaches the buyers' target price and is brought down by the ratchet every day.

Chapter 4

Community Parameter Discussion

1 RAMM Liquidity Parameters Discussion

The goal of these simulations was to verify the parameters proposed by the Nexus community and highlighting areas where there are tradeoffs between risk and reward.

1.1 Overview

The discussion revolves around the parameters for the RAMM as per the whitepaper. The aim is to align the internal protocol NXM price with the open market price, increase the Book Value over time, provide significant exit liquidity near the Book Value, follow the open market price, and capture capital sustainably when the open market price exceeds the book value.

1.2 Key Parameters

1. *target_liq* : Targeted ETH liquidity in the pools.
2. *liq_speed_out* : Maximum ETH removed from the pools daily.
3. *liq_speed_in* : Maximum ETH added to the pools daily.
4. *fast_liq_speed_in* : Maximum ETH added daily before the initial_budget is redeemed.
5. *initial_budget* : ETH amount to be redeemed before switching to long-term liq_speed_in.
6. *ratchet_speed_a* : Daily decrease in spot_price_a when above target.
7. *ratchet_speed_b* : Daily increase in spot_price_b when below target.

1.3 Community Proposed Parameters

1. *initial_budget*: 43,835 ETH.
2. *fast_liq_speed_in*: 1,500 ETH (short-term).
3. *liq_speed_in*: 100 ETH/day (long-term).
4. *target_liq*: 5,000 ETH.

5. *ratchet_speed_a*: 4
6. *fast_ratchet_speed_b*: 50
7. *liq_speed_out*: 100 ETH/day.

1.4 RAMM Design vs. Community Goals

The goals of the RAMM as voted by the community:

1. **NXM Exiting** - Targeting 30% of NXM exiting near book value
2. **Exit Period** - 1 month targeted for the initial exit amount.
3. **Near Book Value Definition** - At least 95% of BV.

Based on the community vote, we have evaluated the likelihood of allowing up to 50% of NXM to exit near book value. As demonstrated in the launch scenario simulations, the most significant factor affecting the exit period is the rate at which wNXM and NXM converge. This is because significant price discrepancies will lead to large amounts of ETH being extracted by arbitrageurs and, therefore, unavailable to exit NXM. Under the assumption that wNXM and NXM will converge at launch around Book Value, the simulations indicate that even 50% of liquidity may exit in less than a month.

1.5 RAMM Behavior During Price Swings

Price Drops

Throughout the simulations, we have examined two types of Book Value price drops driven by events known ahead of time, such as claims being paid. Recognizing that price drops resulting from upcoming claims are expected to bring Book Value down by as much as 5%, the amount of ETH lost under such circumstances is expected to remain below 30ETH.

Buy Pressure

While the intensity of buy pressure is hard to predict, we have used a benchmark scenario of 250ETH per day buy pressure with infinite demand 20% above Book Value and 50% above Book Value. In both cases, we found out that the ETH amount captured by the RAMM is more than half of the maximum possible amount that may be captured with the most aggressive ratchet speed and liquidity injection settings. However, the impact of such scenarios on the Book Value is up to 1%.

Chapter 5

Independent Review of Parameters by Chaos Labs

1 Independent Review of RAMM Parameters by Chaos Labs

1.1 Objective

To provide an independent assessment of the mechanism and parameters for the RAMM.

1.2 Key Findings

Chaos Labs' simulations validate the proposed parameter configurations as apt for the initial launch. The parameters are deemed suitable for the genesis phase.

1.3 Recommendations

1. Post-Launch Monitoring: It's crucial to monitor the mechanism's performance after it goes live continuously.
2. Optimization Over Time: Parameters should be adjusted based on real-world data, including user behavior, market dynamics, and volatility.
3. Community Engagement: Ensure that any parameter modifications align with the community's best interests and are informed by empirical usage and market behavior.

1.4 Conclusion

In the course of our analysis, the RAMM design proposed for the Nexus Mutual Protocol has been subjected to a series of evaluations to ascertain its alignment with the platform's strategic objectives. The findings from these evaluations indicate that the design is consistent with its intended goals. Within the scope of our simulations and stress tests, we have not uncovered any critical vulnerabilities that could be readily exploited for economic gain.

It is advisable that the protocol maintain a regime of regular audits, community feedback, and adaptive updates to navigate the complexities of the market and to safeguard against potential economic threats that may arise.

The proposed parameters have received validation from Chaos Labs as being fit for the initial launch. Since all simulations were conducted and evaluated based on assumptions, such as the price convergence of wNXM and the magnitude of price swings, we wish to signify the importance of re-evaluating the parameters and adjusting them accordingly in case of changes in user behavior and market behavior. As the system evolves, it's essential to remain adaptive and make data-driven decisions to optimize the mechanism for the community's benefit.

Appendix A

About Chaos Labs

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

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

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