Voltz Protocol: An Automated Market Maker for Interest Rate Swaps

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1 Abstract

Voltz is a noncustodial automated market maker for Interest Rate Swaps (IRS). Voltz uses a Concentrated Liquidity Virtual AMM (vAMM) for price discovery only, with the management of the underlying assets performed by the Margin Engine. The combined impact of these modules enables counterparties to create and trade fixed and variable rates through a mechanism that is up to 3,000x more capital efficient than alternative interest rate swap models, whilst also providing Liquidity Providers and Traders with significant control and flexibility over their positions.

2 Introduction

Innovations in DeFi are vast, but arguably one of the zero-to-one moments was the introduction of Automated Market Makers (AMMs). However, attempts to use AMMs as mechanisms to bring fixed rates to DeFi have been wide ranging and produced varied success. These models often have limitations that have either meant capital is inefficiently used, the rates produced are unattractive relative to the variable returns or the AMM design is overly rigid, meaning traders don't have sufficient flexibility to move in and out of positions as desired.

Voltz Protocol, a novel AMM introduced through this paper, brings interest rate swaps to DeFi in a manner that is up to 3,000 times more capital efficient than alternative models. Our model allows for sophisticated trading strategies and produces highly attractive fixed rates of return for investors. Traders and LPs have the ability to operate with approximately 10-15x leverage, meaning the Voltz IRS market has the potential to be 10-15x larger than the underlying. Longer-term, as DeFi continues to displace traditional financial markets, Voltz can displace the c.$1,000tn notional trading volume that is exchanged each year in TradFi IRS markets.

Voltz utilises the constant product invariant, like many other AMMs, but with a few significant differences:

- **Virtual AMM (vAMM)**: unlike a traditional AMM where assets move into a liquidity pool, a vAMM uses the AMM for price discovery only, with the management of the underlying assets done outside of the AMM via the Margin Engine. This approach allows for more flexibility since collateral management is no longer tied to the AMM reserves.
- **Rate-based Axes**: An IRS AMM must allow traders to exchange fixed-for-variable rates and variable-for-fixed rates over an underlying. To enable this we introduce the following novel concepts:
  - The creation of 1% virtual fixed tokens on our x-axis. The concept behind these tokens is relatively straightforward; if an actor is entitled to 100 1% virtual fixed tokens then, at maturity of the IRS pool, they can claim exactly 1 token of the underlying. Note this assumes the term of the IRS pool is precisely one year.
  - The creation of variable tokens on our y-axis. This represents the quantity of virtual variable tokens in the IRS pool. 1 virtual variable token gives an actor exposure to the variable cash-flows that can

be generated with 1 token worth of deposits in the underlying IRS pool (e.g. aDAI), over the term of the pool.

- **Concentrated Liquidity**: Learning from the concentrated liquidity concept pioneered in Uniswap v3, we allow LPs to deposit liquidity within tick ranges, rather than along the whole constant product invariant. The significance of this is two-fold. First, it means LP deposits can be up to 3,000x more capital efficient than alternative interest rate swap models. Second, it means LPs are able to deploy liquidity at the rate they believe is the appropriate market rate, providing greater control over their capital and fee potential.
- **Margin Engine**: The Margin Engine is responsible for the management of assets and pools of liquidity within tick ranges. It defines the leverage available to LPs and Traders, manages the collateralisation of the protocol and deals with liquidation events in adverse scenarios.

3 IRS vAMM

The Voltz IRS vAMM uses the constant product formula (xy=k), where (x) represents 1% fixed tokens and (y) represents variable tokens. Thus, the vAMM defines the rate at which a trader can exchange fixed-for-variable or variable-for-fixed cash-flows. Importantly, the vAMM is used for price discovery only. The management of the underlying assets is done outside of the vAMM via the Margin Engine as outlined in Section 4. Given the axes of the vAMM, the relationship between the vAMM price and the implied fixed rate is of the following form and outlined in Figure 1:

$$ImpliedFixedRate = \frac{1}{AMMPrice} \tag{1}$$

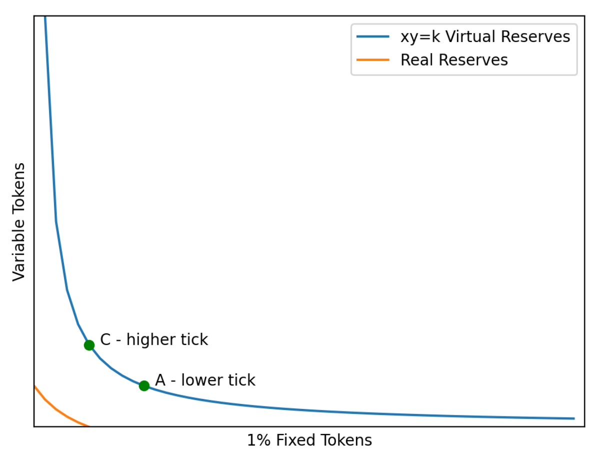

Figure 1. Voltz vAMM

3.1 Concentrated Liquidity

However, the constant product formula has known issues, in that it requires LP liquidity to be placed across the entire price (implied fixed rate) range $(0, \infty)$. To mitigate this the Voltz IRS vAMM uses the concept of concentrated liquidity inspired by Uniswap v3. This allows LPs to deposit variable tokens and 1% fixed tokens into the vAMM at custom price (implied fixed rate) ranges. When the fixed rate is out of an LP's position (range), the liquidity is inactive, meaning the liquidity won't enter IRS contracts and earn fees. Introducing concentrated liquidity means the Voltz vAMM has the potential to be up to 3,000x more capital efficient than other interest rate swap models. It also means LPs can define the ranges within which they're happy to deploy capital, effectively signalling the price they believe represents the market rate. The mechanics of how the vAMM functions are further elaborated in Appendix A.

3.2 Liquidity Provider Incentives

As with other AMMs, Liquidity Providers (LPs) are required for the vAMM to function. However, there are a few key differences for actors LPing on the Voltz IRS vAMM relative to other AMMs. The most significant being:

1. **Single asset LPing**: Each IRS pool is built on top of a single underlying variable asset (e.g. aDAI). In order to deposit liquidity, LPs must provide margin for the interest payments that are produced by the underlying token e.g. DAI. Since variable interest rate payments and fixed interest rate payments are paid in the same asset, an LP only needs to deposit that single asset to act as an IRS LP (i.e. DAI in this example).
2. **LP collateral recycling**: After an LP has deposited liquidity within a tick range, Variable Takers and Fixed Takers can consume that liquidity. If initially a Fixed Taker consumes the liquidity, the LP receives fees but is now locked into a swap at the rate defined by the constant product formula within that tick range. However, if a Variable Taker then consumes liquidity from the same tick range, the LP receives fees again. At this point the Fixed Taker and Variable Taker positions are netted out and the LPs margin is released back into the tick range to generate more fees. We refer to this as Margin Recycling and is outlined further in Section 4.3.
3. **Funding Rate Risk**: Using the example above, if the Fixed Taker is the only actor that trades, the LP is locked into a swap at the rate defined by the constant product formula within that tick range. If no more trading takes place, the two parties will accrue cash-flows depending on the difference between the variable and fixed rates. In the event the LPs leg is out of the money, the LP will end up with "funding loss". This

risk effectively replaces impermanent loss from spot market AMMs.

More details of how to LP can be found in Appendix C.

Since, LPs generate fees every time a trade is made there is an incentive for LPs to deposit liquidity within a tick range where they believe there will be equal trading volume from traders looking to exchange Variable-to-fixed (Fixed Takers, FTs) and Fixed-to-variable (Variable Takers, VTs). This mechanic, alongside the synthetic nature of the Voltz IRS pools, helps ensure the vAMM produces attractive fixed rates of return for investors.

The fee taken by an LP is computed via the following formula:

$$GrossFee = Nt\gamma \tag{2}$$

Where N is the notional amount, t is time to maturity and γ is the fee parameter set by governance. The variable t is equal to 0 if there are 0 days until maturity and 1 if there are t_{max} days until maturity. t_{max} is a parameter set by governance. Additionally, a share of gross fees are collected by the protocol and held within the protocol treasury. These funds can be distributed following governance votes (outlined in Section 6). A proportion of the protocol treasury fees can also be moved into the protocol's Liquidator Incentive Engine outlined in Section 4.5. Therefore, fees can be calculated by the following:

$$LPCollectedFees = Nt\gamma(1 - \lambda) \tag{3}$$

$$ProtocolCollectedFees = Nt\gamma\lambda \tag{4}$$

where λ is a parameter set by governance, which determines the share of LP fees that go into the protocol treasury.

Based on reasonable trading volume assumptions, LP returns can be in excess of 200% APY in scenarios where LPs deploy liquidity in tick ranges that have equal amounts of FT and VT trading. An analysis of potential LP APYs can be found in Appendix C.

4 Margin Engine

The Margin Engine is responsible for the management of assets and pools of liquidity within tick ranges. It facilitates cash flow movements between parties engaged in swaps, via FT and VT pools. It is also responsible for ensuring the system remains collateralised, which drives the leverage available for Traders and LPs. In adverse scenarios where an actor fails to meet their margin requirements, a pool of liquidators can trigger a liquidation event as outlined in Sections 4.1 and 4.2.

All actors must provide margin to Trade or LP on the Voltz Protocol. In order to maximise capital efficiency, the Voltz Protocol uses a model that allows Traders and LPs to partially collateralise their positions. This is done without a meaningful increase in risk of the protocol being undercollateralised since the scenarios that require "full collateralisation" are extremely unlikely to materialise. For example, if a VT were to trade 100 notional at 10% fixed rate for a 1 year term, a fully collateralised position would require 10 notional to be deposited as margin. However, this collateralisation requirement assumes the variable rate drops to 0% and stays there for the entire duration of the IRS contract, a scenario that is unlikely to occur.

Instead, in order to establish the initial and liquidation margin requirements for FTs and VTs, we specify a model that provides estimates for the upper i_u and lower i_l bounds of the underlying pool APY until the maturity of the IRS vAMM pool (see details in Appendix B).

Since the initial margin is calculated based on the liquidation margin, we must outline the liquidation margin computation first. This takes the following form:

$$LiquidationMargin = ((f \times 0.01)) + (v \times APY_{wc})) \times t \tag{5}$$

Where for FTs $APY_{wc} = i_u$ and for VTs $APY_{wc} = i_l$.

If we are computing the initial margin requirement, then $APY_{wc} = \tau_u i_u$ for FTs and $APY_{wc} = \tau_l i_l$ for VTs. Variables f and v are the fixed and variable token balances of the trader. For an FT, the value of f is positive and the value of v is negative. The opposite is true for VTs. The variable t stands for the IRS pool's overall term in years. Parameters $\tau_l < 1$ and $\tau_u > 1$ are the APY Lower and Upper bound multipliers respectively. These parameters ensure there is a healthy buffer between the liquidation and initial margin requirements for both FTs and VTs.

As a safety measure, the protocol also computes the minimum margin requirement for FTs and VTs. This complements the above computations and ensures the protocol has a cap on the amount of leverage FTs and VTs can take:

$$MinimumMargin = abs(v) \times \Delta \times t \tag{6}$$

where Δ is a parameter that is set separately for FTs and VTs and it is free to vary depending on the underlying IRS pool. Additionally, if a trader is a VT, then their margin requirement is bounded by the fully collateralised margin requirement, which assumes the variable rates can never drop lower than the zero lower bound.

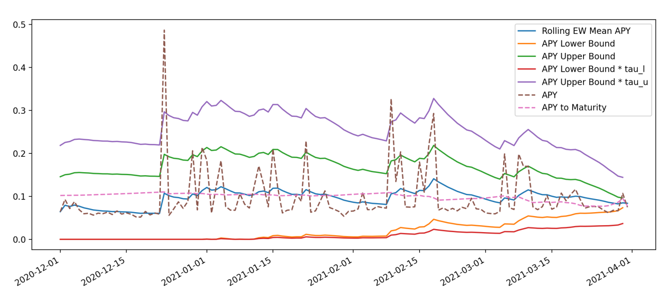

Figure 2. Margin Engine Variables Simulation

Figure 2 illustrates how the APY Upper and Lower bounds (represented by green and orange lines) change over time given historical data from the Aave USDC pool (deposit rates). These are used to determine Liquidation Margin Requirements for FTs and VTs. The violet and red lines are scaled versions of the APY Upper and Lower bounds, and these are used to determine the initial margin requirements for FTs and VTs.

LP margin requirements are based on these same computations. However, the calculation varies depending on what tick range the LP decides to deploy liquidity at, relative to the current price (implied fixed rate) of the vAMM. This is explained in more detail in Appendix C.

4.1 Liquidation

VTs, FTs and LPs can choose any margin level that is above or equal to the initial margin requirement of the IRS pool when they enter into an IRS contract. The closer an actor is to the initial margin requirement, the more levered they are. Whilst actors may choose to do this to boost APYs, this also increases the likelihood of a liquidation event occurring if rates move against them and their margin ends up below the liquidation margin requirement.

Liquidation events are unlikely to occur if there is a sudden spike in rates that are expected to quickly revert. This is due to the fact that a realised sudden spike can cause one trader to be out of the money for a short period of time, meaning their realised IRS cash-flows are effectively negative for only a few blocks before rates mean-revert. Whilst a spike can cause the traders position to get close to the liquidation threshold, the difference between the initial margin requirement and the liquidation margin requirement are designed to protect an actor from sudden and short lived spikes in rates.

However, a liquidation may occur if there is a sudden and continuous expected increase in the volatility of the interest rates in the underlying pool. This would create a wider gap between the APY Lower and Upper bounds in the Margin Engine, which would lead to higher liquidation margin requirements that could cause some existing traders to enter the liquidation zone if they don't deploy additional margin. Additionally, if the position of a VT or FT is consistently out of money on a per block basis then a liquidation event may occur as a traders margin diminishes. This can occur without any changes to the volatility of the underlying pool.

In a scenario where the margin of a VT or FT is in the liquidation zone, meaning it's below the liquidation margin requirement, a pool of liquidators are able to trigger a liquidation event. This works through the unwind mechanic outlined in Section 4.2. With additional incentives provided by the Liquidator Incentive Engine outlined in Section 4.5.

4.2 Unwinds

Traders can unwind positions by entering into an "opposite side" swap contract with the same amount of notional. If the fixed rate implied by the vAMM has not moved since the inception of the IRS contract and the realised rates were in line with the fixed rate at the IRS inception, the trader can effectively exit their position with a zero net cash-flow. However, if the above conditions don't hold, the trader initiating an unwind will be left with non-zero fixed token exposure.

If the fixed token exposure following an unwind is positive, then at the maturity of the IRS pool, the trader is entitled to a deterministic positive payout, which is a function of their positive fixed token holdings.

However, if the fixed token exposure following an unwind is negative, then the trader will need to have enough margin in their account to cover the cash-flows produced by their negative fixed token balance at maturity. This effectively means a trader will be required to leave margin behind in order to unwind a position.

In a scenario where an unwind is being triggered by a liquidator, the liquidators are entitled to receive a proportion of the margin of the liquidated entity. This is referred to as the liquidator reward and is an important incentivisation mechanic to maintain the health of the protocol. In an unlikely scenario where the liquidator reward is not sufficient to encourage liquidators to trigger liquidation events, the reward is topped up by the Liquidator Incentive Engine outlined in Section 4.5.

4.3 LP Margin Recycling

LP Margin Recycling is a key and novel concept introduced within the Voltz Protocol that dramatically improves the capital efficiency of the Voltz IRS vAMM. It allows LP margin to constantly be recycled once corresponding FT and VT trades have been made. This works as outlined in Figure 3 below.

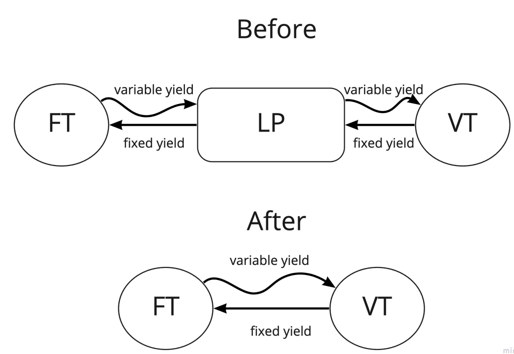

Figure 3. LP Collateral Recycling

Whilst this mechanic allows LP margin to be recycled, it is also worth noting that there will be scenarios where an entire LP position may not be netted out. This is outlined in Figure 4 below, which illustrates a scenario where initially an FT consumes fixed liquidity, moving from A to B and then a VT consumes variable liquidity, moving from B to C. If the LP wishes to remove liquidity from the A-B tick range, then they need to keep enough margin locked in order to cover the un-netted movement from C to A. This margin is computed based on the notional amount of (1250-1000=250) and a fixed rate of ((20000-16000)*0.01) / 250 = 16%.

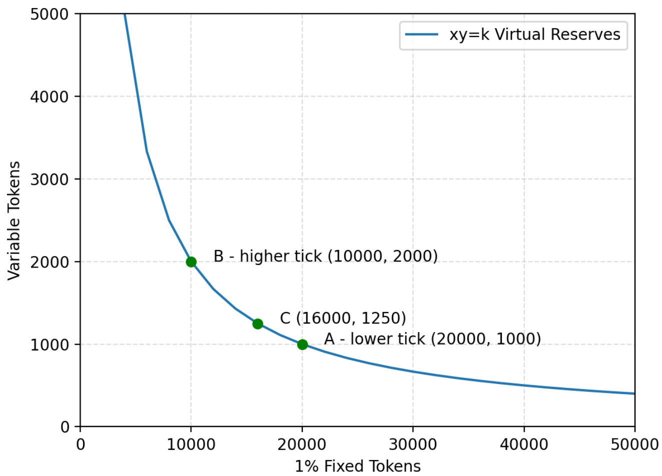

Figure 4. Partially Netted LP Position

4.4 FT and VT pooling

Since trading happens within tick ranges on the constant product invariant, it's possible to pool actors within a given range. As a result, when corresponding FT and VT trades are initiated, they move into a pool within their range. This means swaps are not 1:1 between counterparties, but instead are covered by a pool of corresponding trades, reducing risk for actors on the protocol.

4.5 Liquidator Incentive Engine

A share of protocol earnings can be allocated to the Liquidator Incentive Engine by the protocol treasury. This module is then used as an additional backstop to encourage liquidators to trigger liquidation events. This will occur when the liquidators incentive, a proportion of the margin left when a trader enters the liquidation zone, isn't sufficient to encourage liquidator bots to trigger a liquidation. In this scenario, increasing amounts of Liquidator Incentives are offered until the overall incentive is sufficient enough to trigger a liquidation event.

5 Properties

The Voltz IRS vAMM is architected to be protocol-first (i.e. a low level building block), making it highly composable for other participants to build on. To better understand the types of products, bots and opportunities that can be developed, we explore the primary use cases and properties of the Voltz Protocol.

5.1 Use Cases

5.1.1 Fixed Takers (FTs). Fixed Takers trade variable yield exposure in return for a fixed yield exposure. This is done by depositing margin to cover the variable leg for the notional the FT is trading, as outlined in Section 4.

There's likely to be a wide range of Fixed Taker actors operating on the Voltz Protocol, given the latent demand for fixed rates of return and the flexibility of a synthetic IRS instrument, meaning it can be used for hedging purposes and arb trading opportunities.

Initially these types of actors may be DeFi developers and community members building fixed-rate vaults. Through to CeFi organisations that are promising fixed rates to their users or have variable rate exposures on their balance sheet they wish to hedge. Sophisticated trading teams may also build on top of the Voltz Protocol to trade arb opportunities available between TradFi, CeFi and DeFi rates.

5.1.2 Variable Takers (VTs). Variable Takers trade fixed yield exposure in return for variable yield exposure. When VTs believe the fixed rate is likely to be lower than the underlying variable rate, they get exposure to the variable yield through the Voltz Protocol, with 10-15x leverage. With FTs likely to be more risk averse in nature, sophisticated VTs are likely to be able to extract significant value from the Voltz Protocol in the form of levered yield.

We expect the VT user types to predominantly be sophisticated traders, degens that understand the long-term yield potential of an underlying asset and also DeFi developers and community members building sophisticated VT vaults on top of the Voltz Protocol. As with FTs, acting as a VT also provides opportunity to hedge risks, whilst also opening up arb opportunities between TradFi, CeFi and DeFi rates.

5.1.3 Liquidity Providers (LPs). Liquidity Providers deposit liquidity within tick ranges to allow FTs and VTs to trade. Every time a trade is made the LPs collect fees. When corresponding FT and VT positions can be matched, the LP margin is recycled so it can be used to collect fees from Traders again.

Given these properties, LPs have substantial opportunity to generate fees when depositing liquidity within a range that has balanced amounts of FT and VT trading volume. An analysis of the LP economic opportunities is explored in Appendix C.

We expect LP user types to be made up of Market Makers, sophisticated traders and degens, alongside DeFi developers and community members building LP abstraction layers on top of the Voltz Protocol.

5.2 Building on Voltz Protocol

The APY opportunities of the Voltz Protocol means there are likely to be sophisticated vaults developed by DeFi developers and community members that act as abstraction layers for users to participate in the Volz Protocol. We expect some of the most sophisticated teams to capture large amounts of IRS notional traded by developing LP and VT farming strategies for more risk-loving DeFi actors. Meanwhile, we also expect CeFi organisations to integrate with the Voltz Protocol providing fixed rates through to their more risk-averse consumer bases, or to hedge risks that may exist at a balance sheet level.

Beyond LP, VT and FT farming strategies, there is also scope for the development of sophisticated structured products on top of the Voltz Protocol. These products can have properties that replicate limit orders, have downside protection or even products that compound various rate APYs over time.

6 Governance

Over time, the Voltz Protocol will be governed by the VoltzDAO, so that the protocol is owned and managed by the community that uses it. Decentralising ownership is critical to ensure the strength of the ecosystem we are all looking to build and to provide control to those that use the system. However, Voltz will initially be controlled by the Voltz Multisigs whilst the VoltzDAO is being developed. This transition to a DAO will be incremental, meaning the Voltz Protocol will go through a process of progressive decentralisation. As decentralisation takes place, the protocol will start using its treasury to fund operations and future developments.

Appendices

A vAMM Design Implementation Details

A.1 Trading within a Tick Range

In Figure 5, the ratio of y/x is the price in the AMM pool, if y/x = 0.5 then without loss of generality we can assume y=1, therefore x=2. This means that there is 1 token (y) worth of notional in the underlying variable pool, the fixed taker receives a 1% return on 2 tokens (x) worth of notional which is 0.02. Hence, the effective fixed rate is 0.02/1 which is 2%. Therefore the relationship between prices in the AMM and the implied fixed rates is of the following form:

$$ImpliedFixedRate = \frac{1}{AMMPrice} \tag{7}$$

On Figure 5 (assume trade is done at IRS pool inception), a FT who wants to fix the rate for 1000 tokens of notional in the underlying pool can achieve this by getting a 1000 variable token cover (vertical distance between B and C) in return for 1000 virtual 1% fixed tokens (horizontal distance between A and B), resulting in an implied fixed rate of 1% (1000/1000) due to slippage caused by the movement from A to C along the curve.

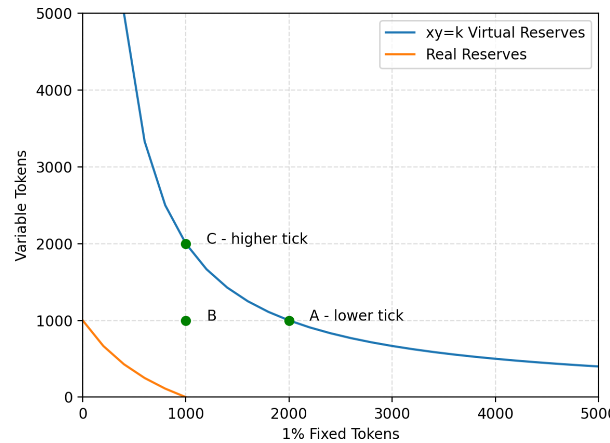

Figure 5. Voltz vAMM (trading within tick range A-C)

This trade should effectively cause the reserves of 1% fixed tokens to get depleted by the counterparty of the LP, which is a movement from point A to point B. However, as 1% fixed tokens are consumed, the LPs automatically deploy virtual variable tokens in line with the constant product formula in order to instead move from point A to point C along the constant product curve. At point C where there is a 2000 to 1000 ratio of variable to fixed tokens which implies a 0.5% point fixed rate, which is in line with what you'd expect since pressure to consume fixed yields causes the fixed rate of the pool to decline.

Following this trade, a VT enters an opposite IRS contract (receive variable, pay fixed) with the LP with the same amount of notional and fixed rate by moving along the vAMM from C back to A.

Hence, after the first two trades, the LP is in two IRS contracts with two counterparties (one is an FT and the other is a VT). As Figure 6 shows, these two IRS positions net each other off, meaning that there is no need for the LP to supply extra margin when issuing variable tokens (when moving from A to C) and there no need to supply extra margin when issuing 1% fixed tokens (when moving from C back to A). At this point the pool is back to where it started, the LP's positions netted each other off making the LP completely market neutral with respect to the underlying pool rates (while collecting fees from trades).

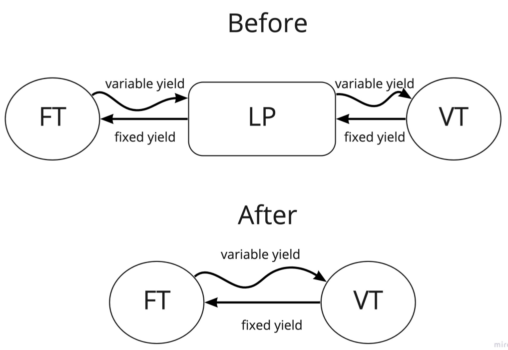

Figure 6. LP Collateral Recycling

If there was no concentrated liquidity, trading would happen along a constant product formula:

$$x \times y = k \tag{8}$$

where x and y are the respective reserves of two virtual assets 1% fixed tokens and variable tokens, and k is a constant. The limitation of this curve is that the LPs provide liquidity across the entire price range, implied fixed rate range $(0, \infty)$. This approach allows for efficient aggregation of liquidity, but means that a lot of the margin supplied by the LPs into the pool is never touched (used in an active IRS contract).

We refer to liquidity concentrated in a finite range as a bounded position. A bounded position only needs to maintain enough virtual fixed and variable token reserves to support an IRS trading activity within its range of implied fixed rates. Hence, it can act like a constant product pool with larger reserves (virtual reserves) within the specified range.

In particular, a bounded position only needs to hold enough of 1% fixed tokens to cover price (implied fixed rate) movement to its upper bound since upward price movement (downward fixed rate movement) corresponds to the depletion of 1% fixed token reserves. Similarly, it only needs to hold enough of variable tokens to cover price (implied fixed rate) movement to its lower bound.

When the price is out of the position's range, the position's liquidity is inactive. This means it cannot enter into active IRS contracts, meaning it cannot earn fees. In that scenario, its liquidity is composed entirely of a single virtual asset (either variable tokens or 1% fixed tokens only), since the reserves of the other token must have entirely been exhausted.

B Margin Engine Implementation Details

B.1 APY Upper and Lower Bound Calculations

APY Lower and Upper Bounds (LB and UB) are always computed for the entire term of the IRS pool. Hence, at any point during the lifetime of the IRS pool, the APY bound will be a function of the accrued APY $APY_{t_0:t}$ since IRS pool inception and the expected (unknown) APY bound $APY^{LB/UB}_{t:t_m}$ from now to maturity of the IRS pool.

$$APY^{LB/UB}_{t0:t_m} = APY_{t_0:t} \times \frac{t - t_0}{t_m - t_0} + APY^{LB/UB}_{t:t_m} \times \frac{t_m - t}{t_m - t0} \tag{9}$$

Where t_0 is the start timestamp of the IRS pool, t is the current timestamp and t_m is the maturity timestamp of the IRS pool. It is important to note that the APY LB is additionally constrained to always be non-negative.

B.2 Computation of APY Bounds from Now to Maturity

We consider the Cox-Ingersoll-Ross model (or CIR model), which describes the evolution of interest rates. The CIR stochastic model is given by the following SDE:

$$dx(t) = \kappa(\theta - x(t))dt + \sigma\sqrt{x(t)}dw(t); x(0) = x_0 \tag{10}$$

where κ is the mean reversion speed, θ is the mean reversion parameter, and σ is the standard deviation that determines the volatility and κ, θ, σ are real parameters (estimated via a calibration model).

Let $\alpha = \kappa\theta$ and $\beta = \kappa$. After substitution in equation 10, we get the SDE below:

$$dx(t) = (\alpha - \beta x(t))dt + \sigma\sqrt{x(t)}dw(t); x(0) = x_0 \tag{11}$$

Let $v(s,t) = x(t)|x(s) = x_s$. We know that $v(s,t) \sim \zeta\chi^2(\lambda)$ with degrees of freedom $k = \frac{4\alpha}{\sigma^2}$, $\zeta = \frac{\sigma^2(1-e^{-\beta(t-s)})}{4\beta}$ and non-centrality parameter $\lambda = \frac{4\beta e^{-\beta(t-s)}x(s)}{\sigma^2(1-e^{-\beta(t-s)})}$.

By approximating the Chi-squared distribution with Normal Distribution, we can obtain a confidence interval of $v(s,t)$:

$$v_{lower}(s,t) = max(\zeta(k + \lambda - \xi_1\sqrt{2(k+2\lambda)}), 0) \tag{12}$$

and

$$v_{upper}(s,t) = \zeta(k + \lambda + \xi_2\sqrt{2(k+2\lambda)}) \tag{13}$$

Where we define x_s as the exponentially weighted moving average of the daily historical APYs over a given time window (including the present day). Time t is in the range between 0 and 1, where $t = 0$ implies the maturity has already been reached and $t = 1$ implies that the time until maturity is t_{max} years (parameter set by governance), which is also the maximum term duration for the underlying pool. σ can be set as a parameter for each IRS pool. α and β are estimated via the calibration of the diffusion process separately for each pool and underlying and are also parameters set via governance.

C LP Margin and Returns

C.1 LP Collateral Details

In order to determine the amount of margin LPs need to submit there are three distinct scenarios that could arise.

C.1.1 Scenario 1: LPs deploy liquidity above current price.

When an LP deposits liquidity into a tick range above the current price, all of the liquidity deposited is in the form of 1% fixed tokens only.

As a result, the amount of margin the LP needs to deposit is based on the notional and fixed rate that arises if the price were to cross the tick range completely, i.e. move all the way to point B. In that case the LP would be fully a Variable Taker, hence the margin requirements are computed based on the margin requirement of a VT.

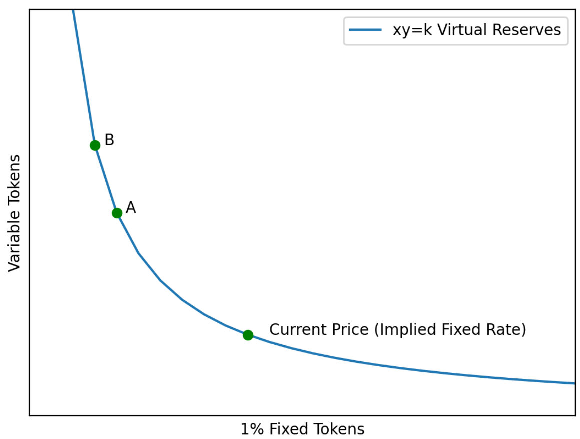

Figure 7. LP deploys liquidity above current price

C.1.2 Scenario 2: LPs deploy liquidity below current price.

When an LP deposits liquidity into a tick range below the current price, all of the liquidity deposited is in the form of variable tokens only. In this case the LP margin is determined based on the formulae used for FT margin calculations. The notional and fixed rate are determined based on the full movement from A to B.

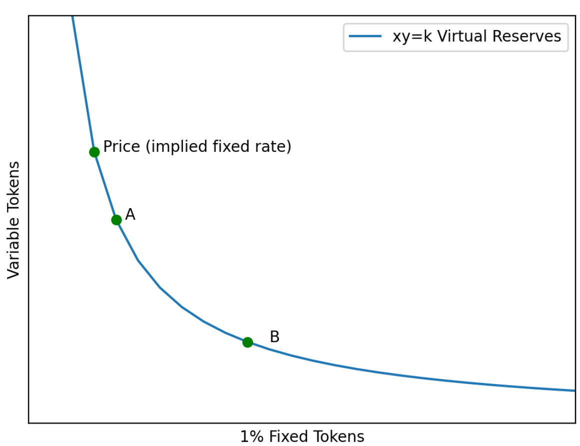

Figure 8. LP deploys liquidity below current price

C.1.3 Scenario 3: LPs deploy liquidity within current tick range.

In the scenario where the LP deposits liquidity into a tick range that hosts the current price, the margin requirement is the maximum of:

- FT requirement based on the movement from the current price to A
- VT requirement based on the movement from the current price to B

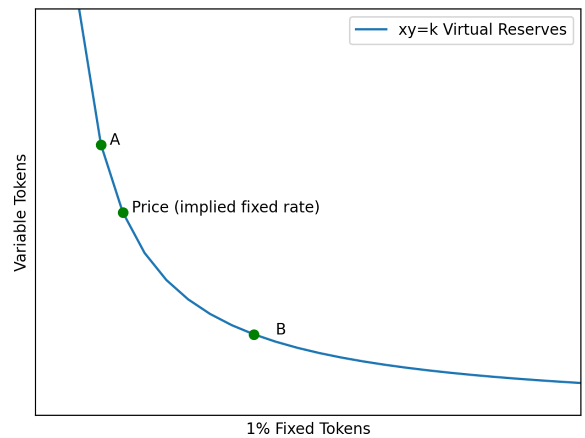

Figure 9. LP deploys liquidity within current tick range price

C.2 LP Returns Detail

LP returns are driven off a number of key variables: leverage, funding costs, margin recycling and trade fees. If we assume fees of 0.3% and 12.5x leverage, we can chart the impact that funding costs and recycling have on LP returns as shown in Figure 8a below. Assuming LPs estimate the implied fixed rate correctly, so that funding costs are 0, and that there is at least 1 recycle per week, LP returns can be over 200%.

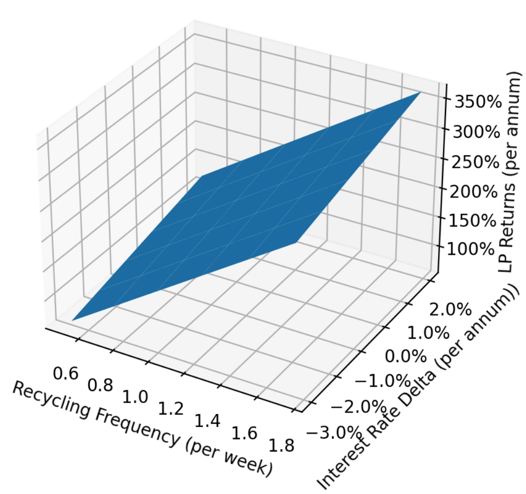

Figure 10. LP Returns Surface