Term Finance

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Abstract

Term Finance is an auction based fixed-rate and fixed-term lending protocol modeled on the tri-party repo transaction familiar in conventional finance. Unlike other decentralized fixed-rate protocols that use automated market makers ("AMM") to facilitate fixed-rate loan origination and price discovery, our issuance mechanism is capital efficient, does not depend on AMM liquidity providers and can converge to an economically efficient clearing price with just a few participants.

1 Introduction

Fixed-rate lending is fundamental to modern developed market economies and some say as old as civilization itself, with the earliest recorded evidence of fixed-rate lending dating back to the Code of Hammurabi (who reigned over Babylon from 1792 to 1750 B.C.). As of Q1 2022, the total outstanding debt of the non-financial sector (including households, businesses, and local, state and federal government) in the U.S. stood at \$66.5 trillion according to the Federal Reserve Board's Z.1 Financial Accounts of the United States – more than three times U.S. annual GDP. Given the magnitude of total debt relative to GDP, fixed-rate loans can be said to be a cornerstone of modern developed market economies.

Within developed market economies, funding rates secured by liquid collateral serve as a "risk-free" benchmark upon which all debt, ranging from consumer to business loans, are priced. According to the 2019 Triennial Central Bank Survey of Foreign Exchange and Over-the-Counter (OTC) Derivatives Markets, the average trading volume for interest rate derivatives on global benchmark interest rates was in excess of \$6 trillion USD *per day* in 2019. Through these derivatives, the market is able to swap, hedge and gauge prevailing benchmark rates for any maturity date or term by referencing the benchmark "yield-curve" or "term structure of interest rates."

Despite the central role a benchmark term structure of interest rates plays in conventional financial ecosystems, the decentralized finance ("DeFi") equivalent of a benchmark term structure is notably absent. Existing fixed-rate protocols have been unable to scale in large part due to their reliance on an AMM model. It is well documented that AMMs are (i) subject to negatively convex payoffs (often referred to as "impermanent loss"), which must be offset by transaction fees or otherwise; (ii) capital intensive and marred by low utilization rates, which mean that the opportunity cost of providing liquidity is high; and (iii) vulnerable to running into states of "liquidity freeze" where AMM liquidity reserves are drained and the market breaks before reaching equilibrium, (see e.g. [CJ21]).

Term Finance seeks to fill this gap by returning to the fundamentals. We implement a single-price multi-unit double auction model (also known as a "call auction" or "call market") to set the market clearing rate and match eligible borrowers and lenders. We implement this entirely on-chain so that the process is fully transparent and accountable. Loans are settled post-auction using a mechanism modeled on the tri-party repo transaction common in conventional finance. Lenders receive "term tokens" representing their claim to repayment upon loan maturity, while a set of smart contracts handle settlement activity and hold collateral on behalf of and for the benefit of the borrowers and lenders who engage the platform.

2 Fixed-Rate Lending in DeFi

2.1 Current Offerings

Existing fixed-rate lending protocols typically fall into one of two categories: (i) "discount notes", and (ii) "strips". The discount note is a token representing a claim to a fixed amount ("face value") of base currency (or "purchase currency", see Section 3.2.1) on a future date, which typically trades at a discount to face value. The difference between face value and the discount represents the fixed rate of interest to be earned from holding the token to maturity. Strip based models, on the other hand, take an existing yield bearing token (such as Aave aTokens or Compound cTokens) and "strip" the token into (x) principal only ("PO") and (y) interest only ("IO") strips. The PO piece then trades as a standard discount note.

Under existing discount note models, borrowers deposit collateral and receive two tokens representing both (i) a claim to the borrow currency at maturity and (ii) an obligation to deliver the borrow currency at maturity, in equal amounts. In order to complete the transaction, borrowers need to take the further step of selling their claim (the discount note) into the protocol's AMM. Lenders, on the other hand, simply deposit liquidity into or purchase claims directly from the same AMM. The rate at which users can borrow and lend are determined by the prevailing AMM price subject to its liquidity constraints.

Rather than depositing collateral in exchange for two tokens representing both an asset and a liability for the same amount, strip protocols have users deposit interest bearing tokens into a smart contract in exchange for two tokens: one representing the IO strip and the other representing the PO strip of the underlying yield bearing token deposited. The PO strips can then be sold into an AMM to raise funds. Lenders can purchase PO tokens directly from the AMM and redeem for par at maturity, earning a fixed-rate in between.

2.2 Existing Limitations.

Because existing protocols require that borrowers sell tokens (either discount notes or PO tokens) into AMMs in order to raise funds, their success as viable fixed-rate lending protocols depend on their ability to attract sufficient liquidity to capitalize their AMMs. For a variety of reasons discussed below, the AMM model has not proven to be successful at achieving either of these goals in the fixed-rate market.

Constraints on origination. In contrast to decentralized exchange ("DEX") AMMs where the AMM model is relied upon primarily for price discovery and facilitating token swaps, existing fixed-rate protocols rely on its AMMs to facilitate price discovery as well as to serve as the source of funds from which they originate loans. This heavy reliance on the AMM for loan origination makes existing fixed-rate protocols particularly exposed to the "liquidity freeze" problem. In a 50-50 AMM, each dollar originated requires that two dollars of capital be deposited in the AMM by third-party liquidity providers. Funds deposited in these AMMs are also exposed to impermanent loss. The result of this model is that the "real" yield earned by liquidity providers to existing fixed-rate protocols is typically low (and in some cases even negative) and insufficient to attract meaningful capital. Low capitalization also exacerbates slippage, imposing significant transaction costs to potential borrowers looking to access liquidity. Liquidity constraints on loan origination and high slippage depress utilization, which in turn lowers the expected revenue to AMM liquidity providers in a vicious cycle that is particularly salient in the fixed-rate protocol use case. Situations such as these where the expected real yield from providing liquidity is less than the expected opportunity cost is referred to in the literature as a "liquidity freeze" [CJ21]. Existing fixed-rate protocols that rely on AMMs to originate loans are particularly exposed to the liquidity freeze problem where the equilibrium level of AMM liquidity is unable to grow to a meaningful scale.

Off-market interest rates. To make matters worse, existing fixed-rate protocols are unable to guarantee that the limited liquidity they have at their disposal can be offered at competitive rates or lead to a market clearing price. Existing literature finds that while decentralized markets can approximate perfect competition in large markets, they are unable to do so in small markets without recourse to intermediation to larger venues [Nav15]. In the standard DEX based AMMs, this intermediation is largely facilitated by automated arbitrageurs known as "flashbots" [DGK+20], who profit from discrepancies that arise between the price of liquid tokens in large centralized exchanges and those available on AMMs. Where recourse to large and liquid centralized venues is not available, as is the case with fixed-rate tokens, decentralized AMMs have been shown to be poor approximations for a perfectly competitive market [CJ21]. Studies by [Smi62] [Wil80] [GS89] [Wil91] show that prices deviate significantly from that predicted by the law of supply and demand in small markets with few participants and imperfect competition. Much of the theoretical literature focuses on the strategic incentives to "shade bids" to avoid overpaying during the price discovery process [Fri91] [EL18], to "hold out" given incomplete information [GS89], or to exert market power [KS18]. The potential for off-market rates only further exacerbates the liquidity freeze equilibrium described above by deterring would be participants.

Sparse offerings. Another unintended consequence of relying on AMMs for both loan origination and price discovery is that their limitations preclude existing protocols from offering the granularity of maturities available in conventional finance for fear of fracturing liquidity. Existing protocols are typically limited to a term structure of just two or three maturities, which may be insufficient for the idiosyncratic needs of the market.

Liquidity mining doesn't work. Lastly, attempts to mitigate the liquidity freeze problem through the issuance of governance tokens to liquidity providers in compensation for low to negative real yields are unsustainable in the long run and are pro-cyclical in nature, proving least effective in bear markets when demand for capital is at its highest. For a protocol to be successful, it must be able to stand on its own merits independent of inflationary tokenomics.

3 Our Mechanism

Term Finance takes an entirely different approach from existing fixed-rate protocols. We draw a distinction between (i) primary issuance where fixed-rate tokens are originated via on-chain auction and (ii) secondary trading where token holders can access liquidity via AMM. Rather than utilize the same AMM for both secondary market trading and loan origination, we originate term loans via a single-shot, single-price call auction model to ensure a market clearing price and to match eligible lenders and borrowers. Because the auction mechanism does not require a standing liquidity pool to originate a loan transaction, it is capital efficient. As a coordination mechanism, it also serves to facilitate price discovery by bringing together multiple borrowers and lenders at a predetermined place and time. The call auction has been shown to converge to economically efficient outcomes, even in small markets [RSW94]. This mechanism allows origination to scale to the actual supply and demand of the market for borrowing and lending, without AMM liquidity constraints and slippage acting as a cap to origination.

Our approach to loan mechanics also differs significantly from existing fixed-rate protocols, which either (i) strip interest bearing tokens into PO and IO strips (strip based protocols) or (ii) provide collateral receipts that can be sold into an AMM (discount note protocols). Instead we rely on a model based on conventional tri-party repo agreements not unlike Compound and Aave.

3.1 Term Auction Mechanics

The call auction is a proven market clearing mechanism that results in an economically efficient clearing price (in that it maximizes total welfare) and converges to equilibrium with relatively few participants [RSW94] [SW02], at a rate of convergence that is amongst the fastest of all market mechanisms [CS06]. The New York Stock Exchange operated solely as a call market from its founding in 1792 to 1865, and continues to utilize a call auction at the market open each morning at the 9:30am open [Exc]. In the government bond market, single-sided auction mechanisms are used for primary issuance across the major developed market economies, and in the U.S., single-price auctions have been used to issue government bonds, notes and bills continuously since the early-1990s [BZ93].

Term Finance implements primary issuance through an auction that allows lenders to tender bids indicating the amount they would like to lend and the rate at which they are willing to do so. Borrowers

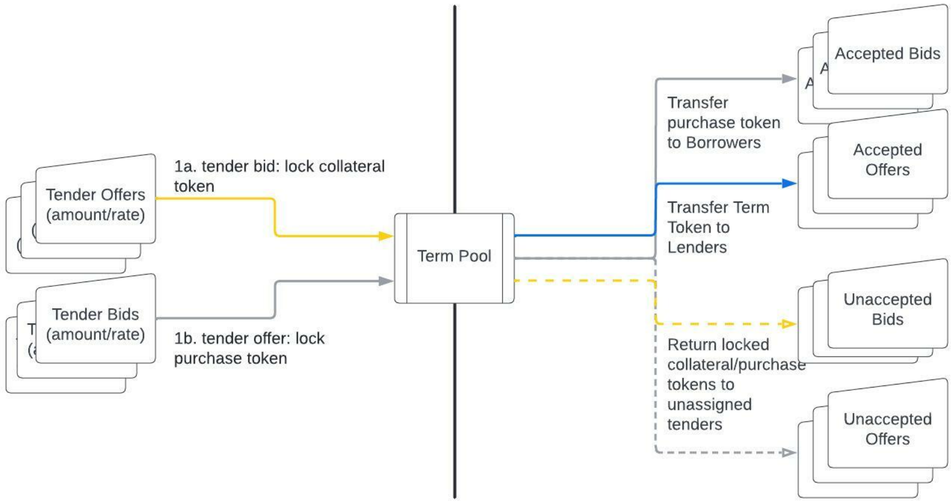

Figure 1: Term Finance auction mechanics.

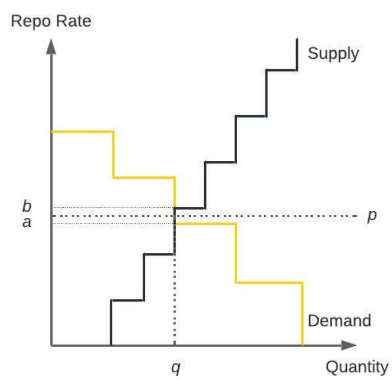

Figure 2: Illustrative supply and demand schedules for a double auction.

tender offers, indicating the amount they are looking to borrow and the rate they are willing to pay. In order to ensure that the auction clears, lenders are required to *lock* the amount of token to be loaned ("purchase token") and borrowers are required to lock the amount of collateral token required to be posted against their borrow at the time any auction tender is submitted (Figure 1). The list of cumulative bids grouped in descending price order represents the demand schedule and the list of cumulative offers grouped in ascending price order represents the supply schedule. Any price $p \in$ [a, b], where $[a, b]$ is the range of values where the supply and demand schedules intersect (Figure 2), maximizes total volume matched in auction and a market clearing price. Our algorithm iterates through the supply and demand schedules tendered in auction via binary search to identify this range of values and the final settlement price p is set at the midpoint of this range. Where there is over supply (or demand) at the settlement price p, as in Figure 2, allocations are made on a "pro-rata on the margin" basis consistent with U.S. Treasury auctions [GI05], where marginal offers (bids) are rationed in proportion to the amounts each borrower (lender) tendered with respect to all total offers (bids) at the marginal price. Any purchase or collateral tokens locked that belong to unassigned bids and offers are returned. Collateral belonging to accepted offers remains in the contract and is released only upon repayment or default.

To ensure that the auction process is "incentive compatible" – where the dominant strategy for all participants is to submit their trust valuations so as to achieve an economically efficient outcome that maximizes total surplus, we implement two features. First, we determine the market clearing price based on the average between the second best bid and the second best offer assigned in auction to encourage users to submit their true valuations for their marginal units of supply or demand, following McAfee [McA92]. In this way, the marginal bidder or offeror has no impact on the final price. Second, we utilize Keccak hash to disguise all bids and offers submitted prior to the close of the auction so as to prevent strategic behavior from influencing the bids and offers tendered in auction. Bids and offers are revealed only upon the closing of an auction, which can be verified against the original Keccak hashes stored on-chain.

3.2 Term Pool Architecture

The "Term token" central to the Term Finance protocol is an ERC-20 token that represents a claim for a certain amount of any existing ERC-20 token used as a base currency or purchase currency on a future date. We model loan mechanics loosely on the tri-party repurchase agreement ("tri-party repo") transaction common in conventional finance that forms the basis upon which benchmark yield curves across developed economies are priced.

3.2.1 Terminology

We adhere to the following terminology in this paper.

Purchase Price The price at which collateral assets are transferred by a borrower to a lender in a repo transaction and can be thought of as the amount borrowed.

Repurchase Price The price at which collateral assets are to be transferred back to a borrower upon maturity or termination of a repo transaction. The repurchase price reflects the interest calculated by applying the pricing rate over the term of a repo transaction.

Pricing Rate The per annum percentage rate for determination of the repurchase price, also known as the "repo rate".

Purchase Currency The base currency in which the purchase price and repurchase price are denominated.

Initial Margin Ratio A ratio, quoted in percentage points, expressing the amount of overcollateralization required to open a given repo transaction. It is equal to the market value of collateral divided by the repurchase price multiplied by 100.

Maintenance Margin Ratio A ratio quoted in percentage points that, when applied to a borrower's repurchase price, must exceed the market value of its collateral. It represents the minimum amount of overcollateralization required to avoid default.

Transaction Exposure Transaction exposure measures a borrower's margin excess or deficit and is calculated by applying a margin ratio to a repurchase and comparing it against the market value of collateral transferred. Where transaction exposure is negative a borrower is said to have a *margin deficit*, and where transaction exposure is positive, a borrower is said to have a *margin excess*.

3.2.2 Settlement and custody

Conventional tri-party repo A tri-party repo agreement is a secured loan structured as a sale of an asset and simultaneous agreement to repurchase the same asset on a future date and at a higher price. The difference between the initial price ("purchase price", see Section 3.2.1) and the repurchase price represents the interest paid for the "loan" in the interim. These agreements typically have a term of one business day, but can be locked for longer periods of time ("overnight repo" and "term repo", respectively).

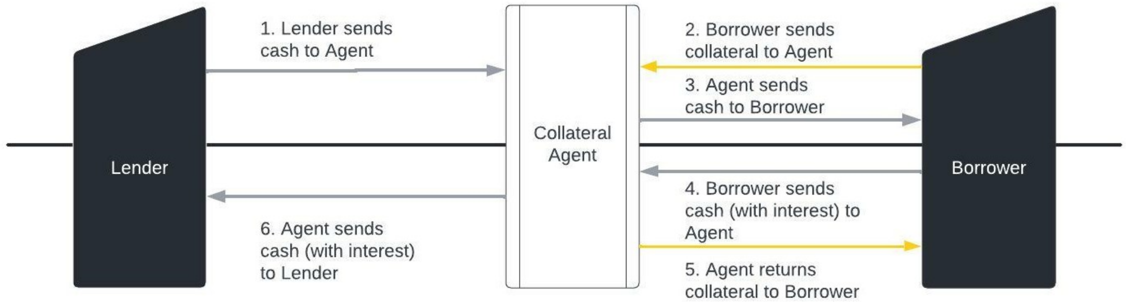

Figure 3: Diagram of tri-party repo transaction.

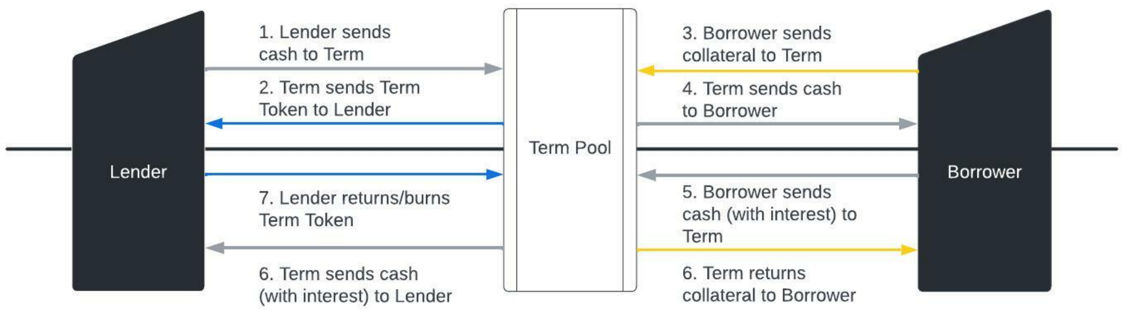

Figure 4: Diagram of Term Finance tri-party repo transaction.

In these agreements, borrowers and lenders enter into a bilateral agreement and mutually appoint a third-party settlement or collateral agent to settle loans and hold collateral on behalf of and for the benefit of the parties in accordance with the terms of the agreement (see Figure 3). Netting across counterparties by these agents allows for more efficient settlement across multiple counterparties. The rise of tri-party repo (in place of bilateral repo) in the past decade was a response to the financial crisis of 2008 that exposed the counterparty risk inherent in bilateral repo agreements. By keeping collateral in separate custody, this ensures that the collateral cannot be rehypothecated and mitigates counter-party risk to the borrower.

Term Finance Term Finance follows this model by establishing Term Pool contracts that hold collateral on behalf of lenders and borrowers, releasing collateral only upon repayment or liquidation in the case of default or margin deficit as determined by Chainlink oracle feeds. An internal ledger keeps track of each borrower's collateral and repurchase price. On the lender side, we innovate on conventional tri-party repo by issuing ERC-20 tokens (”Term Tokens”), normalized to one unit of purchase currency (see Section 3.2.1) at maturity, to track the amount due to each lender (Figure 4). By tokenizing a lender's claim to repayment we simplify the process of trade novation, enable lenders to obtain liquidity through a secondary market if needed, and encourage price discovery for benchmarking purposes. Because this token follows the ERC-20 standard, it is also composable within the broader DeFi ecosystem.

3.2.3 Margin Maintenance

Conventional tri-party repo Under standard tri-party repo agreements, a margin ratio is applied to the repurchase price (”Margin Amount”) to determine the minimum market value of collateral posted in order to avoid default. Transaction exposure is the difference between the market value of collateral and the margin amount. Where transaction exposure is negative, a borrower has a ”margin deficit”, and where transaction exposure is positive a borrower has ”margin excess”.

Term	Frequency
4-week	weekly
8-week	bi-weekly
13-week	bi-weekly
26-week	monthly
52-week	monthly

Table 1: Term auction schedule.

When a borrower has in margin deficit, a margin call will be made against the borrower who will be required to post additional cash or collateral. If this margin call is not met within a certain time, the borrower will be in default and all obligations will be accelerated. The lender will typically liquidate collateral, and the two parties will settle any remaining balances.

Term Finance Because participants in the DeFi market are largely anonymous, participants lack compulsory means on defaults, and crypto asset volatility is extremely high, borrowers are not typically afforded an opportunity to cure margin shortfall. To the contrary, collateral is typically liquidated immediately upon default. DeFi lending protocols typically follow futures margin conventions where a distinction is made between (i) an initial margin required to open a position and (ii) a maintenance margin that determines when a position is actually liquidated (see Section 3.2.1). Requiring a user to open a position in a position of margin excess is designed to avoid situations where a position is immediately liquidated after a establishing a new position due to a *de minimis* decline in market value. Consistent with existing DeFi conventions, Term Finance employs both an initial margin and a maintenance margin in its margin maintenance mechanism.

Where a borrower becomes eligible for liquidation, DeFi lending convention is to either: (1) allow liquidators to repay the debt in exchange for receiving collateral assets at a discount (i.e., "liquidation discount") or (2) liquidate the collateral through an auction process. In both cases, the amount of debt allowed to be repaid (and collateral available for liquidation) may or may not be capped by a (typically fixed) "Close Factor" ("CF") to protect a borrower from excessive liquidation loss [QZG+21]. We follow a fixed liquidation discount model and innovate on established procedures by introducing a variable CF that allows liquidators to liquidate borrower collateral only up to the point where a borrower's account is restored to its initial margin requirement. In this manner, borrowers are liquidated only on the minimum amount necessary to restore their transaction exposure back to where it was when their position was first established.

3.3 Term Finance V1 Protocol

3.3.1 Auction Schedule

Because we do not need to contend with fractured AMM liquidity in determining our term offerings, Term Finance will be able to originate a granular secured rate term structure in DeFi. We intend to hold auctions weekly and offer 4-week, 8-week, 13-week, 26-week and 52-week terms consistent with the U.S. Treasury Bills market. Auction frequency will vary by term (Table 1). In V1, each Term Pool will be segregated by maturity. Where maturities overlap, say, an original issue 8-week term that has rolled down to coincide with a 4-week term, the 8-week term pool will be "re-opened" to ensure all term tokens with the same maturity remain fungible.

3.3.2 Term Pool Lifecycle

The lifecycle of a standard Term Finance transaction begins with the announcement of an upcoming Term Auction and ends with the maturity, repayment and redemption of a Term Pool (Figure 5). Each Term Pool will be unique to a specific combination of the (i) maturity date, (ii) purchase token/base currency, and (iii) eligible collateral. In certain instances, multiple auctions may be associated with a specific Term Pool in the case of a re-opening as discussed above.

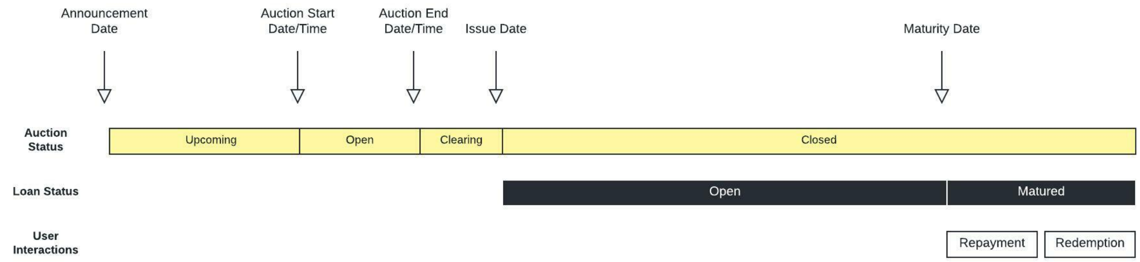

Figure 5: Timeline of Term Finance tri-party repo lifecycle.

3.3.3 Conventions

Day-count convention In calculating the repurchase price due at maturity based on the market clearing repo rate, we follow an Actual/360 day count convention.

$$\text{DayCountFactor} = \frac{\text{Days}(\text{AuctionDate},\ \text{MaturityDate})}{360}$$

Repurchase price To calculate the amount due at maturity, the *repurchase price*, given the amount borrowed, the *purchase price* for any given repo rate:

$$\text{RepurchasePrice} = \text{PurchasePrice}\,(1 + \text{RepoRate} * \text{DayCountFactor})$$

Transaction Exposure Transaction exposure measures the margin deficit or excess of an account at time t. We apply the maintenance margin ratio to the current market value of collateral based on Chainlink oracle feeds and compare that to the repurchase price. Where an account is in margin deficit (negative transaction exposure) its collateral is eligible for liquidation.

$$\text{TransactionExposure}(t) = \text{MaintenanceMarginRatio} * \text{CollateralMarketValue}(t) - \text{RepurchasePrice}$$

3.3.4 Protocol Revenue

Term Finance V1 revenues will be supported by two sources. The primary source of revenues will be a fixed fee of, say, 0.30% applied to the total purchase price on an annualized basis for the term of a loan, the "servicing fee", charged to each borrower upon auction settlement. Fixed fees have been shown to be asymptotically strategy proof and economically efficient in contrast to bid-ask spread fees, which can lead to strategic behavior with unintended results [JNPP22]. The servicing fee will be deducted up front such that the proceeds settled to the borrower are the purchase price net of the servicing fee. This ties protocol revenues to the total notional amount of loans settled through Term Finance. Repayment penalties will be a minor source of revenue in the event that a borrower fails to repay upon maturity and did not previously elect to automatically roll-over the position. The penalty is primarily implemented to discourage repayment defaults, offset contract deployment and keeper transactions fees and discourage avoidable defaults.

3.3.5 Protocol Reserve

Where a borrower falls into margin deficit, his or her collateral becomes eligible for liquidation. Liquidators are able to repay all or a portion of the borrower's balance up to a close factor (see 3.2.3). In exchange, borrower collateral is seized in an amount greater than the equivalent value of exchange for repayment at prevailing market prices. A portion of the excess collateral seized goes to the liquidator and a portion is sent to a reserve fund serving as a form of protocol insurance.

3.4 Future Direction

3.4.1 Pool Variants

V1 Term Pools are segregated across maturities and collateral types. There is no netting of collateral across maturities for the same borrower. Pool structure could be centralized in a single master pool across all maturities and auctions, or be limited to single borrowers (but across all maturities) to allow for collateral netting across maturities for individual borrowers.

3.4.2 Liquidation Mechanism

V1 implements fixed liquidation discounts to incentivize liquidators in the event of margin deficit on an account. Where the liquidation is more than sufficient to compensate liquidation, a gas war ensues and the trade goes to the highest bidder. This profit to the miners is profit that could be going to the protocol. On the other hand, where the liquidation discount is insufficient to compensate for the risk of liquidations, say, in high stress markets, liquidation might not happen at all. An auction mechanism that allows the market to determine the liquidation discount rather than fixing it to some arbitrary number would be an improvement.

3.4.3 Interest Rate Swaps

A liquid cash or "spot" market for an asset is a precondition to a viable derivatives market. Derivatives markets rely on arbitrageurs to intermediate between a derivatives market and the underlying spot market to provide liquidity when demand for derivative exposure is unbalanced. Where an underlying spot market is not available to hedge, a derivatives market is incomplete and AMMs are vulnerable to a drain of reserves when the AMM becomes subject to heavy one-way order flow. Term Finance will leverage Term Tokens to offer an sustainable and complete AMM that will be able to hedge its net exposure through the Term Token spot market.

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