Fei Protocol:

A Decentralized, Fair, Liquid, and Scalable Stablecoin Platform

By Joey Santoro

Abstract

We introduce Fei Protocol and the FEI stablecoin. The goal of the Fei Protocol is to maintain a liquid market in which ETH/FEI trades closely to the ETH/USD price. FEI achieves this via a new stability mechanism known as *direct incentives*. Direct incentive stablecoins use dynamic mint rewards and burn penalties on DEX trade volume to maintain the peg. FEI uses Uniswap as its incentivized DEX at launch. Governance can add and update DEX integrations and other incentives as needed.

New supply of FEI enters circulation via a buy-only bonding curve denominated in ETH. We refer to the ETH accrued from purchases on the bonding curve as *Protocol Controlled Value (PCV)*. We define PCV as any value which is completely owned and controlled by the protocol, without an IOU. It is a subset of Total Value Locked with a stronger use case. The Fei Protocol deploys its PCV exclusively as Uniswap ETH/FEI liquidity at the genesis of the protocol. This is a "liquidity-collateralized" model which removes the need for an overcollateralized debt position. As the supply grows, the bonding curve price approaches a fixed peg to the oracle price. The fixed peg bonding curve creates a guaranteed arbitrage opportunity when the Uniswap price trades above the peg. The protocol will use its liquidity PCV to backstop the Uniswap price when it trades below the peg for a certain period.

The TRIBE governance token is used to upgrade the protocol over time. Fei Protocol releases TRIBE to bonded FEI/TRIBE Uniswap LP tokens. The Fei Protocol design has key advantages that are not present in other widely used stablecoin designs. FEI is decentralized and scalable. New supply is fairly distributed to new demand. PCV provides flexibility to governance to add future integrations and incentives. FEI holders benefit from the mechanisms designed to create a high fidelity peg and liquid exchange.

Direct Incentive Stablecoin

Fei's *direct incentive* approach presents a promising improvement over existing stablecoin models, which fall into three broad categories: fiat-collateralized, crypto-collateralized, and non-collateralized.

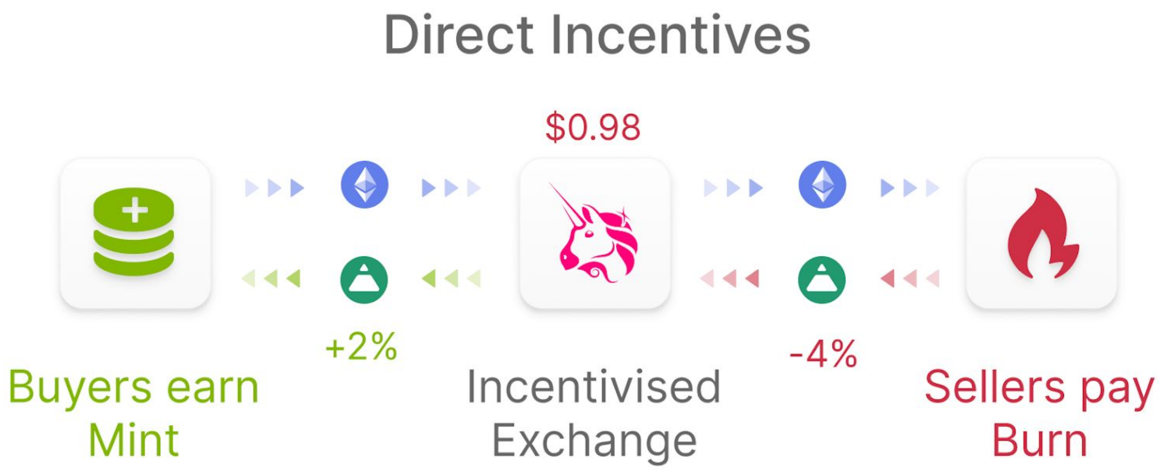
Fiat-collateralized stablecoins, such as USDC and USDT, are issued by centralized entities. These custodians escrow USD and issue the stablecoin on chain. Stablecoins in this category have two key advantages. One is capital efficiency, since they can scale rapidly with demand at a 1:1 exchange rate. The other is collateralization, as they can always be redeemed for underlying assets. However, there are always risks that the centralized authority issuing fiat-collateralized stablecoins is not fully collateralizing them. The reserves are a black box in between solvency audits, if any at all. Fiat-collateralized stablecoins are also subject to regulatory risk. This can take the form of blacklisting accounts, mandatory KYC, or even erasing funds. This poses an existential risk to platforms which integrate with them. The advantages of fiat-collateralized coins have led them to dominate the current market. Decentralization solves the issues with fiat-collateralized stablecoins due to their permissionless nature. The popular decentralized stability mechanisms have their own unique drawbacks. We will explore these below.

Crypto-collateralized stablecoins, such as DAI and sUSD, are issued on chain via some kind of overcollateralization mechanism. The overcollateralization allows for trustless issuance. The drawback is the capital inefficiency that results from the need to have a sufficient buffer to protect against price volatility in the collateral. All supply requires an excess of collateral which must be monitored for solvency. This limits the growth of decentralized stablecoins. The primary example, DAI, even has a debt ceiling which cannot be exceeded.

Non-collateralized stablecoins are a compelling alternative. They enable unconstrained growth in supply and are decentralized in issuance. The current primary mechanisms for achieving this are seigniorage and rebasing. Seigniorage models like ESD have supply adjustment dynamics to maintain the peg. When demand is high, the protocol issues new supply to a group of stakeholders known as the seigniorage holders. When demand is low, there are deflationary mechanisms for contracting supply. These seigniorage models have two drawbacks. First, there is no collateral or liquidity backing the peg. This can create liquidity crises and amplify volatility when these coins fall below their peg. Additionally, the economic mechanics heavily favor the seigniorage stakeholders. The broader community often disregards seigniorage stablecoins due to the unfairly centralized rewards. Fractional reserve models like FRAX attempt to address the no collateral issue, but they still retain the flawed economics of a seigniorage model. Rebasing tokens like AMPL adjust user balances to shift the demand weighted price to the peg. They have usability issues when integrating with other platforms, since user balances are not static. Non-collateralized stablecoins have also proven to be extremely volatile.

This paper proposes a new stability mechanism called *direct incentives.* A direct incentive stablecoin is one in which both the trading activity and usage of the stablecoin are incentivized, where rewards and penalties drive the price towards the peg. In general this would include at least one incentivized exchange acting as a hub. All other exchanges and secondary markets can arbitrage with the incentivized exchanges. This helps maintain the peg throughout the ecosystem. The direct incentive model by itself suffers from similar issues to other non-collateralized stablecoins. There is no guarantee of liquidity and no collateral backing the system. To solve this, Fei Protocol combines the direct incentive model with Protocol Controlled

Value deployed as liquidity. These mechanisms together create a stablecoin that is decentralized, scalable, fair, and liquid.



Protocol Controlled Value

In most DeFi applications, users deposit funds with an IOU attached. For example, users could be issued tokens representing the pro rata percentage of the supplied assets. These assets are a part of the Total Value Locked (TVL). The protocol would define a utility around how these funds are deployed. The contract may offer incentives to keepers to close unhealthy positions. There may even be some fee which accrues to stakeholders or a reserve. This value does not belong to the protocol in any meaningful sense, but rather to the users and owners of the protocol.

This lack of ownership creates the “mercenary capital” problem, evident in all user owned TVL-based mechanisms. For example, Uniswap LP tokens and Aave aTokens are redeemable for the underlying assets. During periods of high APYs or incentives, the TVL would increase. As soon as those rewards dry up, the capital will move on to the next best opportunity, perhaps SushiSwap or Compound.

The key innovation behind the Fei Protocol's mechanism is the idea of *Protocol Controlled Value (PCV)*, a subset of TVL in which the protocol outright owns the assets with no IOU. PCV opens up a new design space for DeFi protocols beyond what user-owned TVL models can do. The protocol can influence market conditions in fundamental ways that are not necessarily profit-motivated. Since there are no users to redeem to, these benefits are guaranteed on the contract level. The clearest use case of PCV is to have the protocol be a liquidity provider (LP) on an Automated Market Maker (AMM) like Uniswap. At sufficient volume, the protocol would essentially control the exchange rate of the trading pair. It can use its PCV to rebalance the price by executing trades against the market and locking or burning excess tokens. For example, let's say there is a Uniswap market denominated in FEI/USDC. The current liquidity depth is 1100 FEI and 1000 USDC. In this example, Fei Protocol owns 90% of the liquidity. Fei Protocol can atomically execute the following trade:

1. Withdraw all liquidity (990 FEI and 900 USDC)
2. Swap ~5 USDC for ~5 FEI (remaining liquidity is ~105/105 FEI/USDC)
3. Resupply 895 FEI and 895 USDC at the 1:1 exchange rate

The net effect of the above trade is the protocol spent ~5 of its USDC PCV to restore the peg.

This design aligns perfectly with the FEI stablecoin use case. This is a marked improvement over models in which all the TVL is user-controlled and frozen as collateral. PCV could also be used to deposit and borrow on lending markets like Compound and Aave.

Funding PCV is a necessary design consideration. The protocol needs to be able to offer a token or service which earns the PCV. A natural mechanism for funding PCV would be protocol fees for functionality. A stronger funding mechanism might be a bonding curve. The bonding curve could mint a token controlled by the protocol for an influx of ETH or other ERC20 tokens. To accrue PCV, the bonding curve must include a spread earned by the protocol. Bonding curves have an elegant mathematical fairness to them. New demand for the token can buy directly from the bonding curve to expand the supply. This is in stark contrast to seigniorage models which centralizes rewards. Arbitrageurs profit off of any market dislocation between the bonding curve and spot exchanges. Users receive the newly minted supply in one of two ways:

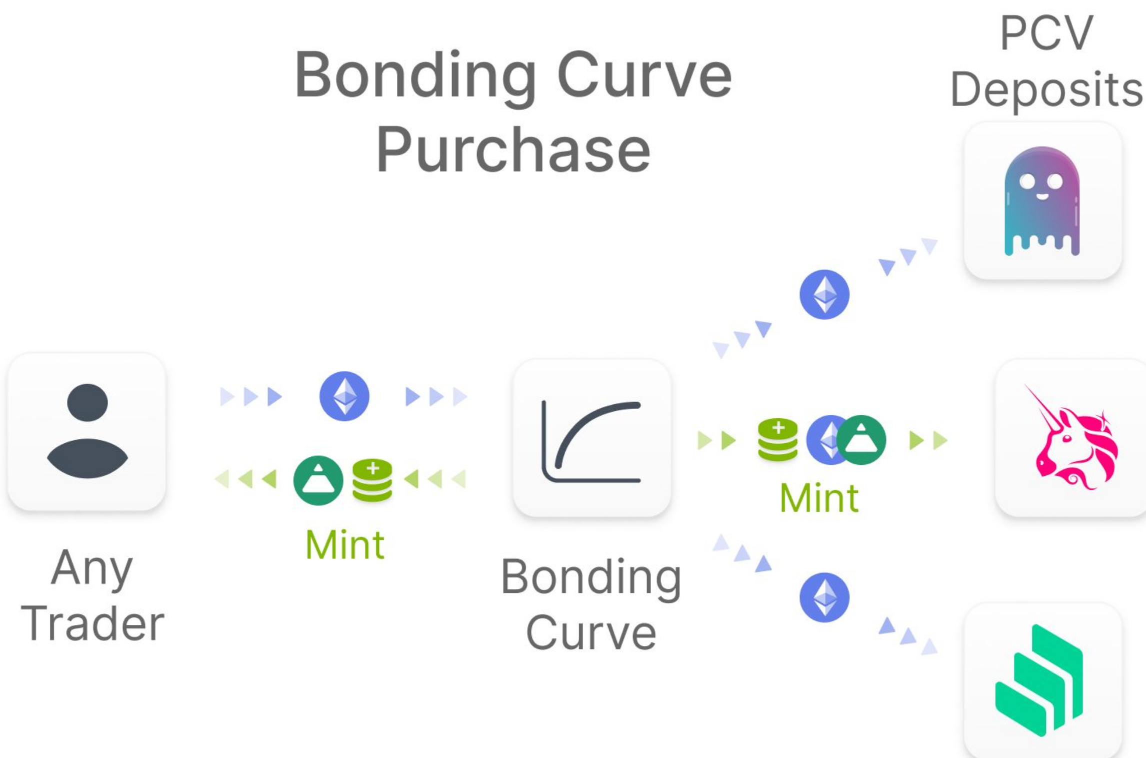
1. Directly from the bonding curve
2. Indirectly from arbitrageurs

Critically, arbitrage is not necessary as users can go straight to the curve. This results in a fair distribution of supply expansions. The protocol benefits in the form of PCV funding.

Fei Protocol uses PCV in the following way. It is funded by a one-way ETH bonding curve which does not allow selling. The PCV is deployed as Uniswap liquidity denominated in FEI and ETH. This can be considered indirect collateralization or "liquidity collateralization".

Liquidity collateralization inverts the traditional understanding of collateral for stablecoins. In an overcollateralized model, a user would supply a fixed amount of collateral like ETH. This collateral could be volatile. As long as the position stays solvent, the debt holder could close the position and redeem their collateral. This collateral now has a new market value. On the other hand, in the FEI model, the only way to redeem for the underlying asset is to sell FEI on a secondary market. For this reason, FEI cannot be used to lever or maintain exposure to collateral assets. Instead, FEI is collateralized by irrevocable protocol-owned liquidity.

This approach has fractional reserve properties. One can consider the collateralization ratio as the amount of PCV divided by the user-circulating FEI. If all outstanding FEI were to be sold or redeemed for PCV pro-rata, this ratio determines the amount received. In this model, there is no requirement for having equivalent levels of PCV liquidity and circulating FEI. The reasoning is the same as in traditional fractional reserve banking: it is inefficient to hold an excess of collateral for every single position if only a subset will ever want to liquidate.

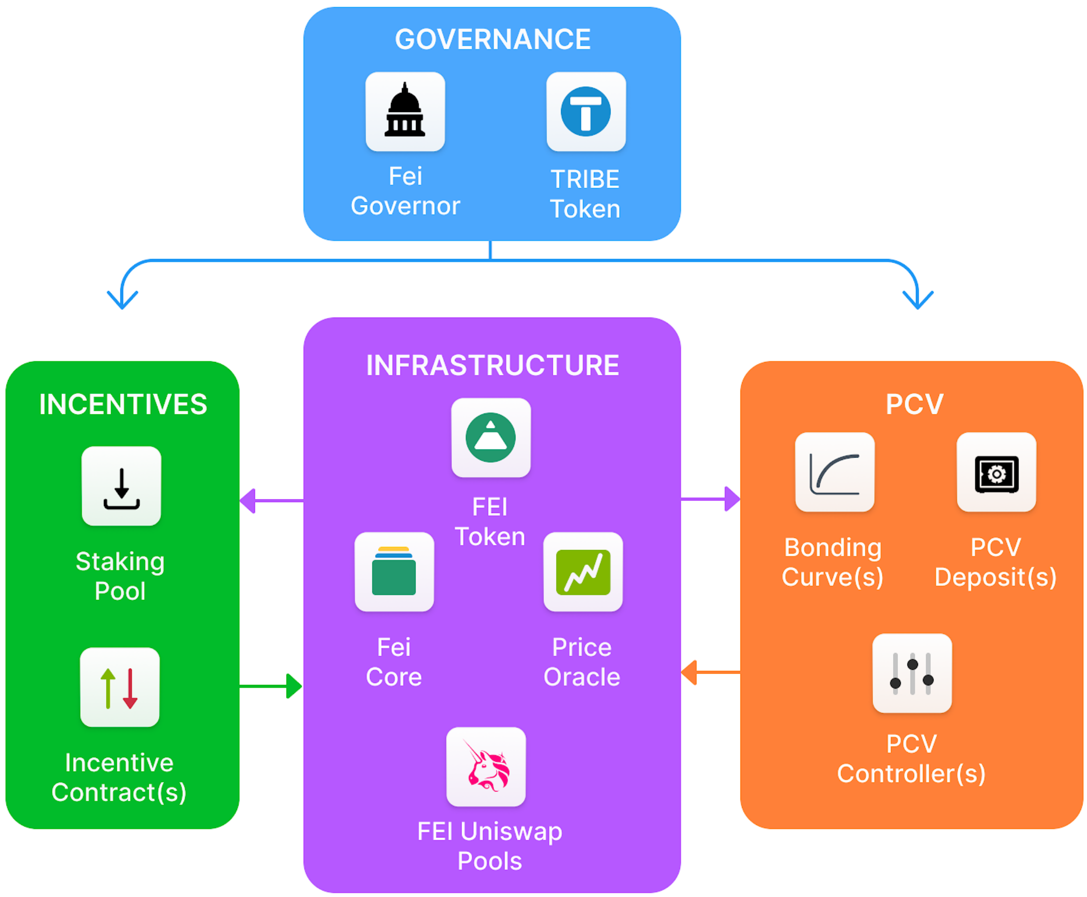


Behind the scenes, Fei Protocol allows for generalized PCV funding and deployment. The funding can come via additional bonding curves denominated in other tokens. Each bonding curve can deploy its PCV to a portfolio which is configurable by governance. A sufficient amount will be allocated to liquidity. The remainder can go to funding interest rate pools on lending markets. It can even be invested in platforms like Yearn to grow the PCV. Another approach could be a Graph Protocol integration in which PCV is deployed to curate a Fei Protocol manifest.

PCV represents a natural progression over Total Value Locked (TVL) in valuing a DeFi protocol. TVL is simply a metric of usage, whereas PCV represents irrevocable value controlled by the protocol.

Fei Protocol Design

As seen below, the system has several core components: Fei Core, the FEI stablecoin, bonding curve(s), PCV Deposits, PCV Controllers, FEI Incentives, and the TRIBE governance token and DAO.



Fei Core

Fei Core is the access control hub for the Fei Protocol. It defines several roles and what each can do. It also maintains a mapping of which contracts have which roles. The roles are as follows:

- Minter - can mint FEI to any address
- Burner - can burn FEI from any address
- Controller - can move PCV in and out from their initial deposit
- Governor - can grant/revoke any role, and upgrade the protocol components. This is discussed further in the TRIBE and DAO section.

The role-based approach in Fei Core allows for complete modularization of the protocol. New features can be voted in by deploying a contract and granting it a role. This flexibility allows Fei Protocol to adapt to ecosystem changes and grow with DeFi.

FEI Token

FEI is the pegged stablecoin produced by Fei Protocol, following the ERC-20 standard. Its supply is uncapped. Minter and Burner contracts control its issuance, via bonding curves and trading incentives. The FEI token exhibits certain non-standard ERC-20 functionality, but only on a subset of transactions. There are dynamic incentives overlaid on transfers involving incentivized addresses. An incentivized address is a contract that Fei Protocol wants to incentivize certain FEI behavior. Incentivized addresses have an associated incentive contract. Incentive contracts control the direction and magnitude of incentives for each transfer. The incentive contract is appointed as a Minter and/or Burner. If a user sends FEI to an incentivized address, their remaining balance will be affected by a mint or burn incentive. The primary incentivized address in Fei Protocol is the FEI/ETH uniswap pool. Traders experience minting and burning controlled by the associated incentive contract. We explore these mechanics further below.

The sender's balance can change by a different amount than the transfer amount. A mint incentive results in a balance increment on the sender, whereas a burn incentive decrements the remainder of the sender's balance after the transfer. An insufficient balance will revert the transaction. This is similar to the functionality of rebasing tokens in that it directly operates on user balances. The important usability benefit of this model is the locality of incentives. They are only applied to the users who engage in the incentivized transfer. Users can plan for non-standard behavior. The incentivized addresses and incentive contracts are publicly known. Users are free to avoid incentivized addresses and other activity is completely standard. The DAO will be able to add and revoke incentive contracts tied to incentivized addresses.

Within the protocol, there are three distinct types of FEI from an accounting perspective, with some overlap. These are all fungible and treated identically from a token perspective. The protocol calculates the supply of each to be used in calculations. The types are the following:

- FEI_p : Protocol-controlled FEI, deployed in LP pools or other allocations per PCV
- FEI_b : Bonding curve distributed FEI given to users. These will be accounted on a per bonding curve level
- FEI_u : User-controlled FEI, the totalSupply() of FEI less FEI_p

In general, there is overlap between FEI_b and FEI_u . When users sell to protocol LP via an AMM, FEI_u can become FEI_p . Vice versa — when users buy FEI, it goes from FEI_p to FEI_u .

Bonding Curves

Bonding curves are Minters appointed by the Fei Protocol. They issue FEI_b and generate PCV used to maintain the peg. The initial curve will be one-sided and denominated in ETH. Its pricing function approaches an oracle peg price. This bootstrapping mechanism offers early FEI at a discount to users for supplying PCV. The point at which the pricing function reaches the peg is known as *Scale.* Scale is the target FEI_b supply at which a Fei bonding curve pricing function switches to 1. The Scale number can be different for different bonding curves. This allows incentivized PCV funding for various underlying tokens. The initial Fei bonding curve will use ETH as the underlying asset. The peg will be the Time-Weighted Average Price (TWAP) of the ETH/USDC Uniswap pool over a 10 minute window.

New Fei bonding curves should only use decentralized tokens to maintain decentralization of the protocol.

The bonding curve issues FEI at a discount with a sublinear growth rate based on the supply. Sublinear curves reward initial investors while still bootstrapping sufficient underlying value to the protocol. A linear or superlinear model would be explosive and lack retained PCV.

Let $O_A(B)$ be the oracle price of A paid in B e.g. $O_{ETH}(FEI)$ = 500 FEI/ETH. The oracle price represents the "target" at which that trading price would imply 1 FEI = $1. Let *S* be the Scale target of a given bonding curve, in terms of FEI_b. The instantaneous ETH price for a unit of FEI at current total supply X pre-Scale uses the following formula:

$$(1) \qquad P(X) = \sqrt{\frac{X}{S}} * O_{FEI}(ETH)$$

One can integrate the curve to determine the quantity Q of ETH required to get from a given level of supply *r* to another level *s*:

$$(2) \quad \int_r^s P(X)\, dx = Q$$

Using the above formula one can calculate the amount of ETH required to achieve Scale for S = 250 million FEI and $O_{FEI}(ETH)$ = 1/500 ETH/FEI:

$$\int_0^S P(X)\, dx = 333,333\ ETH$$

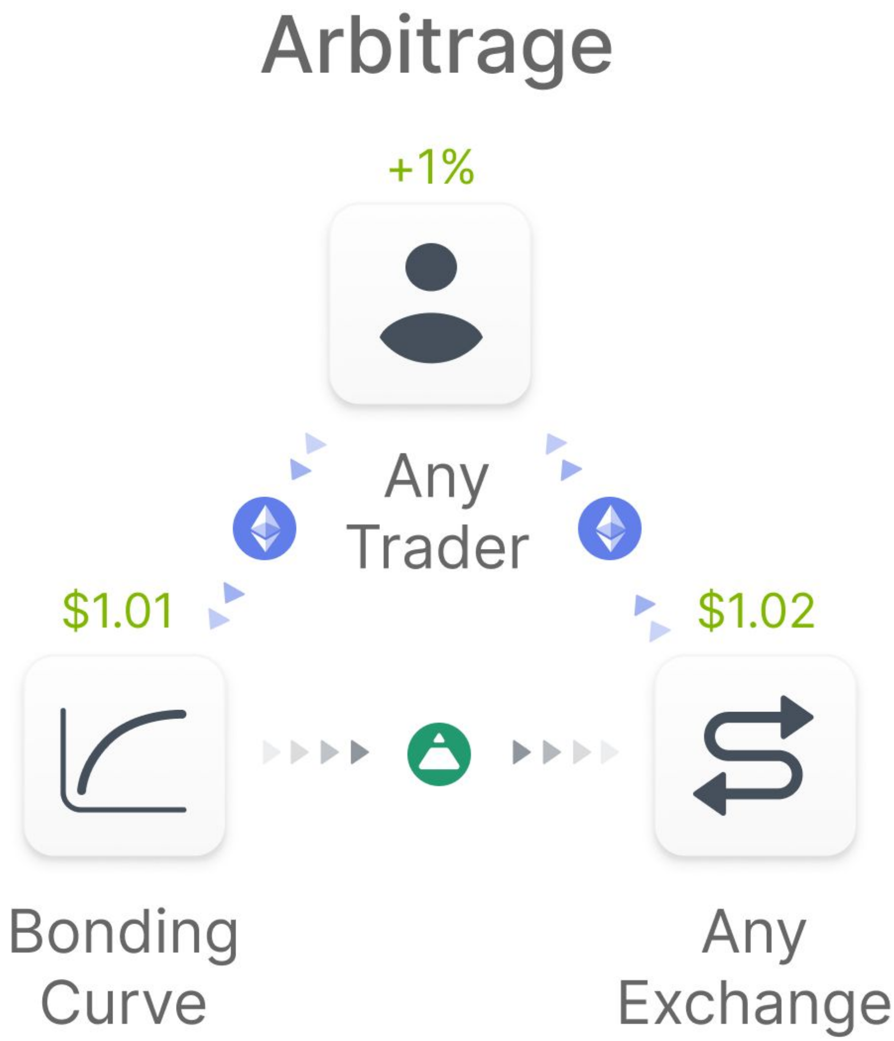
Regarding equation (2), we can define *y* as the end supply. One can rearrange the integral to solve for the amount *y - C* of FEI received for a given ETH investment Q at a current user supply C:

$$\int_C^y P(X)\, dx = Q$$

$$\left(\frac{2\, y^{3/2}}{3\sqrt{S}} - \frac{2\, C^{3/2}}{3\sqrt{S}}\right) * O = Q$$

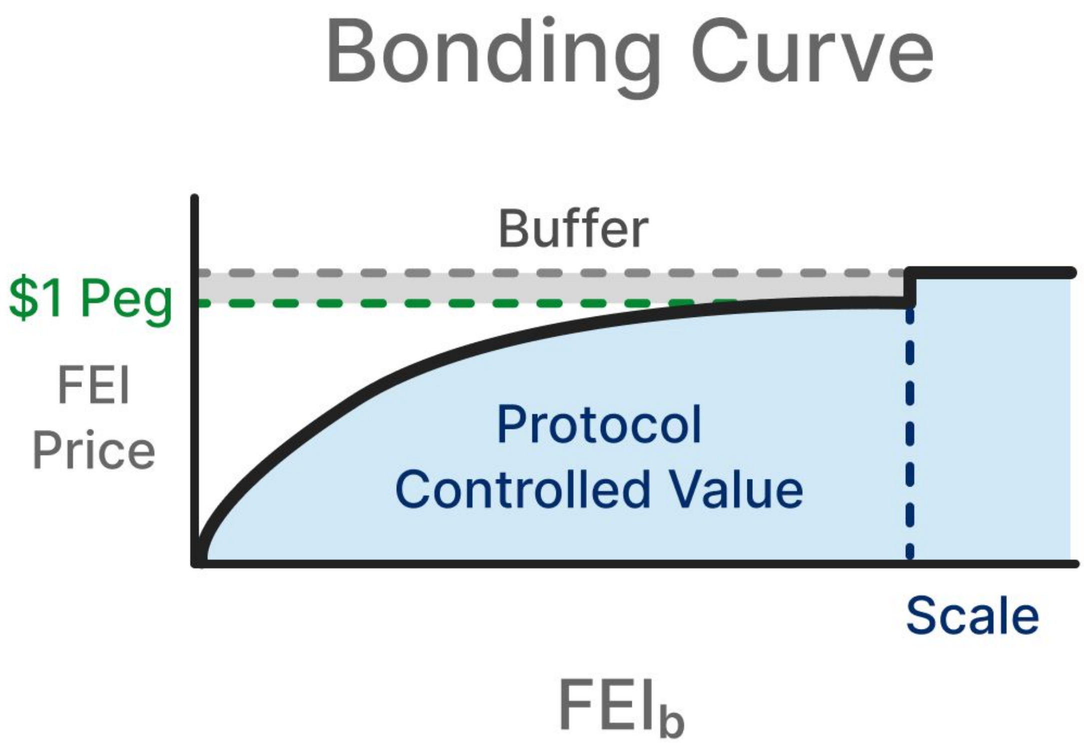
$$(3) \quad y - C = \left(\frac{3\sqrt{S} * Q}{2 * O} + C^{3/2}\right)^{2/3} - C$$

Once a bonding curve achieves Scale, it will fix the exchange rate at $1 + *b*. *b* is a buffer to keep the mean price around $1. When any secondary market price exceeds $1 + *b* there is a riskless profit opportunity. Arbitrageurs can purchase against the bonding curve and sell on the secondary market.



At b=0 the majority of the price variance is below $1. By adding in the buffer b, initially set to 1%, there is room for some variance above $1 as well. Including this price fix behavior, the pricing function extends to

$$P(X) = max(\sqrt{\frac{X}{S}}, 1 + b) * O$$



This pure arbitrage opportunity means the protocol requires no additional incentive to maintain the peg when prices exceed $1 + b. Governance can gradually vote to converge b to 0 as the liquidity increases and volatility decreases.

It is important to note that the curve is one-way and FEI cannot be sold on the curve. As previously mentioned, incoming tokens on the curve are retained as PCV. Deploying the PCV on Uniswap allows for "liquidity collateralization" as opposed to a traditional collateralized model.

Each bonding curve has an adjustable allocation rule which defines a set of PCV Deposits. PCV Deposits are contracts that receive incoming PCV and deploy them in predefined ways. The DAO can adjust ratios and add new contracts (appointed as Minters and/or Burners) as needed.

PCV Deposits

PCV Deposits are the recipients of PCV, funded by bonding curves. Because FEI cannot sell on these curves, it is crucial to create a liquid market that allows for the sale of FEI. The sale price should track the peg. The Fei Protocol will allocate all initial PCV to a Uniswap liquidity pool denominated in FEI and ETH. The concept extends to other token types assuming access to an oracle price to peg to. In this case, the PCV Deposit uses the ETH/USDC TWAP as the oracle. We will now explore the Uniswap PCV Deposit in depth.

The Uniswap PCV Deposit receives incoming ETH from the bonding curve and deposits it into an ETH/FEI Uniswap pool. The FEI for this deposit comes from minting, and therefore this PCV Deposit must be appointed as a Minter by Fei Core. The amount of FEI minted is equivalent to the amount of ETH times the spot price of FEI/ETH in the pool. This mint is distinct from the mint associated with the bonding curve and sent to the user. The former is FEI_p and the latter is both FEI_b and FEI_u. The bonding curve mint is associated with the bonding curve price and the PCV Deposit mint is associated with the Uniswap spot price. These numbers should be similar but do not have to be identical. It seems then that there is double the expected inflation associated with a bonding curve purchase, with half going to the user and half to the protocol-controlled LP. A critical caveat is this FEI_p does not circulate and will only be used as a burning mechanism for the protocol to reweight. It would not impact the price negatively as it would never be sold.

While this is the only PCV Deposit at launch, other implementations are possible to be added via governance. These include liquidity in other AMMs like Curve or SushiSwap. They could also generate yield via a Compound, Aave, or Yearn deposit. They could even serve as collateral to open derivative positions such as FEI yTokens on Yield. The flexible design will allow for new creative deployments of PCV and integrating with future DeFi protocols as they arise.

FEI Incentives

We discuss the mechanics of the FEI incentive contracts in the FEI token section. This section focuses on the way that incentive contracts help maintain the peg. There will be a single initial incentivized Uniswap pool, ETH/FEI. If the price is below the peg, the incentive contract will offer a FEI mint to traders. The next trader to buy FEI on the pool will receive the mint as an incentive for helping return towards the peg. This incentive will take into account the time-weighted magnitude of the distance from the peg.

For example, a 5% immediate deviation from the peg will have a small initial incentive. The incentive will grow over time and at a faster rate than if there was only a 1% deviation from the peg. This creates a reverse Dutch auction mechanism. The mint offered increases over time until a trader accepts the offer by purchasing on Uniswap. This happens atomically and directly on the Uniswap transfer. The traders who are willing to come in for a lower incentive will be the first to restore the peg and get the mint. The following formula is used to achieve this mechanism. Let *w(t)* be a time-weighted function where *t* is the number of blocks since the last time the peg was restored. The output is initialized at 0 and grows linearly at rate *r* per block (set by governance). Let *m* be the magnitude of the price deviation from the peg before the swap executes. *m* is defined as defined as $\frac{P(X) - O(X)}{O(X)}$. The incentive function is:

$$I(x, t) = w(t) * m * x$$

The time variable *t* will reset to 0 each time a Uniswap trade restores the peg. If a trade partially fills the peg, *t* will be partially updated by multiplying it by m_{end}/m_{start} . A 50% move towards the peg by trade volume required would result in a 50% reduction of *t,* which will resume its growth at rate *r.*

To give a concrete example, let's have *r* be .01 per block, the total liquidity in the pool be 200 ETH and 10000 FEI, and an oracle price of 525 USD/ETH. The instantaneous exchange rate here is 500 FEI/ETH, representing a 5% deviation from the peg. After 10 blocks the time weight will equal 0.1. At this point the purchase of FEI towards the peg will reward the trader with 0.5% of the trade value in FEI.

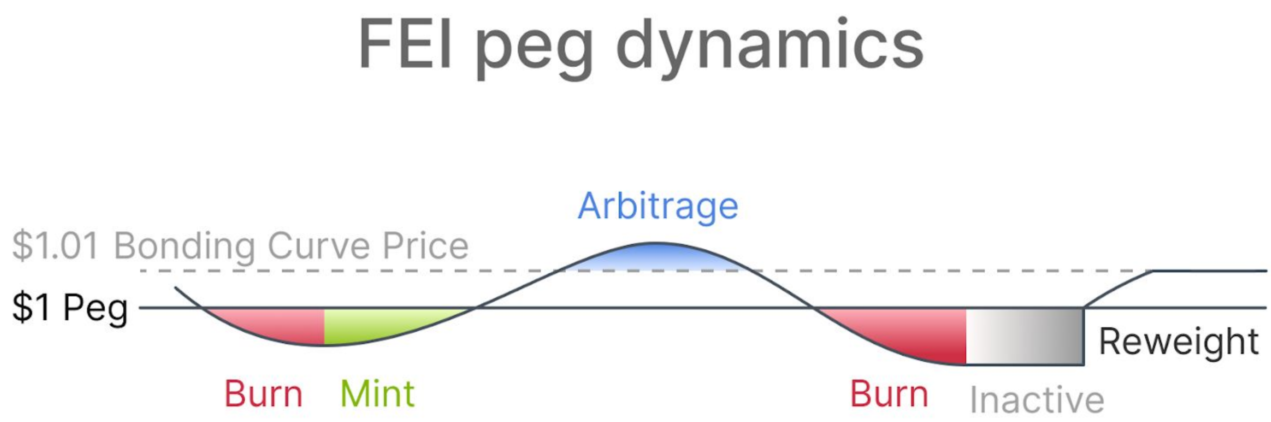
It is important for this mechanism to not be gamed. It is also important to disincentivize trading away from the peg. Fei Protocol achieves this via a dynamic burn mechanism on top of the Uniswap pool when trading below the peg. Similar to the mint, this burn will take into account the distance from the peg. The burn is not dependent on time. The *m* used is m_{end} as opposed to m_{start} in the case of the mint incentive. The FEI balance of the sender will be burned by the fee amount, having a net deflationary impact on the supply. This counters the price movement away from the peg. A quadratic growth rate is used to increase the penalty as the trade size increases via the following burn formula:

$$B(x) = m^2 * x * 100$$

Volatility below the peg should result in net deflation. Any mint associated with buying should not exceed the burn paid to get to that price. For this reason, the incentive is capped at the output of the fee function. The incentive function is extended to:

$$I(x, t) = min(w(t) * m * x, B(x))$$

The peg maintenance mechanics are even simpler above the peg. If the Uniswap price exceeds the bonding curve price, a pure arbitrage opportunity arises. Traders can purchase via the bonding curve and sell on Uniswap. This is true of any other secondary market as well. The buffer plays a critical role here. If the price is always at or below the peg, then every trade would end below the peg and incur the burn penalty mentioned above. By adding in the buffer, users can trade in this window above $1 without incurring the burn for trading below the peg. This one-sided fixed arbitrage loop is a notable advantage to the Fei Protocol mechanism.



An address can be exempted from any incentive or penalty if approved by the DAO. The PCV deposit contract, for example, would be exempted from incentives and penalties. This will also be useful when attempting to integrate with other contracts throughout DeFi.

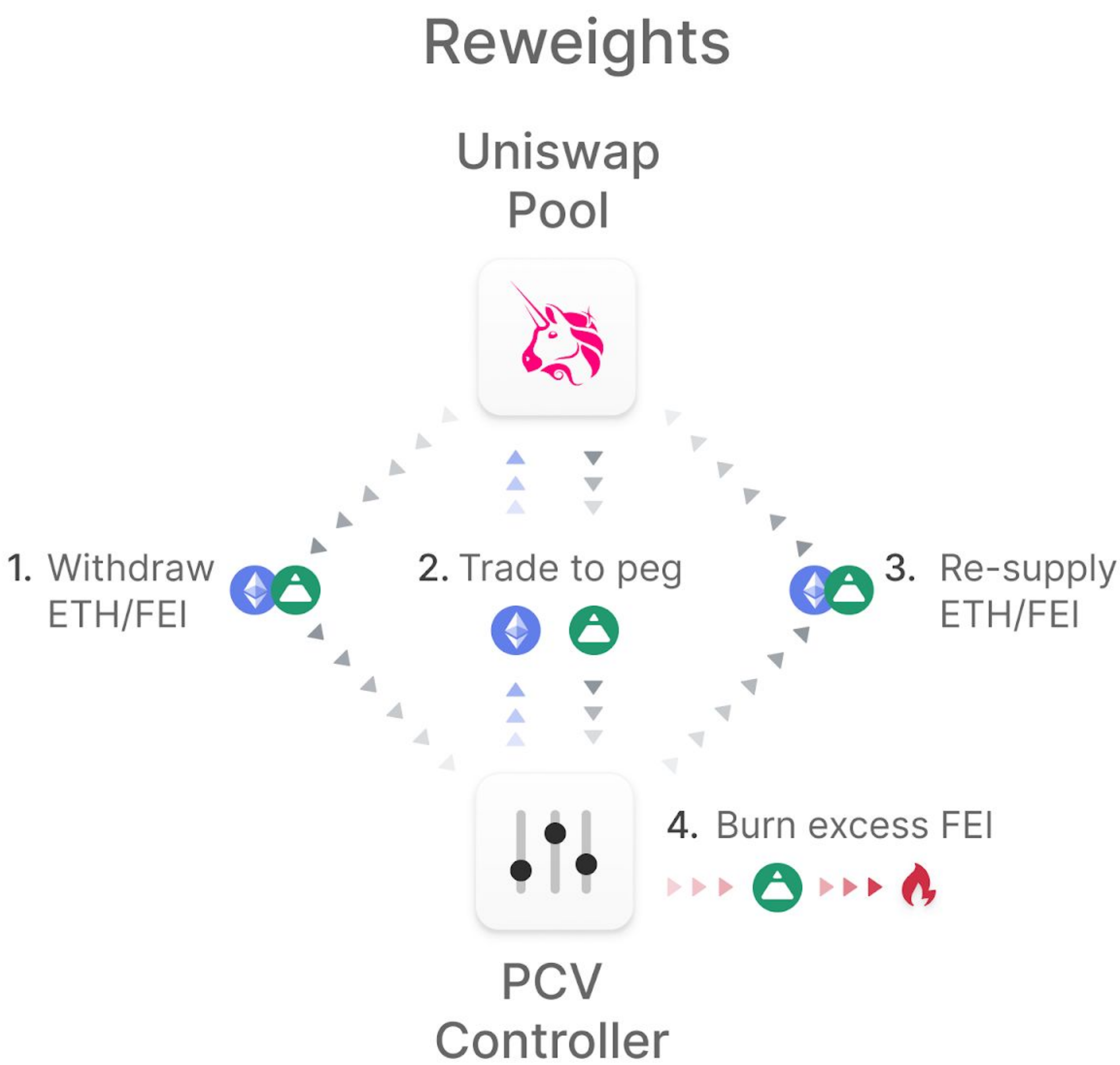
The flexibility of issuing incentives extends beyond simply maintaining the price on exchanges. Incentives can drive behavior such as depositing or borrowing FEI on lending protocols. They can also be used to supply liquidity to AMM pools used as oracles.

PCV Controller

A PCV Controller is a contract approved to withdraw and reweight PCV among PCV Deposits. PCV Controllers are essential to allow the full benefits of PCV to be explored over time. At launch, there will be one primary PCV Controller contract. Governance can add more as needed.

The initial PCV Controller will focus on reweighting the Uniswap ETH/FEI pool. A reweight would mean that the protocol leverages its PCV to bring the spot price of ETH/FEI back up to the peg. This is important in adverse conditions when traders are not willing to support the peg. The FEI incentive may not be enough even at the maximum time weight, calculated as $I(x,t) = B(x)$. When this condition is met, the protocol will open up the ability to backstop the price using this PCV Controller. Any external user, or keeper, can trigger a function which will cause the Controller to reweight the prices. The keeper will collect a mint reward denominated in FEI as an incentive. Reweights use the following algorithm:

1. Withdraw all LP from PCV Deposit
2. If remaining LP exists in Uniswap pool, buy FEI with ETH PCV to restore peg
3. Re-supply the remaining ETH/FEI at the oracle price ratio
4. Burn the excess FEI



Generally, additional Controllers would be able to reweight PCV into other DeFi protocols or Fei contracts. These could include:

- Moving PCV into an oracle LP pool to increase oracle attack difficulty
- Adding to Yearn to generate yield on PCV
- Using governance token denominated PCV such as COMP to vote on proposals
- Supplying collateral for FEI derivatives such as options and futures

TRIBE and the Governance Process

TRIBE governance is critical to the decentralization of the Fei Protocol. The governance mechanism will fork the Compound DAO, where holders can delegate votes. TRIBE is the governance token controlling the DAO, analogous to COMP. Actions follow the proposed → queued → executed flow, if they do not fail or cancel. Governance has control over the following actions:

- Appoint Minter and Burner contracts (including new bonding curves)
- Adjust Scale target and allocation rule on bonding curves
- Adjust incentive time-weight growth rate
- Percent reward for reweight peg restoration
- Reweighting any of the peg Uniswap pools

The Fei Protocol DAO will be able to function like a central bank of DeFi. It can use PCV to adjust rates and market incentives on other platforms. This creates a dynamic ecosystem around FEI.

TRIBE supply will be fixed at 1 billion divided into several categories.

The first category is a FEI staking pool. FEI holders can stake FEI/TRIBE Uniswap LP tokens to earn a percentage of the TRIBE distribution. The rewards will release into the pool over a linearly decreasing schedule. The release will wind down to zero after 2 years. The goal of the staking pool is threefold:

1. Access to TRIBE for early FEI holders
2. A way to deploy FEI rather than statically holding it
3. More liquidity for TRIBE

Another part of the TRIBE supply is allocated to a special group of early adopters known as the Genesis Group. The Genesis Group will be open for a period of 2-3 days in which investors can pool their ETH. At the end of the period, the entire Genesis Group ETH supply will be used to purchase FEI on the bonding curve. This purchase will be the very first bonding curve transaction and have the most attractive FEI price. The Genesis Group participants receive their FEI pro-rata based on the total ETH investment. This is irrespective of when they entered the group. The FEI price will use the oracle price at the end of the Genesis period. The Genesis Group will also receive the aforementioned portion of the TRIBE supply pro-rata.

A portion of TRIBE will be listed on Uniswap in an Initial DeFi Offering. This pair will be denominated in FEI and TRIBE. The exchange rate will be determined as a multiple of the ETH raised in the Genesis Group. The protocol will set this relative to the fully diluted TRIBE market cap. This will give immediate opportunity for price discovery and liquidity to both FEI and TRIBE to all of DeFi. The FEI for this pool will be issued via mint and the Uniswap LP will be owned by the development team. These Uniswap LP tokens will vest over a four-year window to preserve the liquidity for the market. An additional amount of TRIBE will be retained for the development team and investors.

The remaining TRIBE will be held by the protocol as a DAO treasury. The community can distribute this as it sees fit as the protocol develops. This will come in the form of future governance proposals which can gift or delegate TRIBE tokens to users or contracts.

FEI Economic Security

The goal of the Fei Protocol is to maintain a liquid market in which ETH/FEI trades at approximately the ETH/USD price. This should be true even in adverse conditions. PCV allows the protocol to accomplish this goal. When trading activity does not support the peg for extended periods, Fei Protocol spends some of the PCV to reweight the price. We define the *liquidity ratio* as PCV/FEI_u. This is similar to a collateralization ratio. The difference is the PCV is deployed as liquidity rather than directly as collateral.

The liquidity ratio is a measure of how many reweights and corresponding selloff events the protocol can support. If it is less than 1, the protocol is effectively undercollateralized. However, under normal circumstances the protocol would still maintain the ability to repay all outstanding FEI with the collateral. This is a function of the dynamic burn incentives in low demand. Overcollateralization for every single position simultaneously is inefficient. Fei Protocol pools the would-be collateral into a single liquidity pool for any user to redeem. This pool can be either over- or undercollateralized. If it is undercollateralized, it relies on the assumption that not every user would want to sell at once. The protocol deters selling, which incentivizes holding to maintain a robust peg and protect against death spirals. The protocol is designed to improve the liquidity ratio under normal circumstances. This offsets risks associated with the under-collateralization inherent in the mechanism.

In this section we analyze how the liquidity ratio is impacted by trading activity and reweights. We then provide security analysis on the bounds within which the liquidity ratio improves over time.

Liquidity Ratio Updates

A sequence of interactions with Fei Protocol would change the PCV or FEI_u, often in combination. For example, a purchase of FEI on Uniswap or the bonding curve would put ETH into the PCV liquidity pool, and increase the FEI_u. Conversely, a sale of FEI would decrease both values. Let the change in PCV associated with a user action be ΔPCV and likewise ΔFEI_u be the change in user-circulating FEI.

We can define the following update rule to the liquidity ratio for user actions:

$$L_{t+1} = \frac{PCV_{t+1}}{FEI_{u,\,t+1}} = \frac{PCV_t + \Delta PCV}{FEI_{u,\,t} + \Delta FEI_u}$$

Ideally $L_{t+1} \geq L_t$, i.e. the liquidity ratio improves over time. This property is true when the following inequality is true for positive ΔPCV:

$$\frac{\Delta PCV}{\Delta FEI_u} \geq L_t$$

For negative ΔPCV, we flip the sign. Let us call the ratio $\frac{\Delta PCV}{\Delta FEI_u}$ the *capital factor*.
To summarize, when PCV and FEI_u are increasing, we want the capital factor to be greater than the liquidity ratio. When they are decreasing, we want the capital factor to be less than the liquidity ratio.

Effect of Activity on Liquidity Ratio

In this section we explore isolated activities and their effect on the liquidity ratio. Uniswap fees are ignored in the analysis. They are generally beneficial for the liquidity ratio by either increasing PCV or reducing the FEI_u of a trade.

Bonding Curve

The bonding curve has the price of FEI increasing relative to ETH with each purchase. This means the capital factor is increasing. The reasoning is that the new FEI costs more than the previous FEI relative to the same amount of PCV. All else equal, the liquidity ratio must be lower than the capital factor. This is because all prior FEI had a lower liquidity ratio to enter circulation. Each new purchase improves the liquidity ratio and capital factor. Once Scale is reached, the capital factor would fix and the liquidity ratio would converge to it. This can work positively if the liquidity ratio is low and negatively if the liquidity ratio is high.

Trading Activity

When analyzing trading activity, we assume we start at the peg with a certain liquidity ratio. First we look at what happens when FEI trades above the peg. The platform does not incentivize trading activity above the peg. Pure arbitrage should always bring the price down to *$1+b*. Due to path independence on Uniswap, a return to the peg should return to the same liquidity ratio as when last at the peg.

More interesting is the case where FEI trades below the peg. Trading below the peg has a mint incentive *I(x,t)* and a burn incentive *B(x).* The incentive function is capped at the corresponding burn function output. Therefore trading activity below and returning to the peg results in negative ΔFEI_u, i.e. deflation. The amount of deflation is equal to *B(x) - I(x,t).*

Reweights

A reweight by itself only burns FEI_p assuming no other Uniswap LPs. However, reweights must be coupled with a sell. Selling can have a positive or negative effect on the liquidity ratio depending on the current liquidity ratio, the size of the sell, and the associated burn.

Selling reduces FEI_u because the FEI leaves circulation to enter the protocol-owned Uniswap pool. The FEI_u is further reduced via the burn penalty. Likewise it decreases the PCV because ETH is leaving the pool. We need to have the capital factor be less than the liquidity ratio. For a sell amount of *x* FEI we need to have:

$$\Delta PCV \leq -L_t * (x + B(x))$$

We know $\Delta PCV / -x = 1$ because we are selling equivalent amounts of FEI and PCV. Rearranging the formula and pulling out the x we get:

$$\Delta PCV \leq -x * L_t * (1 + m^2 * 100)$$

$$1 \leq L (1 + m^2 * 100)$$

For *L* > 1 this is always true. For lower liquidity ratios we would need a larger burn to hit the appropriate capital ratio. However, the burn formula starts at relatively low numbers. A series of sales coupled with reweights could worsen the liquidity ratio. This would happen when the corresponding burns are too low. The protocol would be relying on excess burning in the peg support case to offset the needed burns for reweights. We formalize this concept below.

External LPs

External LPs are any non protocol actor who supplies liquidity in the incentivized pool. The PCV LP should greatly exceed user LP. This is because all circulating FEI was purchased by ETH which became PCV. User LP does negatively impact the liquidity ratio in the event of a reweight. Reweights would also cost the protocol some PCV if external LPs are in the pool. This is because it needs to execute a trade against the remaining LP to bring the price back up. The relative impact of this grows with the amount of external LP.

PCV Volatility

Volatility in PCV directly affects the liquidity ratio. When the ETH PCV drops in value, traders would sell ETH to the FEI/ETH pool. This increases PCV in the sense that more ETH enters the protocol's control. However all of the other ETH already held as PCV dropped in value. Conversely, appreciation in ETH will have a positive ultimate impact on the liquidity ratio. New bonding curves added to the protocol would diversify the PCV. Diversification would improve the robustness of the protocol because it would less susceptible to volatility. This follows the same reasoning as traditional diversification of asset portfolios.

Fei Economic Analysis

We have analyzed the effect of individual outcomes on the liquidity ratio. Now we can combine them to formalize the economic security bound of Fei Protocol. We have established the following relationships:

- Bonding curve purchases drive liquidity ratio towards 1
- Trading activity below peg improves liquidity ratio
- Reweight can hurt liquidity ratio when below 1
- External LP amplifies the effect of reweights
- Volatility affects the liquidity ratio

The two sources of direct negativity for the liquidity ratio are volatility and reweights. A sustainable liquidity ratio requires that deflation due to trading activity offsets these sources of negativity.

We have already shown the necessary condition for a reweight to be net deflationary.

$$\Delta PCV \leq -L_t * (x + B(x))$$

We can replace *B(x)* with a random variable *B* representing the amount of burn before the reweight. This new random variable includes all prior burning since the last reweight.

If we have the following as true, the protocol should always hold or improve its liquidity ratio.

$$E[B] \geq \frac{\Delta PCV}{L_t} - x$$

$E[B]$ is increased by two factors. The first is concrete burn penalties. Higher burns directly translate to a larger $E[B]$. The second is trader willingness to reweight the peg. More trader support of the peg means less reweights are necessary over time. Additionally, all volatility not resulting in a reweight positively impacts the liquidity ratio. At a sufficient willingness to support the peg, the protocol would never need to reweight. In the event of sustained sell pressure and low willingness to support the peg, governance is expected to intervene. It can adjust the burn formulas to a level which would improve the liquidity ratio.

Governance is incentivized to steward the liquidity ratio and protect the peg. By guarding the key protocol metrics, governance would improve fidelity in the system and grow the protocol. The flexible architecture allows multiple avenues through which governance can add dynamic and autonomous incentives.

Conclusion

The Fei Protocol promotes the sustainable creation of a direct incentive stablecoin known as FEI. FEI issuance is controlled by Minters including one-sided bonding curves used to bootstrap the system. The price approaches the pegged oracle at Scale, after which new FEI can enter circulation seamlessly in direct proportion to demand. The bootstrapped funds are retained as Protocol Controlled Value (PCV) which is used to support the peg. This idea creates a "liquidity as collateral" concept. Value is strategically deployed to create liquidity and incentivize the peg for token holders. Additional direct minting rewards and burning penalties are overlaid on the Uniswap market. This further range bounds the peg. As the platform extends beyond Scale, the collateralization ratio generally increases due to trading activity.
Fei Protocol presents several key advantages over existing decentralized stablecoin models. These include:

- high liquidity via PCV
- decentralized collateral
- capital efficiency
- strong peg
- fair distribution

Fei Protocol is a central bank-like infrastructure that could serve as a backbone to current and future DeFi applications.

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Appendix A — Definitions

The following define variables used by the formulas detailed above.

1. $O_A(B)$: the oracle price of A paid in B e.g. $O_{ETH}(FEI)$ = 500 FEI/ETH
2. $P_A(B)$: the instantaneous price of A paid in B (contextually either on uniswap or bonding curve)
3. S: the Scale target of a given bonding curve, in terms of FEI_b
4. b: the buffer on the bonding curve peg price

5. m : the magnitude difference of a uniswap price and oracle price defined as $\frac{P(X) - O(X)}{O(X)}$

References

1. https://medium.com/hackernoon/stablecoins-designing-a-price-stable-cryptocurrency-6bf24e2689e5
2. https://makerdao.com/en/whitepaper/
3. https://github.com/emptysetsquad/dollar/blob/master/d%C3%B8llar.pdf
4. https://docs.frax.finance/overview
5. https://compound.finance/documents/Compound.Whitepaper.pdf
6. https://yos.io/2018/11/10/bonding-curves/
7. https://uniswap.org/whitepaper.pdf