USDs Whitepaper

Sperax Research

1 Introduction

The main hurdle of cryptocurrency adoption has been price volatility. Most cryptocurrencies have a fixed supply schedule ensuring that fluctuations in demand directly translate to fluctuations in price. Although the predictable supply schedule is a highly desirable feature that enhances the "store of value" capabilities of these tokens, the resulting high volatility acts as a significant hurdle for such tokens to be used as a medium of exchange. Stablecoins have emerged as a solution to this problem. These coins have quickly gained traction and have become one of the most promising and rapidly evolving segment of the crypto space. More than $290 billion worth of stablecoins were moved on-chain in 2020 (Source: TokenAnalyst).

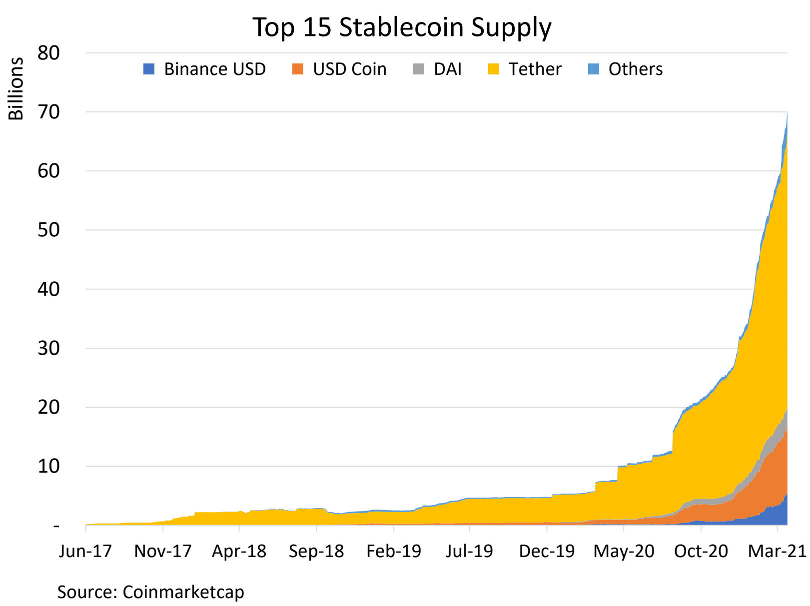


Figure 1: Stablecoins growth.

Figure 1 captures the meteoric growth of the main stablecoins. Stablecoins can be broadly classified under three categories. First, fiat-backed stablecoins are by far the most widely adopted, since these provide a tight peg. However, their success comes with several shortcomings. Fiat-backed stablecoins tend to be highly centralised, which makes them prone to censorship, and subject to counterparty risk. Furthermore, the need to hold fiat reserves makes them capital inefficient, i.e. large amount of capital sitting idle as collateral for the currency. A second category of stablecoins encompasses crypto-backed stablecoins operating on chain. This feature makes them significantly more transparent, however, owe to the cryptocurrencies' high volatility, these stablecoins require overcollateralization to ensure that price fluctuations of the collateral do not translate into fluctuations of the stablecoin. This feature makes them capital inefficient and significantly hinder their scalability.

To solve some of these issues, algorithmic stablecoins –which rely on having an elastic supply schedule–have been proposed. The main advantage is that algorithmic stablecoins are scalable and trustless by design. The limited success of these currencies is mainly due to these coins being hard to bootstrap and prone to periods of extreme volatility.

Figure 2 shows the prices of existing stablecoins of each category 180 days after launching. The fiat-backed stablecoins are the least volatile, whereas algorithmic stablecoins are the most volatile. It is worth noting that most algorithmic stablecoins have existed for less than 180 days, and may stabilize eventually as they mature, as shown by the Ampleforth case.

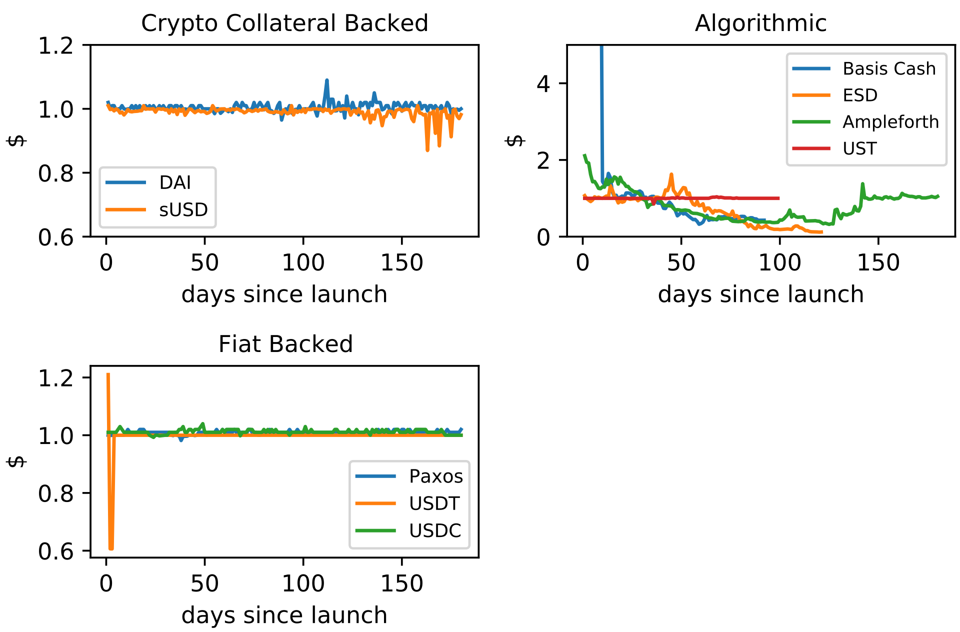


Figure 2: Stablecoin price since launch
Source: coinmarketcap

The growth of the decentralized finance (DeFi) space has spearheaded the adoption of stablecoins. DeFi denotes a wide array of blockchain-based applications intended to enhance cryptocurrency holders' returns without relying on intermediaries. Depositing stablecoins in a savings account, for instance, can now generate positive yields for investors who do not need to fear that changes in the price of the currency could offset any interest gain. Tether has successfully found market fit because of its elastic supply. However, its centralization and fiat-backing feature makes it a suboptimal choice as it is clearly at odds with the core principles of DeFi.

While DAI addresses the demand for decentralization, its high collateral requirements, driven by the volatility of the cryptocurrencies accepted as collateral, make it less successful in scaling rapidly.

The problem of which type of collateral to accept and the amount of overcollateralization is inherently a dynamic problem, which depends on the market demand for the stablecoin and the maturity of the network, among other factors. USDs combines the best of the existing different designs, by being an algorithmic, highly scalable, trustless and decentralized stablecoin protocol that operates fully on-chain. The key innovation introduced by USDs is a dynamic reliance on both cryptocollaterals and algorithm to provide stability, capital efficiency and rapid scalability. Specifically, this novel design allows us to rely on cryptocollateral at genesis to then shift towards an algorithmic-based stability mechanism once the mechanism has proven its efficacy and the need for growth is strongest. This mechanism is likely to benefit both investors and users by taking advantage of changes in market conditions in real time.

The rest of the paper provides more details about the different components of USDs and is organized as follows. Section 2 describes the key elements of the stability mechanism. Section 3 discusses how the protocol determines which collateral is acceptable. Section 4 focuses on the stability levers. The appendix provides further details about the mechanisms by presenting a simulation highlighting the main features. We will also be publishing a separate paper on the economics of SPA staking and their relationship to USDs as well as detailed stress testing to fine tune the parameter choices.

2 USDs Stability Mechanism Outline

USDs is an algorithmic, highly scalable, trustless, decentralized stablecoin protocol that operates fully on chain. Most of the existing algorithmic stablecoins are highly trustless and scalable, but hard to bootstrap and tend to experience periods of high volatility. USDs plans to resolve these issues by borrowing insights from crypto collateralized cryptocurrencies like DAI, and dual token algorithmic stablecoins like Terra.

The Sperax protocol will offer a dual token system with a stablecoin (USDs), as well as a governance/value accrual token (SPA). The USDs will be explicitly collateralized by a pool of existing stablecoins (and other crypto assets), and implicitly by the protocol which utilizes SPA to stabilize the uncollateralized component algorithmically. Finally, to further influence money supply dynamics, the protocol will be paying adjustable interest rate (funded by external DeFi sources and partial SPA inflation) to existing USDs holders.

2.1 Minting and Redeeming Stablecoins

Minting new USDs is meant to be rather simple. Users have to lock eligible collateral within the system. The list of eligible collateral and the initial fraction of USDs collateralized by cryptocurrencies, defined as χ, will be determined at launch by the Sperax Foundation. Accordingly, an aggregate $1-\chi$ units of SPA tokens will be burned for each additional unit of USDs. Decision making will later passed onto DAO after governance rights have been sufficiently distributed through yield farming incentives.

To further describe the mechanism, consider the case of a single collateral, the protocol will mint an additional stablecoin following this simple equation:

$$S = SPA + C \qquad \text{, where} \quad 0 < \chi < 1 \text{ and } SPA = \frac{(1-\chi)}{P_{SPA}} \text{ and } C = \frac{\chi}{P_C} \tag{1}$$

where S is the new USDs minted, χ is the collateral ratio, P_{SPA} is the price of SPA in USD, SPA is the number of SPA coins burned, P_C is the price of the collateral in USD and C is the units of the collateral.

Note that in the case of multiple collaterals, χ will depend both on the assets' characteristics as well as on the composition of a particular trade. However, we want the tokens to be fungible and be redeemable in the same way, independently of their underlying minting collateral. Therefore USDs will act as an IOU on the pooled collateral, with SPA stabilising the algorithmic component of the money supply.

Redeeming 1 USDs at the protocol level always gives the user 1$ back. Specifically the user will receive:

$$1\$ = P_{SPA} SPA + P_{C_i} C_i \tag{2}$$

where

$$SPA = \frac{1-\chi}{P_{SPA}} \quad \text{and } C_i = \frac{\chi}{P_{C_i}} \tag{3}$$

where the first term is "funded" by minting SPA and the second term is funded by releasing locked collateral from the protocol.

The equations above can be summarized graphically by Figure 2:

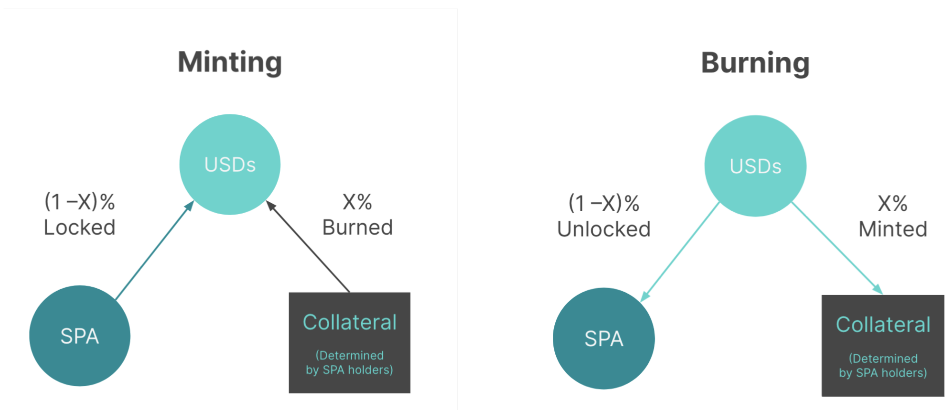


Figure 3: Minting and Burning of Stablecoins

2.2 Dynamic Transition between Algorithmic and Collateralized Mechanism

One of the key innovations of the Sperax protocol is the possibility to determine the fraction of the money supply that is algorithmically determined versus the fraction that is collateralized. In other words, the protocol will automatically adjust the parameter χ. What are the main drivers of changes in χ? In a nutshell, the algorithm will favor algorithmic stabilisation when USDs trades close to the peg and as USDs matures as an asset.

Specifically, the protocol will target the composition component of the money supply using the following equation.

$$\chi_{target} = f(\text{ Time}, \text{USDs price})$$

As USDs matures, the protocol will gradually rely more on the algorithm and less so on the collateral (ie χ_{target} will go down). Additionally, the protocol will adjust the reliance on the algorithm depending on USDs price. If price is well above the peg, the money supply will rely increasingly more on algorithmic stabilisation (ie χ_{target} will go down), while if the coin trades below the peg reliance on external collateral will increase (ie χ_{target} will go up). A simple yet effective parameterization of the above relationship is the following:

$$\chi_{target} = \alpha * \text{Block Height} + \beta * (1 - \text{USDs price})^2 \mathbb{1}_{1 > \text{USDs price}} - \beta * (1 - \text{USDs price})^2 \mathbb{1}_{1 < \text{USDs price}}$$

where

$$\alpha < 0 \quad and \quad \beta > 0$$

We have run extensive simulations to determine the optimal values of the above parameters. We calibrate α to reduce reliance on collateral by about 1% a month. For β we pick values to make the algorithm sufficiently responsive to rapid changes in situations where USDs deviates from the peg.

A final distinction worth-noting is that even if χ_{target} should be close to the aggregate collateral ratio (ie $\frac{\text{Total Value Locked}}{\text{USDs Circulating Supply}}$), due to the volatile nature of crypto collaterals, there will be times where the above relationship won't hold exactly. To alleviate this issue we propose the following solution: We differentiate between minting and burning χ. Specifically we set:

$$\chi_{Minting} = \chi_{Target}$$

and

$$\chi_{Burning} = \chi_{target} + \gamma * max(0, \chi_{Target} - \text{Collateral Ratio})$$

The above distinction will ensure that the protocol will always be solvent even if there is not sufficient value locked. In other words the above equation ensures that the protocol will be forced to utilize additional SPA in situations where aggregate collateral ratio is less than the target. This in turn would lead to a smaller depletion of reserves therefore pushing $\chi_{Burning}$ closer to χ_{Target}.

3 What's the Optimal Collateral?

At launch, the Sperax Foundation has selected an initial basket of acceptable collaterals deemed safer. However, all future decisions will be determined via a DAO process. The key objective is for the reserves to experience high growth, low volatility, and low correlation with each other. Users will have the flexibility to deposit whichever approved collateral they wish, but at the same time, the protocol leverages fundamental insights derived from modern portfolio theory to ensure that the composition of collaterals is on the efficient frontier with a maximum Sharpe ratio.

The selection of collaterals is done through a dual-process model. We first conduct a screening portfolio optimization to eliminate insignificant assets that contribute little to stabilize volatility and generate a return. Secondly, after the list of eligible collateral has been determined, we run a portfolio optimization algorithm using historical data of the collaterals to find the optimal weights for each one of them. These weights will reflect the target reserve composition of the protocol. Whenever the composition of available reserves deviates from the target, the protocol will offer incentives for users to adjust their collateral position. We run the collateral ratio simulation based on historical price data and with the total supply of USDs following a Brownian motion, The volatility of collateral and the probability of under-collateralization for each asset are the two main parameters determining the optimal collateral mix at launch.

3.1 How is the Optimal Collateral Target Determined?

The target will be determined via the following minimisation problem, which gives us the highest possible returns for a specified risk tolerance level:

$$min \quad w^T \Sigma w \quad s.t \quad R^T w = \mu$$

where $\Sigma_i w_i = 1$ is the vector of optimal collateral weights, R is the vector of expected returns of the reserves, $w^T \Sigma w$ is the variance of the reserves, and $R^T w$ is the expected return of the reserves.

The efficient frontier is a set of optimal portfolios that gives the highest possible expected return for a given level of risk. In particular, we are interested in a combination of collateral assets that generates the highest Sharpe (return to volatility) ratio.

Our portfolio optimization involves additional machine learning techniques. Noise in the empirical data makes covariance matrices numerically ill-conditioned, market component in the historical data interferes asset clustering, and Markowitz's curse prevents stable solutions in portfolio optimization. It is then crucial to de-noise and de-tone the covariance matrix of the assets portfolio before we optimize its allocation. In addition, clustering in portfolio optimization is necessary to avoid assets that share common traits to concentrate on higher risks, and deriving relative performance with respect to feature selection and dimension reduction. The goal here is to use the correlation matrix as an objective matrix and then separate the assets into groups, where intragroup similarities are maximized, and intergroup similarities are minimized. By incorporating these techniques to our portfolio optimization algorithm, we are able to generate efficient portfolios with robust weight compositions.

To avoid overfitting in our model, we will include k-degree cross-validation to guarantee that the optimal performance characteristics can also be replicated out of the sample. In the long term, rebalancing serves an important function in keeping a portfolio targeted to the appropriate level of risk, that is, we want ensure we are not exposing the protocol to idiosyncratic cryptocurrency risks. We will apply a hybrid rebalancing method. In doing so, we'd review the target every week, but only rebalance if it falls outside our assigned threshold. This threshold is dynamic and will be adjusted regularly but at random times in response to changes in market conditions. The randomness of rebalancing prevents our protocol from malicious attacks.

3.2 What is the right peg?

Which asset should the stablecoin be anchored to? The most common choice is to target a single fiat currency; the most common asset is usually the USD. Being the reserve currency of the world, it is usually considered the most secure and widely adopted fiat. A key advantage of having a single currency is that price comparison are easy. However, this requires the users to trust that the stablecoin provider is indeed maintaining a fiat reserve to fully back the stablecoin.
Other choices include a basket of currencies. Examples include the IMF SDR (such as Terra SDT or Saga), or other composite baskets of currencies. The main drawback of such options is that they don't have significant use cases and are overly complicated for most retail investors.

Another option is for the stablecoin to be pegged to commodities, such as gold (i.e. Paxos gold and Hellogold). However, commodities tend to have higher volatility than fiat, which makes the peg of such cryptocurrencies harder to defend.

Finally, stablecoins can also target an index such as the CPI, S&P 500 or any other composite index. Though targeting an index might seem different from targeting a currency, the mechanics are actually identical.
USDs: USDs will peg to the USD at first. Our stablecoin design will be sufficiently flexible to ensure that more fiat currencies and assets can be targeted down the road. At any given point in time, SPA holders will be able to expand the selection of stablecoins-currency pais that we offer.

4 Stability Levers

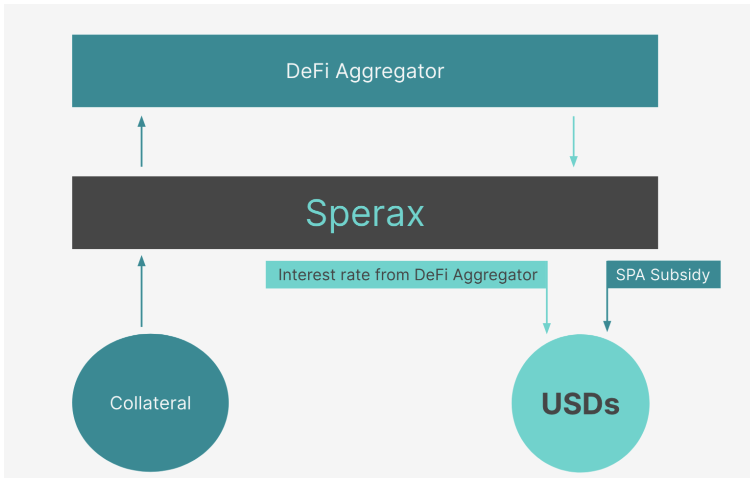
Let's assume that USDs trades at a premium ϵ on exchanges. Under such scenario interest rate payments will increase, causing higher inflation and therefore selling pressure, which will push the price downwards. Additionally the protocol will always mint 1 USDs for 1 dollar worth of SPA and collateral tokens. This ensures that unlike recent coins with algorithmic supply adjustments like Basis Cash or Ampleforth, USDs will exhibit a price ceiling. This is because when the peg trades upwards an arbitrageur can always make money by buying 1 $ worth of SPA tokens and collateral, and using them to mint 1 USDs which he can sell on an exchange to make ϵ profit. The interest rate payments will be calibrated to ensure that the arbitrage strategy is always more profitable than just holding the coins.

As the price of USDs drops below the peg, interest rates will decline (exploring the possibility to also turn negative when the deviation is sufficiently large), and this will encourage more users to burn their existing USDs as well as buying USDs from exchanges to burn them. The burning of tokens via swaps as well as the reduced (or negative) inflation from interest rates, will ensure that the supply of USDs is sufficiently reduced, pushing the price upwards. It's worth noting that a user will always prefer to swap the USDs rather than selling it, because the protocol will always pay more than the open market when the price of USDs is less than 1 USD.

We believe that the combination of a protocol market maker as well as an interest rate mechanism will ensure that USDs trades within a tight range of the peg.

Finally, one might wonder what the purpose of having any collateral is if the protocol acts as a market makers, while also directly adjusting the supply of stablecoins. Since SPA is a novel asset, with no proven track record, we believe that a high collateral ratio will build more trust towards the system in the early days. As USDs adoption widens and SPA becomes more scarce and valuable, we believe that the economy will be able to handle higher levels of leverage and in turn of SPA burn.

4.1 Defi Yield Aggregator



Decentralized yield aggregators are financial protocols that enable users to automate the process of deploying assets into the most lucrative yield farming opportunity.

USDs holders will earn passive income from the protocol through yield aggregators. The collaterals including USDT, USDC, DAI, UST, WBTC, ETH that users locked will be re-invested through an external yield aggregator (yearn.finance) while UST will be re-invested in Anchor. Later on, Sperax will deploy its own aggregator.

The key advantage of implementing an external aggregator is that yearn.finance has extensive optimization strategies in its vaults to guarantee the best possible interests for our collaterals. However, we will eventually deploy Sperax yield aggregator, a more sophisticated tool where users can customize their collateral strategies, maximize profits, and reduce transaction costs.

4.2 Interest rate stabilisation

To lower the velocity of the money supply and ensure that holding USDs is attractive, the protocol will stabilise the interest rate by employing the following equation:

$$\text{SPA Subsidy }\% = max(0, \text{Short Term APY}_t - \text{Long Term APY}_t)$$

where Short Term APY_t denotes the short term moving average APY generated on the total collateral at time t, and Long Term APY_t refers to the Long Term Moving Average APY of total collateral at time t.

This will ensure that the protocol will offer a relatively stable APY, independent of market conditions. This is because the above formula will subsidize the yield given to the USDs holders by ensuring that it is as close as possible to its long term value.

4.3 Swap Fees

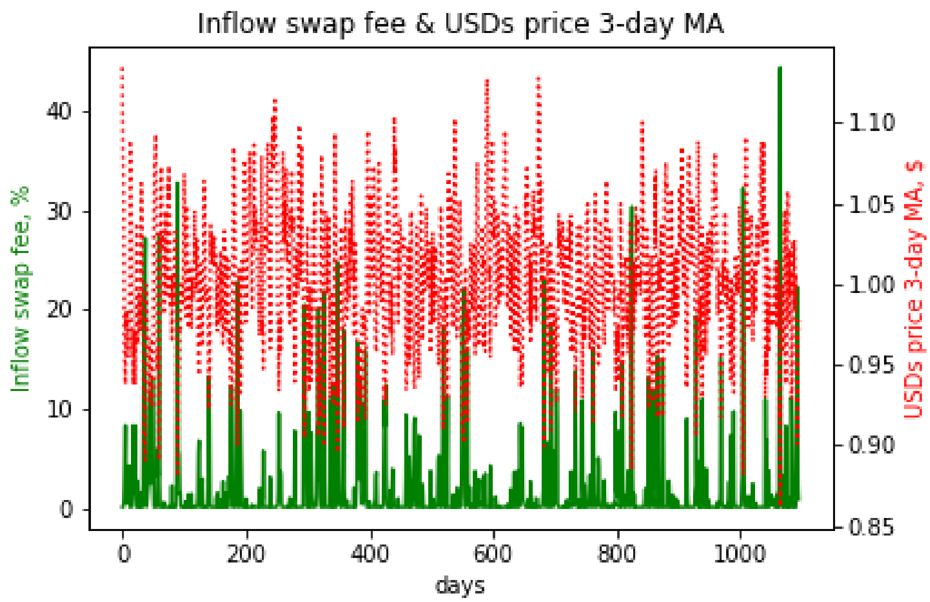
A user mints USDs by burning SPA and locking collateral in the protocol (protocol inflow), and retrieves his SPA by returning the USDs (protocol). We impose fees both when SPA and collateral is sent to the protocol (inflow swap fee), and when SPA and collateral is retrieved from the protocol (outflow swap fee). Both fees have a baseline of 0.1%, which, assuming an average USDs loan duration of 3 months, translates into 0.8% annually, uncompounded.

4.3.1 Inflow Swap Fee

The purpose of the inflow swap fee is to prevent excess minting of USDs. As long as the 3-day average USDs price is above $\underline{p}\frac{\$}{\text{USDs}}$, the inflow swap fee per transaction is kept at a minimum of 0.1%. When 3-day average of price falls below $\underline{p}$, the fee increases quadratically based on the size of deviation. At any given time, the inflow swap fee (c^i) is calculated according to the following equation

$$c_t^i = \begin{cases} 0.1\%, & \text{if } \underline{\text{p}} < P \\ 0.1\% + [(\underline{p} - P)\delta]^2\%, & \text{o/w} \end{cases}$$

where $\underline{p} = 0.995$, $\delta = 50$, and P is the 3-day average USDs price. The following figure shows the simulation of daily USDs price and inflow swap fee for three years.

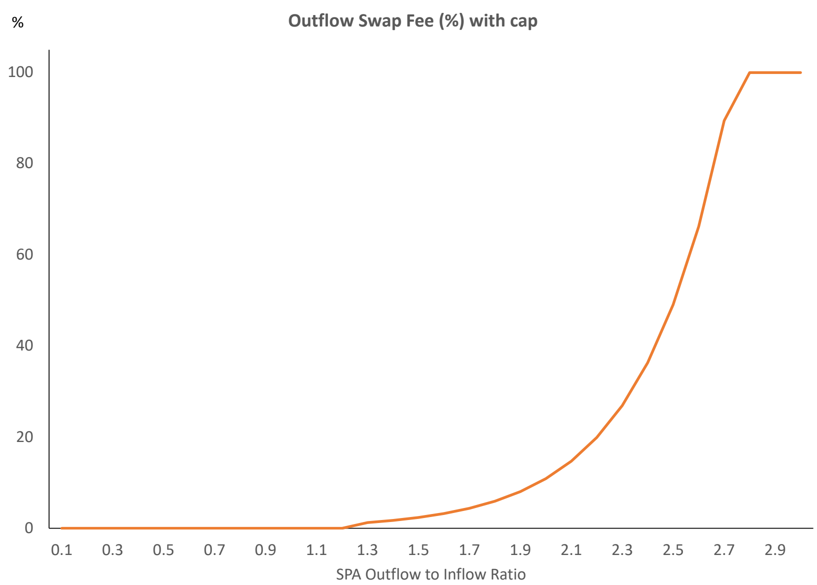


4.3.2 Outflow Swap Fee

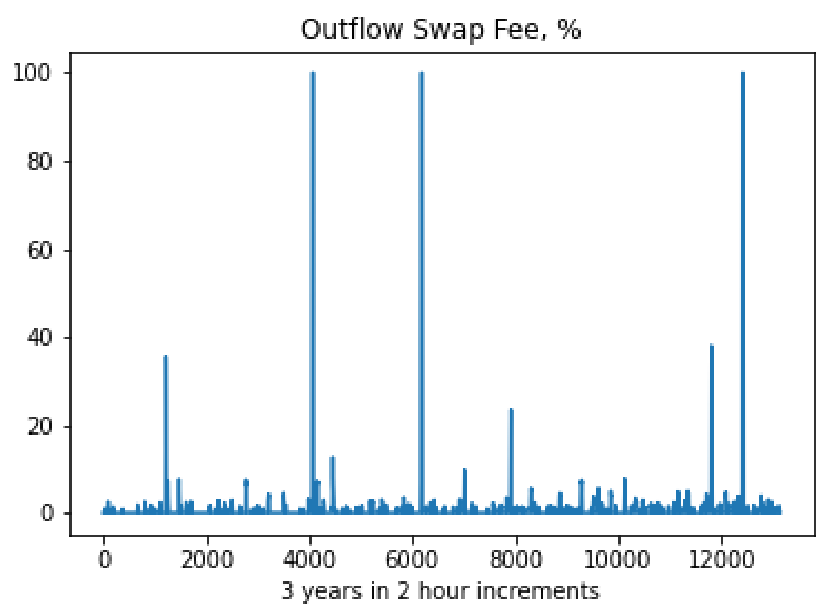
The purpose of the outflow swap fee is to prevent a bank-run situation that depletes the amount of SPAs locked in the protocol. The fee is set at a minimum of 0.1% and increases exponentially when the average 3-day outflow to inflow ratio ($\frac{\text{O}}{\text{I}}$) exceeds threshold $\underline{a}$. This fee is capped at 100%.

$$c^o = \begin{cases} 0.1\%, & \text{if } \frac{O}{I} \leq \underline{a} \\ A^{\frac{O}{I} - \underline{a}}, & \text{if } \frac{O}{I} > \underline{a}, \text{ up until } 100\% \end{cases}$$

With $\underline{a} = 1.2$ and $A = 20$, the following figure plots outflow swap fee as a function of 3-day average outflow to inflow ratio.



Lastly, we simulate the USDs demand to derive net SPA outflow and inflow at a two-hour frequency, and calculate the outflow swap fee for three years.



4.4 Spreads and Liquidation fees

4.4.1 Conversion and Withdrawal

Fungibility is crucial for USDs to be reliable and exchangeable, so we will implement a withdrawal process to guarantee all USDs in circulation have identical collateral. Users are free to lock any collateral given the current eligible choices. There will be a 7-day lock-up period. Users can redeem USDs and withdraw collateral at any time but will only start receiving interests if they lock it for an interval longer than the lock-up period. The interests earned for each eligible collateral are dynamic according to market condition. When users request to redeem USDs, they can actively choose and receive the collateral of their choice. The withdrawal process needs a 24-hour unbinding period, in which the protocol can accumulate bundles of withdrawal requests and reduce transaction costs by processing together. A flash swap function will also be implemented if users need to redeem and withdraw immediately. However, any additional costs will be accrued to the users. After the redeem and withdrawal process, users will receive equivalent value of SPA and collateral.

5 Conclusion

Our current design allows for a fully permissionless, scalable, yet stable money. By having some explicit collateral, we increase trust towards the system in the early days, making the bootstrap of our stablecoin easier while allowing for our native token to grow. Additionally, by being not fully collateralised, we make USDs more scalable and also allow ourselves to increase adoption by offering interest rate payments generated via seignioage. By combining a protocol market maker with swap functionality, as well as a rebase functionality, we are able to create a protocol that responds to market conditions more dynamically and accurately. The current design is highly deflationary for the SPA token. Additionally there will be a couple of fees (minting, burning, transaction) that will all accrue to SPA holders. The ongoing yield, flexibility, scalability and decentralised nature of USDs, will massively increase their adoption. The generated cashflow of increased USDs adoption, as well as the realised SPA deflation, will lead to significant value accrual of SPA.

6 Appendix

6.1 Monte Carlo Simulation

Since USDs hasn't been launched we don't have adequate data to directly study real world supply dynamics. To bypass this problem we will conduct a simple Monte Carlo simulation, where we simulate USDs demand dynamics combined with real world observed collateral prices.

6.2 Modelling USDs Demand

We decide to model USDs demand in a parsimonious way that captures the two main aspects :1) volatility and 2) growth rate. A Geometric Brownian Motion is a natural choice that allows us to study such dynamics in a tractable way. Accordingly, the law of motion for USDs demand S_t can be expressed as:

$$D(t) = D(0)\exp\left(\sigma W_t + (\mu - 0.5\sigma^2)t\right) \tag{4}$$

with

$$\mu = 1500/(365 * 3)$$
$$\sigma = 1.65$$
$$D(0) = 1$$

where μ gives us the drift component (ie annualised growth rate in the absense of volatility) and σ gives us the annualised volatility component and W_t is a Brownian motion. We parametrized the simulation so that USDs market cap after three years will be \$1.5B. To extract stablecoins in circulation from the demand function we make one additional simplifying assumption. Specifically we abstract away from peg dynamics and we assume that $USDs = 1\$$ at all times and that

$$Supply_t = Demand_t = S_t \tag{5}$$

We run the simulation 5000 times, and the figure below gives us an illustration of the median USDs demand dynamics for 3 years post launch.

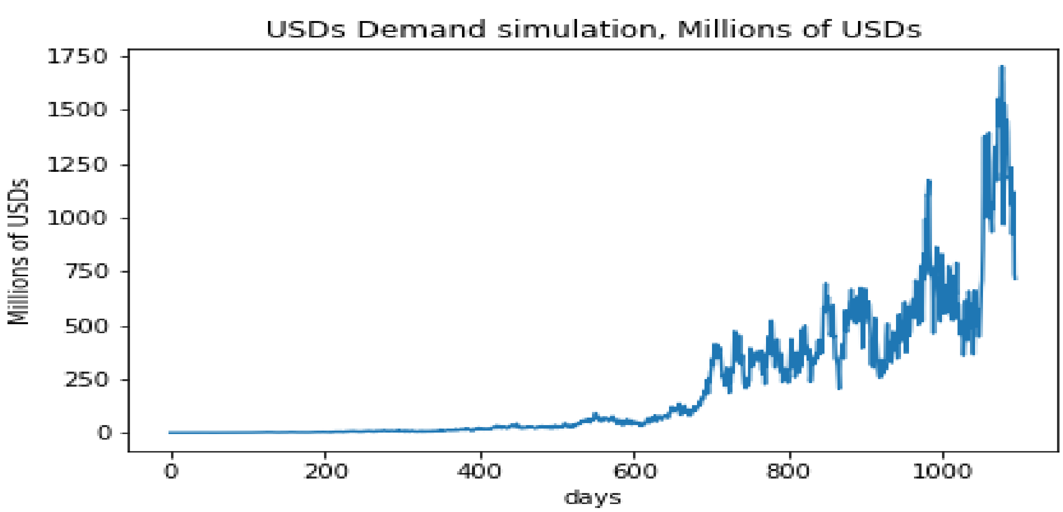


Figure 4: Illustration of median USDs demand for 3 years

6.3 USDs price simulation

The USDs price series used in swap fee and χ simulations follows a normal distribution.

$$P_{USDs} \sim N(\mu, \sigma)$$

with $\mu = 1$ and $\sigma = 0.075$

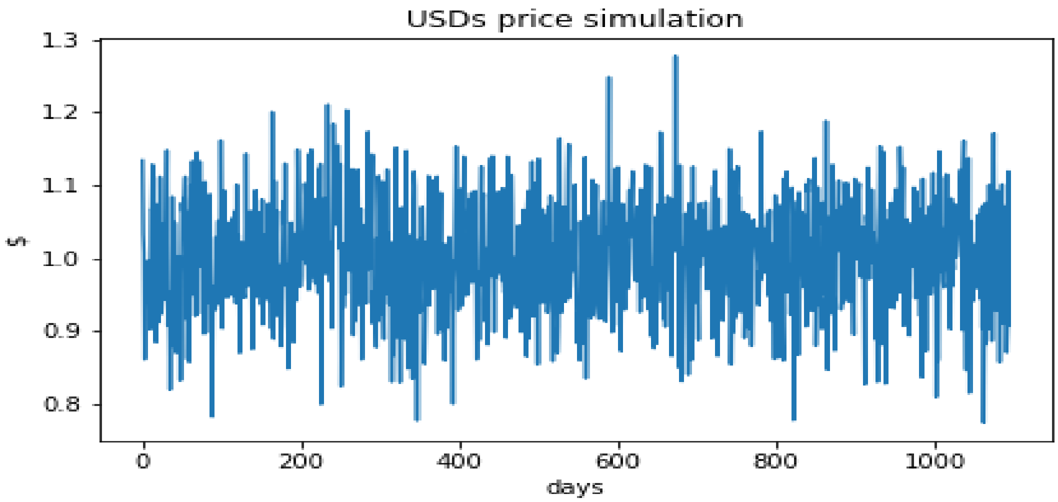


Figure 5: Illustration of USDs price for 3 years

7 DAO Governance

We would also like to introduce a DAO governance mechanism for users to participate and vote on major decisions including but not limited to collateral type, swap fee parameters, and withdrawal lock-up period. For a proposal to be implemented, three stages are included in the process. The initiating stage is to gather the minimum required amount of security deposit within two weeks when a proposal was submitted. Security deposits can be made by the proposer or any SPA holders interested in potentially passing the proposal. After the initiating stage, the proposal enters the voting stage. SPA holders are granted four voting options: "Yes", "No", "No with Veto", "Abstain". Only the stakeholders are allowed to participate in governance. The voting stage will last for a week. The counting stage determines whether the proposal will be implemented. When making the decision, we consider three parameters. First is Quorum, which is the number of participants that voted for the proposal divided by the total staked tokens at the end of the voting stage. Second is approval rate, which is the number of participants that voted "Yes" divided by the total number of participants that voted anything but "Abstain". The third is the denial rate, which is the number of participants that voted "veto" divided by the total number of participants that voted anything but "Abstain". At the same time, we want to lower the quorum requirement when the approval rate is high. A power function is included to dynamically adjust the quorum requirement with different approval rates under the predetermined maximum denial rate.

7.1 Portfolio optimization results and visualization

We simulate over 20,000 portfolios with historical price data to derive meaningful results. For each level of annualized volatility, the highest expected annualized returns are connected to form the efficient frontier. On this curve, we can find the optimal portfolios with minimum volatility and maximum Sharpe ratio. Since we want the collaterals to experience high growth and low volatility, maximizing the Sharpe ratio would be our prioritized objective. We visualized the result in the figure below.

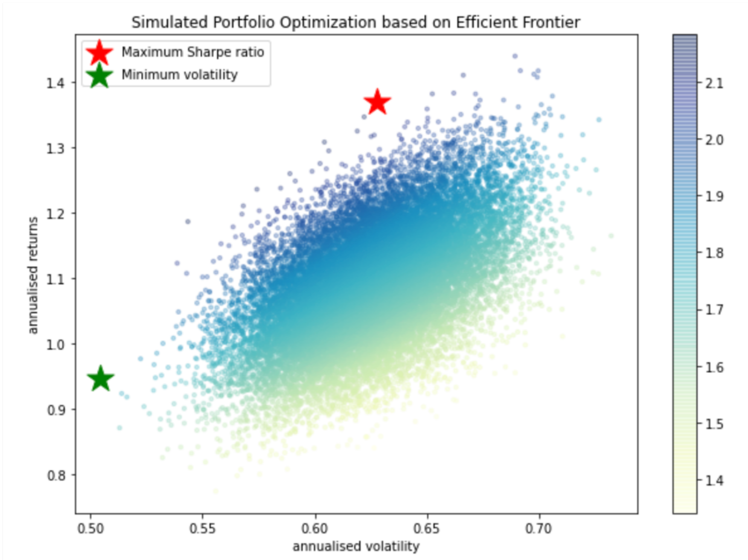


Figure 6: Efficient Frontier Simulation

Furthermore, we backtest the portfolio optimization algorithms to compare the in-sample Sharpe ratio with the out-of-sample Sharpe ratio. It is worth noting in the table below, *before detone and denoise* means that we apply the original empirical covariance matrix and mean return into the optimization algorithms and *after detone and denoise* means that we first transform the covariance matrix and then we put it into the algorithms. Also, NCO stands for nested clustering optimization. Here, it means that we apply clustering during the Markowitz optimization. The result is consistent with our hypothesis that the out-of-sample statistics is underperformed. One important realization is that if we preprocess the data before optimization, we can generate better results both in-sample and out-of-sample. Also, if we apply both detonedenoise and clustering in the optimization, we can have a consistent performance both in-sample and out-of-sample. More detailed statistics are summarized below.

Rebalancing is crucial in stabilizing the volatility and promoting the long-term growth of our collaterals. We also backtest and analyze the importance of rebalancing on a 7-day horizon with a 10% threshold for selected assets. The figures below show that DAI's weight deviates from our initial target with the highest frequency and magnitude. Especially in the crypto market, assets fluctuate more than traditional stock markets. Constant rebalancing with a lower threshold is more imperative to stabilize our portfolio and generate positive returns. In particular, the rate of return is over 100% and the standard deviation is around 20%. in practice, the external oracle will calibrate rebalancing frequency and threshold to guarantee a dynamic and randomized mechanism.

	In-Sample	Out-of-Sample
Markowitz before detone & denosie	3.07	0.24
Markowitz after detone & denosie	29.56	15.58
NCO before detone & denosie	1,39	-0.41
NCO after detone & denosie	11.63	11.11

Figure 7: In Sample/Out-of-Sample Results

Figure 8: Rebalancing Backtest