A Survey of Techniques for Price Stabilisation of Cryptocurrencies

Robert Wessel Blokzijl TU Delft
Delft, The Netherlands
R.W.Blokzijl@student.tudelft.nl

***Abstract*—Stablecoins are a hot topic in the crypto space. With the original cryptocurrencies like Bitcoin and Ethereum garnering a lot of interest because of their volatile natures and consequently exiting investment opportunities, other cryptocurrencies fill the opposite niche in the market. Today many stablecoins are exploring the techical and financial opportunities of providing a currency that maintains its value over time independent of the movements in the crypto space. With the 3th largest cryptocurrency and stablecoin Tether breaking a market cap of 63 Billion Dollars, it is becoming clear that stablecoins are a noteworthy contender in the race for the future of money. Decentralised stablecoins like MakerDAO are combining financial derivatives with smart contracts and create a completely distributed and open market that dynamically stabilises a token. Other initiatives like Facebooks Diem (previously Libra), are presenting themselves as the next world currency providing a stable store of value and medium of exchange to the world, while being controlled by a handfull of opaque multinational corporations. It is clear that not all stablecoins are created equal, the techniques used and their implications on security, privacy and control, vary massively. In this paper we survey the techniques used by the largest and most prominent stablecoins and organise them into a taxonomy based on their features and implications.**

***Index Terms*—Stablecoins; Blockchain; Cryptocurrencies; Tether; MakerDAO; Diem**

I. Introduction

While the original cryptocurrencies are struggling to become stable enough to become a viable store of value, some currencies are using a collection of stabilisation techniques to become the worlds first digital currency to replace your bank account. Stablecoins promise to offer all the advantages of the digital world, while being as reliable as a briefcase of 100 Dollar bills. The market appetite for this has been proven in the success of Tether, now the 3rd largest cryptocurrency in the world by market cap at 63 Billion Dollars. While their success is undeniably, they have been criticised for their methods as Tether is a centrally controlled stablecoin that derives its stability from the collateral managed by the Tether Holdings Limited company.

With Tethers success showcasing the potential of price stable currencies, other organisations have started similar initiatives using various methods of stabilisation. Facebook's Diem being the most notable, with their stability dependent on their reputation rather than some collateral. This essentially makes them a world wide fiat currency, with the benefits of programmability, but lacking the guarantees of government run central banks.

Both Tether and Diem effectively create a privately managed central bank that used their centralised control to keep their currencies stable. Some argue that this centralisation is counter to the mission of cryptocurrencies: to require no corruptible third party to manage the management and exchange of money. In response to this centralisation and to solve the stability issued plaguing the original cryptocurrency, fully decentralised cryptocurrencies have been created. Tracking the US dollar only as a reference value, currencies like MakerDAO have found ways to stabilise their currency through a smart contract controlled system of financial derives that influence the market forces to stabilise a token.

Regardless of the motivation of the creators, all stablecoins are subject to the trust of the public as well as traditional market forces. The value of an asset follows whatever the public thinks its worth, this means that influencing the price means that aligning investor incentives is key in stabilising any currency.

Within this paper we will survey the most common techniques to stabilise cryptocurrencies, and show the inherent trade-offs between various methods. First, in chapter 2, we discuss the topic of the purpose of money, the meaning of value and stability, and some currency pegs used in our traditional monetary system. We then describe the simplest and most successful stablecoins, namely the centralised coins in Chapter 3. In Chapter 4 and 5 we go into the more complex topic of decentralised assets and their methods for maintaining pegs to real world assets without a central party guaranteeing the peg. We then go deeper into the theory in Chapter 6 where we look at the research into the viability of stablecoins. We then end with a discussion of the research on stablecoins in Chapter 7 and a conclusion of the survey in Chapter 8.

II. Background

Before we present out taxonomy we will explore the background of asset stabilisation. In further chapters we

then explain how the various currencies use various digital versions of these techniques to achieve price stability.

We first explain an economic model by which we can understand the various methods employed by different currencies. Then we explain the oldest concept of stabilisation, namely collateralisation. This will define the relevant terms and give the necessary background to understand the different techniques used by the different stablecoins.

A. The quantity theory of money

The laws of supply and demand model how the price of an asset in a market is determined by the amount on offer versus the amount required at any given time. This model does a good job explaining price changes following events that impact either. For the purpose of controlling the price however, we need a model that gives us inputs that we can affect. As both demand and supply are usually controlled by independent actors in a market, we look at the quantity theory of money instead.

In The Value of Money [45] Pigou describes the role of the money supply in the Quantity theory of money and its relation to the price. The quantity theory of money states:

$$M \times V = p \times T$$

Where M is the total money supply, V is the velocity of circulation, p is the price of good and services and T is the total volume of transactions.

Note that p is the price of goods and services, and is thus the inverse of the price of the currency. To reduce complexity later on in this paper we will use an adapted version of the theory:

$$M \times V \times P = T$$

Where P is the price of a unit of currency.

The velocity of circulation V is a measure of how quickly money is spent after receiving it. Together with the total money supply M it makes up the supply side of the theory. If either of these factors increases, everything else being equal, the price P will have to decrease. These two variables therefore make up the supply side of the quantity theory of money.

The amount of transactions T makes up the demand side of the theory. T is alternatively described as the total amount of goods and services offered. Regardless, it is a measure of the desire of people to aquire the currency. If the rate at which people want spend money increases, the demand for the money follows. If all supply side factors stay the same, the price will follow this demand.

In this survey we will see mechanisms that control the price by influencing the total supply M, the velocity V in order to respond to the changes in the demand T.

B. Collateralisation

The easiest way to keep a token stable is to simply have it derive its value from a different asset that is already stable. This is called pegging. The pegging of a token to another asset can be achieved by allowing investors to one asset for the other at any time for a set exchange rate.

The guarantee of a set exchange rate E allows a single party to control the price of the currency in the market R. If the price on the market is below the set exchange rate ($R < E$), it becomes favorable for any investor to buy the asset on the market and sell it to the centralised party for a direct profit of $E - R$. Conversely, if $R > E$, an investor can buy the currency at the exchange and sell it on the market for a direct profit of $R - E$. This effectively reacts to all market changes by varying the total supply M.

Additionally, this mechanism provides a guarantee about the minimum value of a currency. Even if noone is interested in buying the currency, the single exchange will always accept it for a known value. This increases the addoption and trust in a currency.

This guarantee in times of crisis is ofcourse dependent on the trustworthiness and ability of the single exchange to provide the exchange rate. Unless the exchange always has enough collateral available, the guarantee will not be maintainable in all economic conditions. Non-collatoralised exchange rate systems are also vulnerable to attacks like on black wednesday [52]. This happened in 1992, when the European Exchange Rate Mechanism (ERM), an exchange rate agreement between most of the nations of the European Economic Community[44], was famously attacked by George Soros. By taking on huge amounts of debt denominated in british pounds, he was able to weaken the Brittish Pound to the point where they had to leave the ERM, and allowing the currency to quickly drop in value, making Soros over 1 Billion Pounds.

The most common way to guarantee the exchange rate even at times of great economic stress is to hold some form of collateral. Collateralised currencies are not vulnerable to the Soros attack. If the total value of the collateral, more than 100% of the outstanding currency, that means in the hypothetical event of a total shutdown of the currency, everyone can be made whole with the stored collateral. This makes it immune from bank runs, which greatly increases confidence. If the total value of the collateral is less than 100%, the token is considered under-collateralized. This can have large ramifications to investor trust, and may thus undermine the stability of the coin itself.

The first collateralized pegs were tracking the value of gold. Every unit of a currency could be exchanged for a certain amount of gold. As described in “The Gold Standard” [14] by Cooper, the US dollar has been pegged to Gold for many years. By allowing the public to trade their Dollars for a predetermined amount of gold, confidence

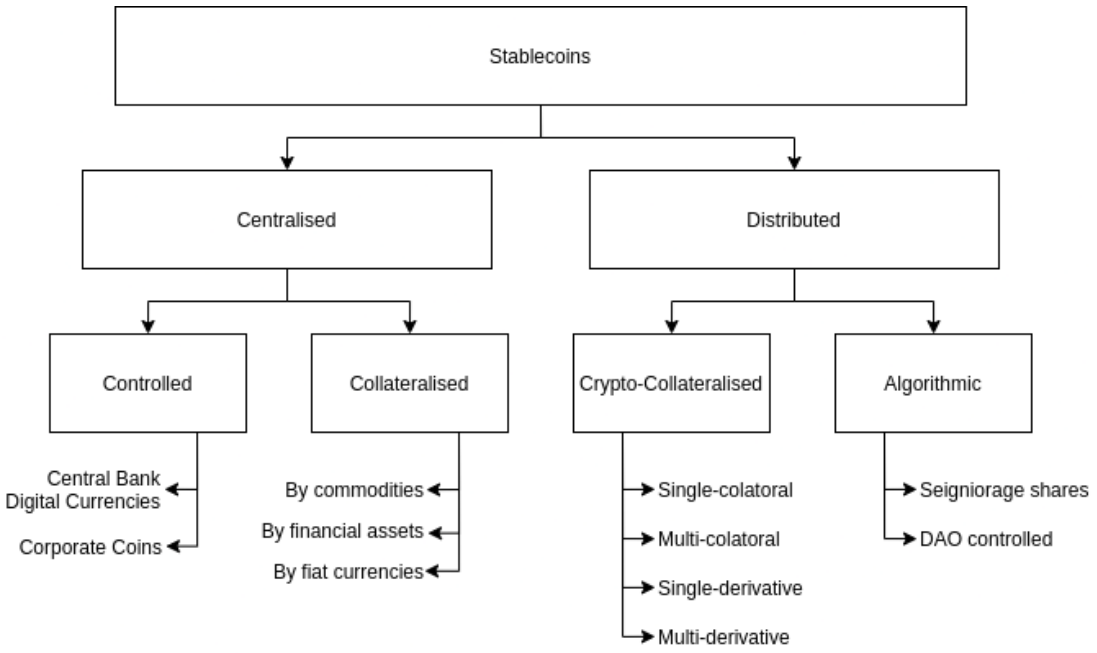

Figure 1. Taxonomy of stablecoins

in the value of the currency was maintained even during harsh economic times.

The concept of collateralization is highly utilised in stablecoins. It is the methods of storing and managing the collateral that differentiates the currencies.

III. Taxonomy of stablecoins

The price of any commodity or market traded asset is subject to supply and demand, this includes crypto-currencies. If there is a difference in demand and supply at a certain price, the price will move until demand and supply are equal. The only way to make sure the price doesn't move is to influence supply to match demand or vice versa. All the stablecoins discussed in this survey will do this in a certain way.

To manage market forces a diverse set of strategies have emerged, which can be categorised in the categories visualised in 1. The easiest way to manage the price is through centralisation. This involves a centralised party that controls the currency in various ways to keep it stable. Within the centralised category category there are two sub categories. In the controlled category, we have currencies that are stabilised through monetary policy like systems. This includes coins announced by some investment firms, but also digital currencies deployed and run by a central bank. The other category under centralised stablecoins, is those that are collateralized. These stablecoins are generally managed by an organisation that guarantees a 1:1 exchange rate between a token and underlying stable asset, most commonly the US Dollar.

Though many centralised stablecoins are becoming more diversified in their collateralization, the organisations that run them remain a central point of failure. The risk of collateral depletion by the market maker failure is always prevalent and though some stablecoins store their collateral with bankruptcy remote companies, this just moves the risk to a different central entity. To protect investors from the failure of any central entity and even the failure of the financial system as a whole, stablecoins have emerged that remain price-stable in a decentralised manner.

Decentralised stablecoins come in two main categories. The first is Crypto-Collateralized Stablecoins. These peg to the value of some stable currency, usually the dollar, and creates a tailor made derivatives market using smart-contracts that makes sure the currency is stable with respect to the pegged asset. They remain collateralized at over 100% in some other currency than the pegged currency. The second is Algorithmic Stablecoins. These dynamically and automatically vary different parameters of the network to influence one or more of the quantity theory of money parameters.

Every stablecoin optimises has chosen its own set of trade-offs. These trade-offs are illustrated in figure 2. Ideally all cryptocurrencies are fully collateralized on some stable entity, fully-capital efficient at a collateralization ratio of exactly 100%, and fully decentralised to eliminate a central point of failure. However, not stablecoin has achieved all 3 of these. Centralised stablecoins sacrifice decentralisation, algorithmic stablecoins sacrifice collateralization, and all crypto-collatoralised stablecoins are collateralized for more than 100%.

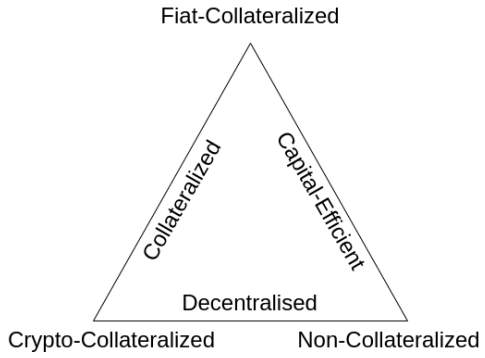

Figure 2. Inherent trade-offs of stablecoins

IV. Centralised stablecoins

With more control over the supply of a currency, the price stabilisation of a currency is significantly simplified. Minting more in times of high demand is a powerful way of controlling the value of a currency and preventing runaway deflation. Conversely, reducing the rate of minting slows down inflation of the currency.

Another way of stabilising a currency is to peg it to an already existing currency or commodity. This method brings with it questions about collateralization, transparency, risk, and the meaning of value.

In this section we explore the techniques employed by both central reserve, and pegged stablecoins.

A. Centalised collatoralised stablecoins

The most successful strategy to create a stablecoin has been to simply tokenise an existing fiat currency. This is done by guaranteeing a 1:1 exchange rate, which allows creates a hard price floor and ceiling.

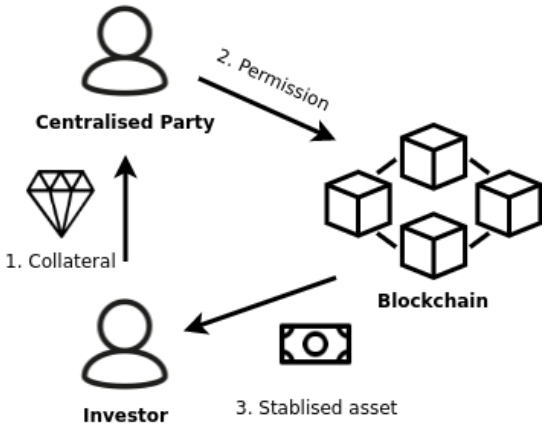

Figure 3. Minting a pegged crypto-asset

Figure 3 describes the way in which pegged crypto assets are created. The centralised party in the image provides some guarantee about the exchange rate. For this example we assume a peg for 1 stabilised asset to always be worth 1 dollar. In this context, the dollar is provided as collateral for the asset in the following way.

1. 1 dollar is transferred from the investor to the centralised party using traditional payment systems.
2. The centralised party mints 1 stabilised asset and transfers it to the investor
3. The investor is free to use the asset as they please, and might even trade it on the market for some other currency

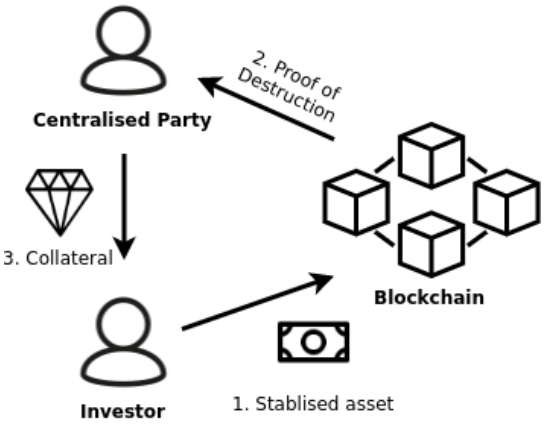

Figure 4. Burning a pegged-crypto asset

Figure 4 illustrates the general way in which pegged crypto assets can be traded back for the original asset.

0. Anyone can obtain the stabilised asset by trading for it on some market or by having one minted by the centralised party.
1. Any investor who holds a stabilised asset can send it to the blockchain to be burned.
2. Upon receiving a proof of destruction, the centralised party will send an equivalent amount of dollars back to the investor.
3. The investor is now out of their position.

By guaranteeing that there is always a 1:1 exchange rate between the collateral and the stabilised asset, the asset is pegged at a 1:1 ratio even in external markets. This illustrated using the following two scenarios.

When the stabilised asset trades for more than 1 dollar on the open market, anyone can make an instant profit by minting more assets, and immediately selling them on the open market. This process will continue to increase the supply of the asset until the price is back down to 1 dollar.

Conversely, when the stabilised asset trades for less than 1 dollar on the open market, anyone can make an instant profit by buying the coins on the open market, and immediately burning them. This process will continue to decrease the supply of the asset until the price is back up to 1 dollar.

1) Benefits of Centralisation: While decentralised currencies can peg to fiat-currencies, these pegs can not be maintained by maintaining fiat collateral. This is because fiat-currencies need to be held in trust by some party. There simply is no such thing as a decentralised bank account.

Having real fiat-currency in reserve lends legitimacy to the system. Even in the case of very turbulent markets, there will always be enough collatoral to repurchase every token from the market. This makes centralised stablecoins, the safest, and most achievable stablecoin.

The success of the 3 top stablecoins Tether [35], Centre's USDC [13] and Binance's BUSD [1] prove the benefit of the system with their combined market capitalization of 99 Billion USD.

2) Critiques and dangers of Centralisation: Having a centralised storage does create a central point of failure. Since trust in the crypto space has been based on what is public on the blockchain and verifiable, proving the absence of fraud in the centralised systems becomes a new challenge. To address the concerns of token holders, the different stablecoin organisations provide some indication of the proper storage of collateral. Common ways to improve investor confidence include:

1. Regular audits providing proof of collateral in escrows (Tether [35], USDC [13], PAXos [9], TrueUSD [54])
2. Multiple independent collateral trust accounts (TrueUSD [TrueUSD:whitepaper], Stasis Euro [24])
3. Subjecting themselves to established regulations and providing FDIC- insurance. (PAXos [9])
4. Organising the escrows as "bankruptcy remote" companies, that will still pay out collatoral if the organisation goes bankrupt.

Through these means stablecoin organisations aim to counteract the lack of transparency and the fear of undercollateralization by investors.

3) Expansions on fiat-currency pegging: Essentially, a centralised currency pegged stablecoin is just a tokenised fiat-currency. This concept can be expanded to more than just traditional currencies. Using tokenisation and central storage it is possible to peg the value of a crypto coin to anything that has value in the real world. As such some stablecoins peg their value to the original form of money: Gold. Today, stablecoins like PAX Gold [10] and DigixDAO [21] hold gold in trust for their crypto holders. Though the gold provides a strong guarantee that the stablecoin will hold its value, the coins are still less stable than the Dollar as there is no central agency stabilising gold.

Expanding further on the concept of tokenised assets as stablecoins, any collection of assets that is stable can provide collateral for a stablecoin. Even though the US Dollar is seen as the most stable currency world-wide, it is still highly dependent on the stability of the United States economy. To address this, stablecoins like Globcoin [51] and x8currency [27] aim to create an asset that tracks multiple currencies as well as gold. This type of pegged currency can provide a level of stability seperate from the US dollar, and can also be a good candidnes for the collateralization of decentralised currencies.

4) Overview of the largest centralised stablecoins: To provide a glimpse of the usage of the techniques described in this subsection, Table I describes the 9 central stablecoins with the highest market capitalisation and some of their operational aspects:

Some interesting observations can be made from the table.

1. The PAXos company operates the escrows of 3 of the top 9 stablecoins.
2. 3 of the top 9 stablecoins are operated by exchanges including the second largest stablecoin USDC.
3. Gold based stablecoins still make up a small portion of the market with PAX Gold being the largest with a market cap of 108 million, indicating that the US dollar is the most trusted asset.

B. Centrally controlled stablecoins

Combining the proven success of central banks with the benefits of fast payment systems [19], organisations like JPMorgan [12] and the Diem Association [5] aim to create a stable currency by using their reputation as established financial institutions. So far, no coin has managed to be stable off of its reputation alone, and whether this will ever happen is yet to be seen.

Central bank digital currencies have been the center of debate among central banks themselves over the last few years [48] [42] [38] [37] [16] [40] [6] [7] [43] [15] [39] [41]. Partially in response to the announcement by Diem, many are publishing discussion papers and road maps. Some banks even dare to make some design decisions. However, with the exception of China [47], no countries have deployed a real world trial.

While none of these currencies have seen real world deployment, in the future they are likely to receive a lot of attention. Methods for applying existing monetary policy in the context of digital currencies will be developed, as well as new policy options enabled by the new methods of digital accounting. These may well displace the centralised stablecoins of today as they have the same benefits, but are backed by governments.

V. Crypto-Collateralized Stablecoins

The success of centralised stablecoins shows that the backing of a stablecoin with 100% collateral is a reliable way to keep a currencies price stable. The main problem with backing a decentralised stablecoin with collateral is that there needs to be a mechanism of exchange between the stablecoin and the collateral. When the collateral is fiat-currency or some real world asset, there must always be a central party that holds the collateral and facilitates the mechanism of exchange.

Crypto-collateralized stablecoins build on the idea that a holder of a stablecoin can always get their share of the collateral back, but in a fully automated and decentralised manner. They allow the exchange of the pegged currency

Table I
8 LARGEST STABLECOINS BY MARKETCAP

Stablecoin	Market Cap (USD)	Pegged asset	Escrow	FDIC-insurance	Launch
Tether [35]	62 Billion	USD	Single organisation	No	2014
USDC [13]	26 Billion	USD	Single organisation	Some exchanges	2018
Binance USD [1]	10 Billion	USD	PAXos	Yes	2019
TrueUSD [54]	1.5 Billion	USD	Multiple independent	Some escrows	2018
PAXos [9]	921 Million	USD	Single organisation	Yes	2018
HUSD [2]	577 Million	USD	PAXos	Yes	2019
Gemini [26]	295 Million	USD	Si	Yes	2019
PAX Gold [10]	108 Million	Gold (1 ounce)	PAXos	No	2019
Stasis [24]	106 Million	Euro	Multiple independent	No	2018

such that even the organisation that created the stablecoin has no power over the collateral. The easies way to collateralize a decentralised stablecoin is with a currency that is:

1. Stable - to stabilise the stablecoin
2. Decentralised - to avoid central control
3. Fully programmable - to automate the collateral exchange mechanism

This leads us to a problem, we are looking for precisely the thing we are trying to create, a decentralised stablecoin. To solve this, crypto-collateralized stablecoins build on top of two currencies. The first is a currency that is stable, usually an fiat-currency. The second is a decentralised and fully programmable currency, this is used as the collateral. Instead of guaranteeing the direct exchange of the stablecoin for the pegged currency, say 1 token for 1 dollar, the system aims to guarantee that an investor can exchange 1 token for 1 dollars worth of the collateral at any time.

This leaves a problem, what if, because of the volatility of the collateral, the market value of the collateral drops such that there is no longer enough collateral to back all outstanding stablecoins. This could lead investors to scramble to get their share of the collateral out before its gone, rapidly undermining the price of the stablecoin. The solution to this is over-collateralization. In order to guarantee that there is always enough collateral in the system for every investor to be made whole, the minting of the token has to be paired with the deposit of **more** than 100% collateral.

This mechanism is interesting for those who want to speculate on the collateral. Instead of buying the collateral and just saving it, they can exchange it for the stablecoin, which allows them to get some of the value of the currency back. This can then either be loaned out, or be reinvested into more collateral.

This mechanism can be implemented in many ways, but there are always 2 ends to this trade. There is the speculator, who invests the collateral, and is expected to act if the collateral loses its value. And the investor, who is looking to store their wealth in a stable token.

This concept is effectively a financial swap. A swap is a contract where two parties swap some properties of some underlying assets. In the case of our stablecoin, one party, the investor, offloads the risk associated with the price instability of the collateral to the second party, the speculator. For this, the speculator is usually rewarded in some way.

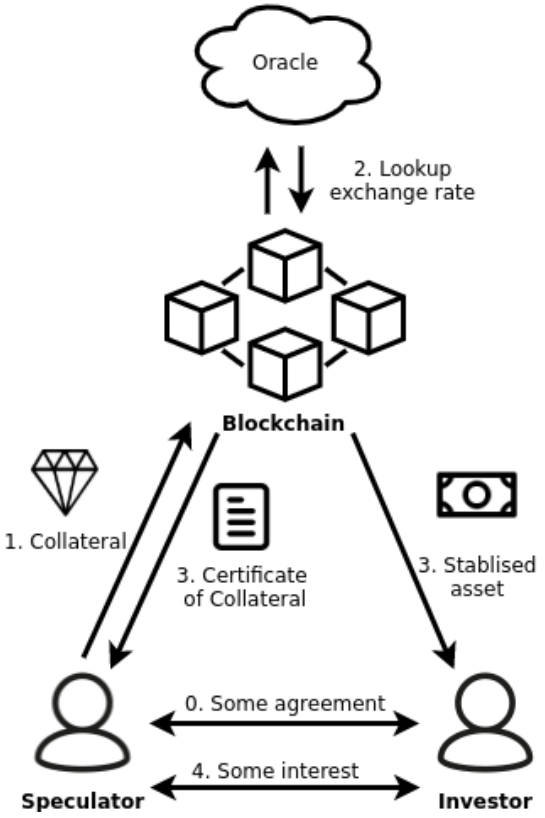

Figure 5. Stablecoin minting through debt creation

Figure 6 describes the process of minting a decentralised stablecoin that uses the swap mechanic:

0. Some agreement is reached between the investor and the speculator. This might happen on an individual basis, but sometimes the terms of the agreement are pre-defined by parameters of the network.
1. Some crypto, lets say Ether, is sent as collateral to a smart-contract. Some of this, usually 100% of the

value of the stablecoin, might come from the investor, white the speculator provides the remaining collateral necessary for the over-collateralization, lets say 50%.
2. A smart-contract checks the price of the Ether in terms of the pegged currency, lets say dollars. Mechanisms for the decentralised lookup of Ether prices vary between systems. We explore these differences later in this section.
3. The stablecoin is minted and issued to the investor, while the speculator gets some proof of deposit for their collateral. We call this a collateralized debt position (CDP).
4. Some interest might be payed from the investor to the speculator or vise versa.

The investor might pay interest to the speculator as a reward for providing the capital for over-collateralization and taking on the risk of the collateral dropping in value while the stablecoin is in circulation. On the other hand, the speculator might pay the investor as a reward for providing extra capital for the speculator to leverage their bet on Ether. The direction of interest depends on the design of the stablecoin and sometimes the market conditions.

While the stablecoin is in circulation the speculator is responsible for maintaining the collateral of the CDP. Should the value of Ether drop, they must deposit more Ether to the smart contract, or risk getting margin called. A margin call is the automatic closing of a CDP. A margin call happens when the value of the collateral drops below the minimum collateral requirement of the system. In the case of our example this means there is not enough Ether in the CDP to cover 150% of the outstanding stablecoins of the contract. A margin call opens the CDP to be closed by anyone that pays its outstanding stablecoins back into the system. Say the collateralization-ratio of the contract is 140%, the person that buys out the contract will get 100% to pay them back for the stablecoins, plus some portion of what is left for their trouble.

The settlement of an contract burns the same amount of stablecoin that it initially created and the releases all the underlying collateral. The process for this is illustrated in figure and includes the following steps:

0. Some agreement is reached between an investor willing to sell a stablecoin, and a someone willing to close out a CDP. This agreement could come be in the form of a speculator simply buying the coins from an investor at market rate, an investor acting on a margin call, or by some other matching mechanism between stablecoin and CDP.
1. The stablecoin is sent to a smart-contract, which burns the coin.
2. The oracle is consulted for the current price level of Ether in dollars.
3. The collateral is provided back to the speculator and investor at some defined ratio. Usually 100% of the stablecoin value goes to the investor while the remaining 50% or more goes back to the speculator.
4. Some settlement may be done, this could be the payment of interest between the two parties or some fee to the blockchain.

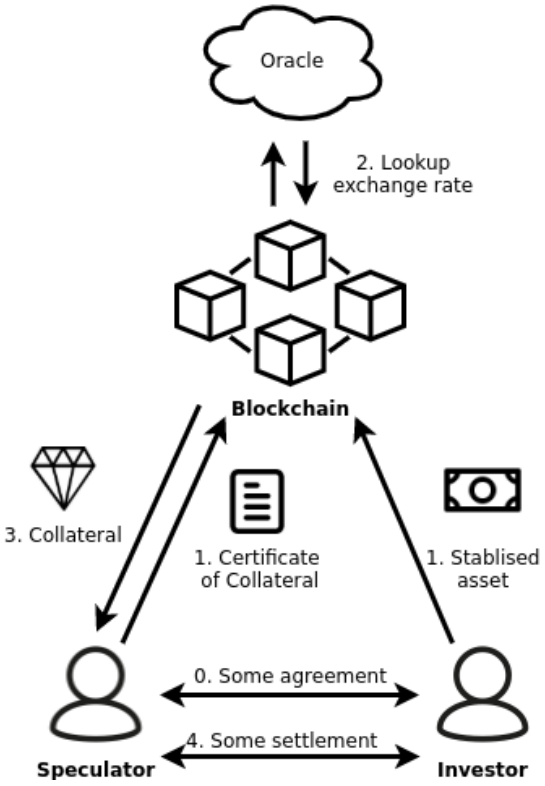

Figure 6. Stablecoin burning through CDP settlement

As an extra line of defence against the falling of the collateral value or some attack against the system, crypto-collateralized stablecoins often have a mechanism for global settlement implemented. In the case of a global settlement event, the underlying collateral gets returned to the stablecoin holders without any conditions. All CDPs will be locked, allowing all holders of the stablecoin to trade in their tokens for 1 dollars worth of collateral. After a period of time, the contracts will be released and return all collateral left in the contracts back the speculators.

The triggers for a global settlement differ per stablecoin, but mechanisms include: global collateralization under a minimum ratio, high price instability, or a decision by holders of some governance token.

A. Governance

In addition to triggering global settlement in the case of some "black swan" event, decisions often need to be made about the network in general. Examples of this can be parameter tweaking like the collateralization ratio or network fees, as well as network upgrades. For this

reason most decentralised stablecoins are managed using a Distributed Autonomous Organisation (DAO). Shares in the DAO, or governance tokens, allow the holders to collectively control inner workings of the network, as well as some claim of the profits of the network. This ties the value of the tokens to the to the performance of the network, which in turn incentivised the holders of the governance tokens to remain invested in the network and to vote for parameters and mechanisms that improve the utility and stability of the stablecoin.

B. Minimum Collateralization Ratio

The minimum collateral required varies between systems. It is the responsibility of the speculator to maintain a collateralization ratio above the minimum requirement, or they get margin called. The collateralization requirement depends on the volatility of the collateral used, as well as how the network is intended to be used. Since the margin call of a contract takes time to find an investor someone willing to close it, there needs to be a buffer for the price of the collateral to fall even further. This buffer is the gap between the minimum ratio and 100%. Networks with faster methods of margin calling, can have lower collateralization ratios, thus allowing investors to leveraging their bets even higher.

C. Mechanisms for speculator to investor match making

Stablecoins that utilise the CDP model are part of a system that aligns the incentives of the markets. Variations in these incentives these systems lead to differences in features like:

- the direction of interest payments
- the investor to speculator matchmaking,
- the amount of collateral put up by each party,
- the mechanism for handling under-collateralized CDPs

To explain the variation between the systems we use some examples. We show how differences in the purpose of the system leads to differences in the features, and parameters of the network.

1) Reserve bank speculator model: In the first type of system the speculators collectively act like a reserve bank. The creation and destruction of stablecoins are controlled by the speculators. Anyone can create a debt-contract, deposit collateral and mint stablecoin tokens as long as they remain properly over-collateralized. The contract can also be closed at any time by depositing an equal amount of stablecoins to get the same collateral back.

In this system, the amount of stablecoins created is determined by the price, in say dollars, of the collateral at the time of minting. This leads a particular incentive structure. If the market value of the token is higher that 1 dollar a speculator is incentivised to deposit more collateral and mint more tokens. These token can then be sold on the market. Increasing the supply, thus dropping the price back to one dollar. The benefit of the speculator here is that they were able to create a CDP at a favorable rate. If, when they pay back the tokens, the market value of the token is lower than when they sold the coins, they will make a profit.

If the market value of the token is lower than a dollar, any speculator with an open contract can buy the tokens at a discount and close out their CDP at a profit given that they bought sold the tokens at a higher price. This leads to fewer coins on the market, thus increasing the value back up to a dollar.

This creates a "soft peg" as there is no guarantee for the speculator that when they mint and a coin they will be able to buy it back again at a lower price. This can lead to the market price of the token rising to a different price level, and the peg can stabilise at a price level that is higher or lower than any collateral held. The price level of the token is thus still determined by what the market believes it is worth. There is some indication however, that the coin will not drop below 1 dollar, since that is the value that is returned to investors in the case of margin calls or a global settlement scenario.

In this scenario, the speculator takes on a certain amount of risk speculating on the value of the collateral and the price of the token. Initially it seems like the speculator gets their value from speculation only. They can, for example, sell their tokens on the market for more of the collateral thus leveraging their speculation on the collateral by some factor.

Usually, the intended way for the speculator to make a profit is by peer to peer lending. Instead of selling the tokens on the market, the speculator can lend out the tokens to makes some extra dividends while speculating on the collateral. In this way, the speculator acts as the reserve bank increasing the supply of the token by lending out more.

Irregardless of how the speculator chooses to use their tokens, anyone investor buying them has a some guarantee that they will be worth at least a dollar in the future, thus creating an asset that is more stable than the underlying collateral.

The complete risk acceptance and decision making of the speculator allows for a number of expansions on the already explained concepts. First, since the success of the network is dependent on everyone being properly collateralized on average, and this in turn is dependent on the market value of the collateral, it makes sense to diversify the collateral. Thus, a multi-collateral system, which improves guarantees for token holders can be created, where the speculators have a choice in what collateral they want to stake. This protects the system against a price crash in one collateral category, as speculators are incentivised to exchange the collateral that is dropping in value for more price-stable collateral.

2) Speculation market model: In this model the stablecoin can still be bought by the investor to offload risk to a speculator on some market. On the other side of the coin, the speculator still puts up extra collateral to back the coin in order to speculate on the underlying assets and provide collateral in case of a price dip.

The first differences between this model and the reserve bank model is that the mechanism to match investor to speculator, hereafter called the "internal market", is done through margin trading. This means that the internal market is effectively an exchange where speculators and investors put up offers to be matched with each other.

The model relies on the fact that the investor, at any time, can redeem the stablecoin for 1 dollars worth of collateral. This way the price should always be around 1 dollar.

When a speculator puts up an offer, it acts like a proposal to the investor. The offer describes the amount of collateral that the investor should pay into the debt position. The investor knows that they have some guarantee to redeem it for 1 dollar of collateral at any point later. This fact provide a lower bound on the value of the coin as coins sold below a dollar will immediately be bought up and redeemed. This creates a price for the investor of 1 dollar plus some premium. This premium acts as an incentive for the speculator to put up the extra collateral and is variable based on the market.

After two orders get matched on the internal market, the investor provides the agreed upon amount of collateral, and the speculator puts up the rest of the collateral required to meet the minimum ratio and maintains this throughout the lifetime of the contract.

The generated stablecoin is given to the investor and is fully fungible as they can be redeemed for 1 dollar at any time regardless of how much collateral the first investor put up. The coin can now be traded just like any other currency on some external market.

Interest in this is payed from the speculator to the investor, as the investor allows the speculator to use their collateral to speculate on.

When finally a stablecoin holder wants to close out their side of the contract and redeem their dollar of collateral, they make another order on the internal market. They will then get matched with a speculator wishing to close out their contract.

The investor gets 1 dollar of collateral from the contract of the speculator, and the speculator gets the rest. At this point the speculator will take their earnings or losses as they will have get more collateral than they put in if the price of the collateral has gone up, and they will lose collateral if the price of the collateral has gone down.

In order to make sure there are always enough speculators willing to settle a stablecoin, this model can employ some ways of forcing speculators to match the settlement. The first way is a maximum lifetime for speculator contracts. This forces speculators to close out their contract within a set time, say 30 days. This guarantees that any investor can redeem their coin within this time as the full outstanding amount of stablecoins in the system have to be bought back every 30 day. The second way is to simply close out the speculators contract that has the lowest collateral ratio. This has the benefit that investors get their money back quicker than the first option. This also incentives the speculator keep a high collateralization ratio.

This system, though similar, is fundamentally different from the reserve bank model in that the speculation is meant act like a prediction market while the stablecoin aspect is secondary. It also has the issue that there needs to be some exchange mechanism to match orders.

This system differs from the reserve bank model in the fact that the guarantee for the investor generated after 2 people create a coin together. The first and last investor are always interacting through the internal market, which causes the investor to be more that just someone looking for a safe position. As the investor buys the coin at some "premium" they are betting that the price on the market when they want to sell accounts for this premium.

However, when buying a coin on the open market this stablecoin is only subject to the change in the premium and not the volatility of the coin.

The feasibility of this mechanism is yet to fully prove itself in reality, though some steps have been made. The BitShares exchange was the first to use this mechanism and originally implemented a 30 day limit for speculator contracts, thus guaranteeing a maximum liquidation delay of 30 days. This was stable for a while but eventually lead to a distrust in the "guarantee" that the coin was redeemable, as you essentially have to freeze your asset for 30 days to get your money back. This lead to the value of BitUSD dropping, which lead in turn lead to people "shorting" BitUSD by taking worse and worse prices for the stablecoin, as they expected to be able to close their contracts while the price of BitUSD was even lower. This created a negative feedback loop where the dropping price of BitUSD acturally provided an incentive to create more BitUSD.

As a result, the BitShares holders voted for global settlement to avoid the further loss of stability. Eventually the stablecoin was relaunched with the 30 day limit removed and a 24 hour guarantee built in that matches the settlement order with the lowest collateralized contract. The price has not made it back to one dollar and remains relatively volatile.

Other BitShares stablecoins like BitCNY also use this mechanism and are stable, likely because of a larger, thus more resilient, market.

3) Debt-pool Tracker service: The final matchmaking system is very similar to the reserve bank system, but ab-

stracts away from the concept of having a single stablecoin, and just aims to track the prices of many different assets.

The system tracks the total debt of a speculator, rather than the specific stablecoin assets. This means that, just like in the reserve bank model, a speculator can put up any amount of collateral and issue "debt" based on some collateralization ratio. This means that the speculator is again the party that provides the stability, and absorbs any price shocks to the collateral.

As an investor the story changes. Any holder of a stablecoin can directly exchange it for a different stablecoin of equal value, at any time, using only the blockchain. Like before, the investor buys the stablecoin on the market. Lets say they buy a stablecoin that tracks the dollar. The blockchain allows them to exchange it for a stablecoin that tracks the euro at some exchange rat between the dollar and the euro.

Since no money was created, the total value in the system did not change and thus no interaction with the underlying collateral was needed. This allow the system to create synthetic assets that track any underlying assets, including currencies, stocks, other cryptos, and even the inverse of these.

When a speculator wants to leave the system, they simply have to buy back some assets worth what they originally created before they get their collateral back.

In this system interest is periodically payed from all investors to all speculators as incentive for the speculators to collateralize the system.

This system can provide a whole ecosystem for tracking real world assets and allows easy movement between them.

D. Oracles

All stablecoins that peg to a fiat currency need some information about the price of that currency at any point in time. So far we have referred to Oracles as a source of this. In reality, this is a non-trivial problem and it is solved in a couple different ways.

The simplest solution is having a centralised source, this does create a central point of control and thus a central point of failure. When there is a central party that facilitates the exchange, this is not a problem.

Efforts have been made to decentralise the oracles as well. When every other aspect of the network is decentralised, a decentralised oracle will provide more security, which in turn boosts investor trust as this removes the central point of failure.

One way to decentralise the network is to have all nodes in the network vote on the value of the input. Here a proof of stake system can be used that punishes bad inputs to the system. If there are multiple different values given, the median can be taken.

Some decentralised currencies have a DAO token or similar that is tied to the health of the network. Since the value of the DAO token is dependent on the health of the network, holders of this token are incentivised to act honestly. In addition, some punishment for bad behaviour can be added in the form of proof of stake to aid in determining the correct price.

This mechanism also more specifically applicable, just determining precise price levels. Some stablecoins do not track the price, but have token holders vote whether the price is too high or too low, and based on that will trigger either "inflationary", or "deflationary" periods [55].

This concept can also generalised even further. A long desired goal is to get real world information onto the blockchain in general. Solutions have emerged [20] that aim to solve this problem by creating a general infrastructure of nodes that access real world data and record this data onto the blockchain. To incentivise honesty of nodes, they stake an amount of network tokens that can be taken from them if the rest of the network disagrees with their votes. In addition node reputation van be tracked on-chain in order to allow users to choose the most trustworthy nodes.

E. Overview

As can be seen in II There are a few large players in the crypto collateralized stablecoin scene.

MakerDAO is currently the largest most trusted system. They now allow for multiple different types of collateral, including Ether, BAT, REP and X0. They allow the community to vote using their (MKR) token. On which assets will be added for collateral.

BitShares is the system with one of the oldest working stablecoin, BitCNY, active since september 2014. BitShares is a decentralised exchange that allows users to speculate on a number of different BitAssets, including BitUSD, BitEUR, and BitBTC.

Synthetix describes itself as a "synthetic asset platform" and provides a number of stablecoins that track multiple real world currencies and assets. They allow direct conversion from one to another using the debt-pool tracker system where speculators are collateralizing the system at a minimum of 750%. The Synthetix platform started of centralised and is still a work in progress but is making major steps towards decentralisation. They offer many tracking assets like: sEUR, sUSD, sBTC, sETH. They also offer inverted assets to bet against some assets like: iBTC, and iETH. Currently they also support commodities like sXAU which tracks the Philadelphia Gold and Silver Index, and they plan to add trackers for various company stocks.

VI. Algorithmic Stablecoins

Crypto collateralized stablecoins are dependent on the overall stability of their collateral currency. If the price of

Table II
Decentralised collateralised stablecoins

Stablecoin (System)	Collateral	Min. col.	Matchmaking	Interest paid
DAI (MakerDAO) [53]	ETH + 6,	150%	Reserve bank speculator model	To Speculator (external)
BitAssets (BitShares) [23]	BTS	300%	Margin Trading	Variable premium, once to speculator
Synths (Synthetix) [25]	SNX	750%	Debt-Pool Tracker	Global interest calculation
USDQ (QDAO) [46]	Bitcoin	200%	Reserve bank speculator model	To Speculator (external)
LUSD (Liquity) [33]	ETH	110%	Reserve bank speculator model	None

the collateral drops fast enough in relation to the pegged currency, many of these stablecoins would lose their exchange guarantee, and therefore lose investor confidence. Though these risks can be reduced in various ways, the general stabilisation of a currency without the reliance on collateral is a sought after feature that could improve significantly stablecoins.

Some stablecoins, rather than offloading risk to speculators, aim to reduce volatility by controlling the demand and supply of currencies in other ways. In this section we describe the seigniorage model for expanding and contracting the money supply, as well as some more theoretical techniques and currency parameters for reducing volatility.

A. Seigniorage model

The stabilisation of currencies is much older than cryptocurrencies. So to see how cryptocurrencies can be stabilised, some have taken inspiration from the way central banks stabilise traditional currencies. Specifically open market operations employed by central banks and the federal reserve.

When the fed wants to increase the money supply in times of deflation, they often buy government bonds thus getting money out into the hands of the public. When they then want to decrease the money supply, they will sell the bonds thus getting the money out of the system.

The seigniorage stablecoin model utilises this concept. In times of inflation when the currency is undervalued, the blockchain will start selling bonds. These bonds lock up a buyers coins for a period of time, and will pay them back, including some interest, after a certain time. Since some of the money is now temporally out of circulation, the currency left on the market will go up in value.

In times of deflation when the currency in overvalued, bonds can be discouraged or disabled. Outstanding bonds can also be payed back prematurely in order to increase the money supply. When all bonds have released and deflation is still a problem, more money can be printed and distributed in some way until there the price is back down to the desired level. This creates a natural tendency in the market towards the desired price.

In order to tune the effect of the price corrections differences parameters can be tweaked to maintain the desired price level. These are:

- The interest payed over the bond - higher encourages purchase
- The lifetime of the bond - this is how long the money is out of circulation

These techniques have the potential to stabilise a currency without any collateral being needed. However, the choice of when the money supply should be expanded or retracted still needs to be made in a decentralised way. Consequently this is where the largest differences between the existing stablecoins lie.

1) Self stabilisation mechanisms: By tweaking bond lifetime and interest rates a currency can be stabilised. However there still needs to be some decentralised mechanism that triggers changes to these parameters. Usually one of two self stabilising mechanisms is used:

- Share voting based parameter setting
- An Oracle based price feedback mechanism

Voting based parameter setting works how one would expect. The holders of a token, in some cases the stablecoin itself but usually a governance token, vote periodically on the stabilisation parameters of the network.

Within the oracle based system, the blockchain will activate an "expansion phase" in a time where the price of the coin is above the target, and a "contraction phase" when the price is below the target. The bond yield can be static or scale with how far the price is from the target, thus rewarding larger risk takers.

Note that even oracle based stablecoins are usually DAO's that vote on the function that maps price target mismatch to bond parameters.

B. Overview of real world algorithmic stablecoins

The first stablecoin to be stable for a year was NuBits[34]. NuBits stabilised by using a bond mechanism as well as voted in "guardians" who would get newly printed NuBits and would in turn provide liquidity to the market. These guardians would sell and buy the NuBits on the market at the price determined by the peg. In a way this turns the guardians into holders of collateral.

NuBits lost their peg twice and successfully recovered once in 2016, but after the "Christmas crash" of late 2017-2018 investors massively bought the stablecoin as presumably it was safe compared to the rest of the crashing crypto market because of its peg to the dollar. This grew the

Table III
Algorithmic stablecoins

Stablecoin (System)	Target	Method	Price tracking	Interest rate	Governance (token)
TerraUSD [30]	USD	Seigniorage (Luna)	Oracle		Central, DAO planned
Neutrino USD [28]	USD	Seigniorage (WAVES)	Oracle		DAO (NSBT)
Reserve Rights [8]	None	Yes ()	Oracle		Central, DAO planned
Nubits [34]	USD	Yes ()	Voting	Voted	DAO (NuShares)
BitBay [55]	None	Yes ()	Voting	None	DAO (BitBay)

market cap of NuBits by 1500% over a few months while the guardians mostly held collateral in bitcoin. When then the crypto market started to recover, many sold their NuBits putting large pressure on the guardians who were now forced to buy NuBits for fewer bitcoins than they bought then for during the crash. This under-collateralized NuBits to a point where the guardians ran out of collateral, the currency lost its price guarantee, and the peg could no longer be maintained.

NuBits provides an example of the main flaw of the securities model, it requires trust in the mechanism, which lacks when it is needed most: in a down market.

C. General techniques for adding stability to any currency

Collateralized stablecoins by definition are pegged currencies. They rely on other currencies to provide their stability. Without the stability of the US dollar or other, none of these currencies would work. When it comes to inherent stability of blockchain currencies, a number of academic papers are available. Following is a survey of techniques to reduce the volatility of any decentralised blockchain based currency.

1) Changing proof of work parameters to dampen demand shocks: Taking the quantity theory of money as a given, the price of a currency depends on the total supply, velocity of circulation, and the total amount transacted. These things are often set by the parameters of a blockchain network.

In the case of Bitcoin, the total supply is set, and slowly increased at a set rate without reacting to supply and demand. However, there is a link between the price levels and mining efforts [49]. If the price of bitcoin drops below a certain level, the mining reward will no longer outweigh the electricity costs. This miner response to the markets gives a natural input that somewhat tracks the price.

The block speed, and therefore the rate of supply of new coins, increase as the price increases. Therefore, if the mining difficulty stays the same, the currency will naturally respond to, and dampen, demand shocks [49].

Additionally, if the block speed is changed, the transaction throughput changes proportionally. This has the extra benefit of changing the velocity of money, which dampens the demand shock even further.

It is important to keep in mind that there are both upper and lower technical limits to the block speed. Set it too low and the transaction throughput suffers. Conversely if the block speed is too high forks are more likely, which undermines the security of the network.

2) Allowing for inflation: This method of controlling price levels has some implications [49] on long term price. In bitcoin, long term inflation is curbed by periodically halving the block reward. If these changes were used, this system would unnecessarily lower the mining incentives for miners, thus leading to a lower block rate.

One solution is to no longer halve the block rewards, thus turning Bitcoin into an inflationary currency. This is very controversial and has large economic implications who's details go beyond the scope of this survey.

As it is not possible to remove currency from the market, some rate of coin depreciation might be desirable to allow for absorption of future demand shocks [29]. A coin depreciation rate can be applied by gradually increasing the mining rewards over time.

3) Open mining using Proof of Sequential Work: If block speed should remain constant, a different way to build a more stable currency is to build a secondary token. This token would use Proofs of Sequential work (PoSW) [18] to generate currency at a fixed rate. This allows anyone to mine a coin by putting in some work. This leads more mining when the price is high and less when it is low.

PoSW has the benefit of scaling better into the future as the sequential speed of processors improve at a much slower rate than parallel speeds.

VII. Discussion

Stablecoins are an even younger development in the young field of cryptocurrencies. As such it isn't yet clear how the future of stablecoins will look. In addition to the currently existing stablecoins and proposed stablecoin concepts, research is being done into the general viability and security of stablecoins. This section discusses the viability of stablecoins and aims to answer more general question about their future and usefulness.

A. Centralised Stablecoins

Centralised stablecoins have so far found their usecase as a stable way to store your crypto away from volatility and bear markets. When looking to the future, much literature is available exploring where stablecoins can become useful.

When looking at ways cryptocurrencies can improve the current financial system centralised stablecoins can be

seen as a midway solution [32]. It marries the stability and legal security of central trusted organisations, with the benefits of fast, programmable and more transparent payment systems [19] [17]. This leads to a system that relies less trust in large banks.

B. Crypto Collateralized Stablecoins

Decentralised currencies are more aspirational. Where Bitcoin provided a completely trust less currency. Decentralised currencies aim to do the same, but with guarantees about price stability. Though this is much more difficult to get working securely [31], the benefit of these coins to society might be much greater than that of any centralised currency.

C. Related Work

1) Surveying the stablecoin space: In "The State of Stablecoins"[3] the "blockchain team" present an empirical study of 57 live and pre-launch stablecoins showing adoption, trading volume and market cap. They describe a taxonomy where they differentiate between "traditional" collateralized, crypto collateralized and algorithmic. They describe many pros and cons of these types of coins. The survey is very extensive and describes all 57 currencies in terms of their investors, tech, legal structure and collateral format.

2) Speculating on the future of stablecoins: In [19] Darrel Duffie describes the use of stablecoins for banks aiming to digitise both inter-organisation value transfer and governments wanting to implement a digital currency with the utility benefits of cryptocurrencies and the stability of fiat.

In "Stablecoins in Cryptoeconomics. From Initial Coin Offerings (ICOs) to Central Bank Digital Currencies"[17] Erba discusses the stablecoins in the context of the law in both the united states and Europe. Erba argues for crypto-currencies "fully backed by Central Bank reserves"

In [32] Koning describes the requirements and considerations for a stable currency controlled by a central bank. Koning describes the monetary policy and choices that comes along with implementing a digital currency on a large scale.

3) Critiques of common techniques for cryptocurrency stabilisation: Chohan discusses the difficulties in maintaining a properly collateralized peg in "Are Stable Coins Stable?"[11]. Chohan describes how maintaining a true 1:1 peg leads to funding and scalability issues.

In [31] Klages-Mundt et al. look at the existing stablecoins through a critical lens and describe some ways in which the currency pegs can be broken. Klages-Mundt build a generalised model of decentralised crypto-collateralized stablecoins. It describes possible attacks on these systems where the pegged currency is bid up so an extent where collateral starts to get margin-called creating a run-away feedback loop.

VIII. Conclusion

There is a lot happening in the stablecoin and DeFi space right now. Stablecoins are being tested in a trial by fire in the real-world as we speak. While central banks are still deliberating on their requirements for their CBDCs, market stablecoins are innovating at a rapid pace. Centralised stablecoins, currently the biggest players in the space, are getting a lot of attention for their success. Meanwhile, decentralised stablecoins such as MakerDAO and Synthetix are developing completely systems that promise to either take Decentralised Finance to the next level, or fail spectacularly. Within the last year algorithmic stablecoins have entered also gained significant traction. The future of stable currencies will depend on the success of the decentralised players, and the next steps of the central banks.

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