

CAS Report

Analysis of Stablecoins during the 2020 Global Financial Crisis

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Abstract

In the past, cryptocurrency prices have been notoriously volatile. Stablecoins were introduced to provide a means of cryptocurrency payment and also a value store that remains stable. We give an overview of stablecoin stability mechanisms, the current stablecoin market landscape and investigate the performance of a selection of stablecoins during the 2020 financial market crisis. We find that stablecoin performances during the financial crisis and in particular the market crash are very individual, and some behaviors can be attributed to different design aspects. From the six stablecoins in our sample, we find that the ones with fiat collateralization are the most stable.

Contents

Abstract	ii
1 Introduction	1
1.1 What are Stablecoins?	1
1.2 Report Outline	1
2 Fundamentals of Stablecoins	2
2.1 A Basic Stablecoin Ecosystem	2
2.2 Classification of Stablecoins	3
2.2.1 Pegs and Collateral Type	3
2.2.2 Collateral Amount	3
2.2.3 Stability Mechanism	4
2.3 Examples of Active Stablecoins	5
3 Stablecoins and Financial Markets	6
3.1 Current Cryptocurrency Market Share	6
3.2 General Vulnerabilities of Stablecoin Systems	7
3.3 Market Risk of Stablecoins	8
3.3.1 Measuring Volatility	8
3.3.2 Measuring Market Risk of Stablecoins	8
3.3.3 Stablecoin Price Distributions and Our Data Set	9
4 Stablecoin Performance during the 2020 Global Financial Crisis	11
4.1 General Market Performance during the 2020 Financial Crisis	11
4.2 Market Performance of Stablecoins	11
4.2.1 Stablecoins SX rates	11
4.2.2 Trade Volume and Volatility	12
4.2.3 Market Capitalization	13
4.2.4 Discussion	15
5 Final Considerations	16
5.1 Conclusion	16
5.2 Outlook	17

1 Introduction

Since the release of Bitcoin more than a decade ago, cryptocurrencies have evolved into a multi-billion dollar market. One of the major obstacles seen to prevent wide-spread use of cryptocurrencies as a means of payment and investment is price volatility [JS18]. This issue is tried to be resolved with stablecoins. Like other cryptocurrencies, stablecoins have enjoyed rising popularity in recent years, now also amassing a market capitalization of many billion USD. This has prompted economic organizations like the G7 to assess their impact on the global economy [oS19]. We take a closer look at different stablecoins and their role and behavior during the recent financial market crisis.

1.1 What are Stablecoins?

In short, stablecoins are cryptocurrencies designed in such a way that their price remains stable. There are different interpretations as to what stability means and therefore also different approaches to achieving it. One popular stablecoin design is mimicking the value of the US Dollar by using it as a collateral and then tokenizing its funds (*cf.*, Section 2.1). The largest stablecoin system Tether uses this design. This design requires involvement of a central institution (a custodian) who administers the funds. But there are also stablecoins using other cryptocurrencies as a collateral, resulting in a more decentralized system. For these kinds of stablecoin systems the law of supply and demand is often not enough to achieve price stability, which is why some of them use sophisticated mechanisms to secure the stablecoin's value.

Price stability of stablecoins has been analyzed in various studies, both theoretically ([Cho19][KMM20][MM19]) and empirically ([WG19][DB19]). It is stated in [JS18] that a crucial aspect of a stablecoin system is how well the stablecoin does during times of financial crisis. We take the 2020 financial market crisis as an opportunity to empirically assess the performance of a selection of stablecoins, including Tether. To this end, we make use of a stablecoin classification framework described in [MSS19] (*cf.*, Section 2.2) as well as basic methods from quantitative finance to measure market risk (*cf.*, Section 3.3).

1.2 Report Outline

To the best of our knowledge, there are currently no studies investigating the performance of different stablecoin designs during a financial crisis. After all, the current 2020 financial market crisis is the first global financial market crisis during which stablecoins have been around. Our investigation will be centered around the following two questions:

- How did stablecoins perform during the beginning of the 2020 financial market crisis with respect to stability and also popularity?
- During that period, how was stablecoin performance related to different design aspects of the stablecoins?

Accordingly, we first explain the fundamental design of a stablecoin and discuss different individual design features in Chapter 2. We also present some examples of currently active stablecoins. In Chapter 3 we give an overview of the stablecoin market and discuss different types of risks associated with stablecoin investments, most importantly market risk. In particular, we present a unified approach to measure and compare price volatility for stablecoins with different pegs. We then select six individual stablecoins whose market performance during the 2020 financial crisis we analyze in Chapter 4. The analysis will be based on historical market data for stablecoin prices, market capitalization and trade volume. The main findings are summarized in Chapter 5.

2 Fundamentals of Stablecoins

In this chapter we first outline the basic components of a stablecoin system. We then describe different stablecoin design variants, in particular different stability mechanisms, and give some examples for each case.

2.1 A Basic Stablecoin Ecosystem

We describe herein a basic stablecoin framework as defined by popular stablecoins such as Tether. In this most basic framework, stablecoins take on the form of **tokenized funds**. The funds, transferred by users in fiat currency, are converted into the corresponding amount of tokens, and the tokens represent the fiat currency. The system depends on a custodian maintaining the user funds and a coin issuer keeping a smart contract. The smart contract determines the allocation of stablecoins and is maintained on a distributed ledger such as a blockchain.

If a user wants to exchange his funds to obtain stablecoins, it is possible to transfer funds to the custodian (usually a bank). The bank then sends a receipt to the issuer. The issuer in turn updates the smart contract and the user receives the stablecoins. Then, the user can use the stablecoins as a means of payment to other users. In order to send stablecoins to another market participant, the user would simply instruct the smart contract to perform a transfer. The transfer is then persisted in the distributed ledger and validated by the network. In case a user wants to cash in his stablecoins, he sends an instruction to the smart contract. The smart contract then destroys ("burns") the stablecoins and sends a "proof-of-burn" to the stable coin issuer. After receiving the proof-of-burn, the issuer orders the bank to transfer the funds back to the user. The process is illustrated Figure 2.1.

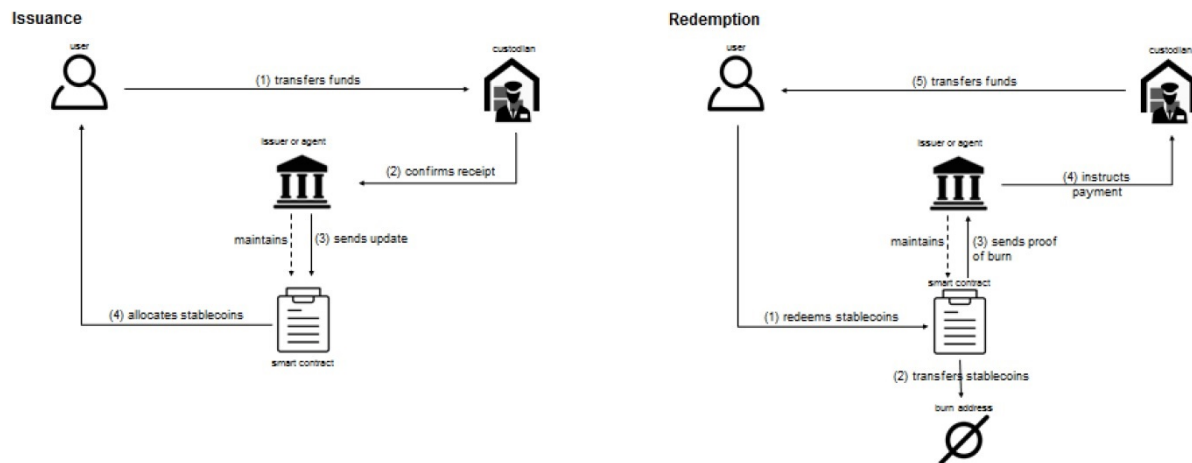


Figure 2.1: Issuance and redemption of tokenized funds. Source: [DB19]

There are design variations to this basic framework. One fundamental difference arises when, instead of traditional fiat currency funds, the user can obtain stablecoins by transferring digital assets like other cryptocurrencies. Then, the whole process of issuance and redemption can take place within the network and a central issuer is no longer necessary. Instead of a custodian maintaining the funds, there is a "cryptographic vault" that stores the digital asset as a collateral. Issuance and redemption of stablecoins is managed by the smart contract in a fully automatic way. In comparison with the first design, this stablecoin system works in a more decentralized way, which brings it conceptually closer to other cryptocurrencies.

Alternatively, there are stablecoin systems including mechanisms where in certain situations, particularly if the collateral value falls too much, there are compulsory redemptions. In the event of compulsory redemption, the

collateral is automatically liquidated, the collateralized assets transferred back to the users and the stablecoins are burned. There are many other mechanisms that more or less directly affect the stablecoin holdings of users. We discuss some of them in Section 2.2.3 on stability mechanisms.

2.2 Classification of Stablecoins

According to the classification suggested in [MSS19], stablecoins can be characterized by the following attributes:

- **Peg:** The asset whose value the stablecoin tries to maintain. Examples are traditional currencies like the US Dollar or commodities like gold.
- **Collateral:** the asset that is pledged as security. Examples include fiat currencies, gold, cryptocurrencies and mixtures of the above.
- **Collateral amount:** The amount of circulating stablecoins that are collateralized, if any. Variants are none, partial, full or over-collateralization.
- **Stability mechanism:** The mechanism used to adjust price and supply (*cf.*, Section 2.2.3).
- **Price information:** How the price of stablecoins is determined.

Further distinctions can be made considering technical features like the used distributed ledger platform and how the stablecoin can be traded. For example, this can be measured by the number of supported trading platforms or the number of tradable currency / cryptocurrency pairs. Furthermore, one might also consider legal aspects like ownership and legal jurisdiction. We will focus on the above-listed bullet points, with the exception of the "price information" which we will not look into.

2.2.1 Pegs and Collateral Type

Arguably one of the most important aspects of a stablecoins is the value it is pegged ("tethered") to and how this value can be maintained. There is no need for intrinsic connections between the peg and the collateral. Nevertheless, it should be noted that a popular choice for stablecoin designs is pegging a currency (mainly USD) and holding the collateral in the pegged asset [blo19b]. Apart from fiat currencies like USD and EUR, there are stablecoins pegged to gold and even stablecoins whose peg is another cryptocurrency. Examples for all these variants are given in the examples Section 2.3.

As to the type of collateral, popular choices are fiat currencies, commodities (mainly precious metals), other cryptocurrencies or any mix of the aforementioned. Often, a distinction is made between **off-chain** and **on-chain collateralization**. The latter refers to stablecoin systems in which the collateral is integrated in the blockchain ecosystem. As an example, collateralization could be achieved by issuing stablecoins in exchange of other cryptocurrencies (*e.g.*, Ether) and then "locking" them into a smart contract. The exchanged cryptocurrency would then serve as collateral. This system is used by DAI [MSS19], currently the largest on-chain stablecoin.

Off-chain collateralization means that the collateral is deposited outside of the blockchain ecosystem and maintained by a custodian, *e.g.*, in traditional institutions like banks. This distinction between on-chain and off-chain collateralization aligns with the stablecoin system being **centralized** or **non-centralized**. Centralization refers to the fact that off-chain collateralized stablecoins require financial institutions that hold the respective collateral, reducing transparency and introducing counterparty risk. However, central institutions are inevitable when collaterals are to be stored off-chain, which is the case for stablecoins using fiat currency or commodity collaterals.

2.2.2 Collateral Amount

Stablecoins can be constructed using different levels of collateralization. We summarize a few of the arguments presented in [Cho19]. To achieve **full collateralization** or even **overcollateralization** of a stablecoin, the coin issuer is required to hold reserves that amount to or surpass the market capitalization of the stablecoin. In other

words, the value of the collaterals must cover the value of all available coins in the market. This is more expensive (and less scalable) for the issuer than **partial collateralization**. Conversely, with partial collateralization there is a risk that the coin issuer is not able to redeem all coin holders in case of a bank run. This in turn lessens the trust of coin holders, negatively affecting the stability of the coin itself. However, it should be noted that even in the case of full collateralization, if the collateral is stored in a bank (which is the case for example for USD Coin) then functionally the system is still only partially collateralized, since commercial banks themselves only hold a fraction of their capital assets.¹

In the case of uncollateralized coins, it is suggested in [Cho19] that apart from issuing coins, the coin issuer would also need to issue some sort of a fixed income instrument to compensate coin holders for their risk. Possible solutions would be the payment of interest through "crypto-bonds" or the payment of "dividends", which is in fact a mechanism used by many stablecoin systems [Blo19a]. However, with the notable exception of Tether that is only partially collateralized, the most successful stable coins (in terms of market capitalization) such as USD Coin, DAI and PAX are all fully collateralized (*cf.*, Appendix B in [MSS19]).

2.2.3 Stability Mechanism

In the upcoming section, we again follow the categorization scheme from [MSS19]. As mentioned before, the conceptually simplest stablecoin design is to have a **collateral of the pegged asset**. Stability is then supported by the arbitrage principle. Suppose for example a stablecoin pegged to 1 USD. If the price of a stablecoin drops below \$1, redemption is incentivized since coin holders can trade something worth less than \$1, the stablecoin, against something worth \$1, namely the collateral. Redemption of coins contracts the total market supply, which in turn increases the price by the economic law of supply and demand. On the other hand, should the price of one stablecoin rise above \$1 then traders have an incentive to generate coins in turn for a collateral, thereby increasing the supply of coins and therefore lowering the coin price. Many of the most widely used stablecoins are based on this design, for example Tether, USD Coin and Paxos (see also [Blo19a]).

The second stability mechanism that we would like to describe are **leveraged loans**. It has also found successful applications, for example in the DAI (*cf.*, section 2.3), but is considerably more sophisticated. As opposed to having identical pegs and collateral, leveraged loans rely on the use of a so-called **CDP**, which is short for **collateralized debt position**. This is essentially a smart contract handling the issuance / redemption of stablecoins in return for a digital asset. More specifically, a collateral consisting of cryptocurrency is deposited and in return stablecoins are issued according to the value of the collateral. When the stablecoins are redeemed, the smart contract unlocks the collateral. Using CDPs it is possible to design a stablecoin entirely on-chain, since no central party is required in the process. To achieve stability, leveraged loans use three mechanisms.

1. **Stability fee**: boosts demand when prices are low and adversely affects demand when prices are high.
2. **Automatic liquidity**: if the collateral falls below a pre-defined percentage, it is automatically unlocked and the corresponding coins destroyed, cutting back the total stablecoin supply.
3. **Dual coins**: involves auctioning (and then burning) additional coins to counteract a low stablecoin price, and issuing additional coins to counteract a high price.

While the first is related to a fee incentivizing (or disincentivizing) the demand when prices are below (or above) a certain target, the second provides an automatic liquidation of CDPs. The third mechanism concerns the use of an additional safety as a part of its design, which itself has been used as a standalone stability mechanism (however not successful yet, to the best of our knowledge - *cf.*, for example the case study of Basis in [Blo19a]). In case of the DAI, only the first part of the dual coin mechanism is included. It is used to prevent undercollateralization, which by design only happens in case the collateral value depreciates by more than a third in a short time. The concept of leveraged loans is nicely explained for the case of the DAI in [MSS19].

There are many other stablecoin designs. Alternative ones are briefly mentioned as below:

¹More information on capital requirements of banks can be found for example in the voluntary regulatory framework Basel III [oBS19].

- **Algorithmic adjustment of total market supply:** if the price rises, by say 10%, then all balances are inflated by 10% and vice versa. There is no collateral involved, so stablecoins using this design are completely uncollateralized. It is evident that such stablecoins are not useful as a value store, because balances are continuously adjusted. An example of an algorithmically adjusted stablecoin is Ampleforth.
- **Interest rates:** these are adjusted in order to keep the coin from losing its value. As in the previous example, there is no collateral involved. SteemDollar is a stablecoin with this design. Since this particular implementation does not allow for negative interest rates, there is no mechanism preventing SteemDollar prices from rising too high, which is what happened in 2018.

2.3 Examples of Active Stablecoins

In the previous sections we have discussed different stablecoin designs. We come to an end of this chapter with an overview of examples for the different design variants, presented in Table 2.1. The first six stablecoins have already been mentioned. All examples are taken from [MSS19] and [Blo19a].

Ticker	Peg	Collateral	Stability Mechanism	Launch Year	Market Cap (USD)
USDT	USD	Fiat	Reserve of pegged asset	2014	\$8858M
USDC	USD	Fiat	Reserve of pegged asset	2018	\$726M
DAI	USD	Crypto	Leveraged loans	2017	\$110M
sUSD	USD	Crypto	Leveraged loans	2018	\$7M
AMPL	USD	None	Algorithmic supply adjustment	2019	\$ 6M
SBD	USD	None	Interest rates	2016	\$6M
PAXG	Gold oz	Gold	Reserve of pegged asset	2019	\$43M
DGX	Gold gram	Gold	Reserve of pegged asset	2018	\$6M
LUNA	None	None	Dual coin	2019	\$34M

Table 2.1: A selection of currently active stablecoins.

Data on market capitalization obtained from `coinmarketcap.com` on May 15th 2020.

In leading position we have Tether (USDT), which is by far the most largely capitalized stablecoin. It is also one of the earliest stablecoins. Its closest competitor is USD Coin (USDC), which essentially uses the same stability mechanism, peg and collateral.

Currently, DAI is the leading on-chain collateralized stablecoin according to market capitalization. It is still far from its largest off-chain collateralized competitors. Another on-chain collateralized stablecoin is the Synthetix USD (sUSD). Apart from Stablecoins, Synthetix plans to offer tokens with exposure to a wide range of asset classes, including stocks.² Two examples of stablecoins not pegged to fiat currency but to gold are Paxos Gold (PAXG) and Digix Gold (DGX). To the best of our knowledge, PAXG is currently the largest gold collateralized stablecoin in terms of capitalization. For these gold stablecoins the collateral is physical gold, so for each of these gold coins in circulation there must exist a corresponding amount of gold held as a collateral somewhere in a vault. These two stablecoins have been introduced rather recently (in 2019 and 2018, respectively), and their market share is small in comparison with the largest fiat collateralized stablecoins.

Our examples of uncollateralized stablecoins have similar market capitalizations of between \$5M to \$50M. They all differ by their stability mechanism: Ampleforth (AMPL) uses the algorithmic supply adjustment mechanism mentioned before. SteemDollar (SBD), which is one of the more older stablecoins around, uses interest rates to stabilize the value of its coin. Lastly, Terra (LUNA) underlies a dual coin mechanism that also finds application in leveraged loans. Moreover, Terra does not have an explicit peg but still amasses a notable capitalization due to its support by Asian e-commerce firms [Blo19a].

²<https://www.synthetix.io/>, visited on 25th of May 2020

3 Stablecoins and Financial Markets

This chapter starts with a short overview of the cryptocurrency market. The data used was obtained from `coinmarketcap.com`. After discussing general vulnerabilities of stablecoin systems, we focus on the market risk of stablecoins.

3.1 Current Cryptocurrency Market Share

Within the last ten years, the cryptocurrency market has grown substantially, amassing a total market capitalization of over \$200 Billion in April 2020. The relative market shares of some of the largest cryptocurrencies are presented in Figure 3.1. Bitcoin accounts for roughly two thirds of total cryptocurrency market capitalization. Since the Bitcoin price changes frequently, this implies that total capitalization of the market also varies accordingly. The second largest cryptocurrency is Ether, which accounts for roughly 10%. With a market share of roughly 3%, Tether is by far the largest stablecoin. As to the remaining cryptocurrencies, there are market shares in magnitude of Tether and Bitcoin Cash (BCH), which are not explicitly discussed. However, we estimate that the market capitalization of other (self-declared) stablecoins accounts for less than 1% of total market capitalization, so less than 5% of other cryptocurrencies.

It should be mentioned that there is uncertainty in this data. Reasons are that some cryptocurrencies might be missing from the listing on `coinmarketcap.com` and that market capitalization and trade volume might be based on wrong or incomplete data. However, we compared the reported numbers for the largest cryptocurrencies to those reported on other platforms and concluded that they are in line.



Figure 3.1: Relative Market Share of Cryptocurrencies. Total market capitalization amounts to \$218 Billion. Data from `coinmarketcap.com` on 25th of April 2020.

Although the market capitalization of Tether is small compared to the likes of Bitcoin and Ether, it is the cryptocurrency with the largest monthly trading volume as of April 2020. More precisely, Bitcoin and Tether each account for roughly one third of monthly cryptocurrency trading volume. However, this is not a totally unexpected event since Tether often functions as a means to liquidate speculative cryptocurrency positions, in particular in Bitcoin. The relative trading volume of the previously mentioned cryptocurrencies is shown in Figure 3.2. Average daily trade volume in the cryptocurrency market was around \$ 123 Billion, which is more than half the total market capitalization. In particular, the daily trading volume of Tether is a multiple of its market capitalization. This means that Tether is an extraordinarily liquid cryptocurrency. We will discuss the above-mentioned observations regarding trading volume in detail in the next chapter.

We have claimed before that Tether often serves as a means to liquidate Bitcoin positions. To support this claim we refer to the March 2020 Exchange Review from Cryptocompare [Cry20], which contains a figure on the "proportion of monthly Bitcoin volume traded into fiat or stablecoin". The figure shows that in the last two

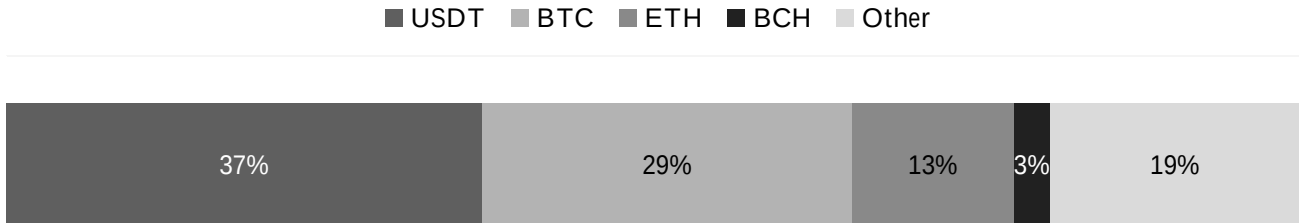


Figure 3.2: Relative trade volume of popular cryptocurrencies. Average daily trade volume amounts to \$123 Billion in April 2020. Data from coinmarketcap.com on 1st of May 2020.

years there has been a shift in how Bitcoin positions were liquidated. While in 2017 essentially all liquidations were trades against fiat currencies such as USD, EUR, JPY and KRW, trades into fiat currency accounted for only around 30% of Bitcoin liquidation volume in 2019. In particular, by 2019 roughly two thirds of Bitcoin liquidation volume was due to exchanges against Tether. The figure also shows that a small percentage of Bitcoin liquidations was performed against USD Coin, which has gained popularity since late 2019. One reason for the rising popularity of stablecoins as a means to trade other cryptocurrencies is that transactions are much faster. Whereas on-chain transactions can be performed in a matter of minutes or even seconds [BSAB⁺17], transactions involving a bank can take one or two business days to be processed.

3.2 General Vulnerabilities of Stablecoin Systems

Stablecoins aim at reducing the financial market risk associated with many cryptocurrencies such as Bitcoin. Nevertheless, they are exposed to a variety of risks specific to their ecosystem, many of which they share with other cryptocurrency investments. Based on Section 2.2 in [Boa20], we distinguish three types of vulnerabilities:

1. **Financial vulnerabilities:** involve market, credit and liquidity risk whereas the magnitude of these risks depends on the specific stablecoin. While off-chain collateralized stablecoins are exposed to traditional credit risk of the custodian, on-chain and uncollateralized stablecoins in particular are not affected by this kind of risk. However, all stablecoin systems are vulnerable to market and liquidity risk.
2. **Infrastructural vulnerabilities:** concerning the distributed ledger network and also the custodian. As before, uncollateralized stablecoin designs do not rely on a custodian. However, all stablecoin designs rely on a distributed ledger, and around half of them are developed on the Ethereum network [blo19b][JS18]. This means that many stablecoins depend on the availability and the validation speed of the same network, which becomes a systematic risk in case of many transactions. Furthermore, there is a risk of flaws in the ledgers and validation mechanisms used by the different stablecoin designs.
3. **Service application vulnerabilities:** regards the applications used for the holding and exchange of stablecoins. Apart from common issues like temporal unavailability, there is also a risk that service operators behave fraudulently by manipulating prices, committing theft or are even affected by theft themselves. As a prominent example of the latter we refer to the case of former cryptocurrency exchange Mt. Gox [CD14].

The third kind of risk is not related to global economic events. This cannot be said for infrastructural vulnerabilities, the reason being that economic stress may result in stress on infrastructure. In particular, an increased demand for liquidity results in an increased trading volume, which significantly increases network load. This is because transactions (trades) need to be verified; in particular, for Proof-of-Work-based blockchains there is a known limitation on the capacity to process transactions (see Table 1 in [BSAB⁺17]). This is precisely what could be observed during recent events, as described in the next chapter.

Concerning financial vulnerabilities, there are arguments defining that a stablecoin can only sustain its value in the long-term when it is fully non-collateralized and decentralized, thereby avoiding credit risk and vulnerabilities

associated with the issuer or the custodian [MM19]. This suggests that stablecoins not following these principles are inherently unstable, in the sense that they cannot sustain their peg in the long term. However, our analysis of market data for the examples in Section 2.3 have shown that this is not the case. Indeed, widely used stablecoins are without exception partially or fully collateralized, and centralized at a certain degree. This can be interpreted as a trustworthiness of these kinds of implementations, meaning that they are considered the least vulnerable. Therefore, it is important to consider the relevance of market and liquidity risk rather than credit risk. Following, we focus on the market risk of stablecoins, with occasional mentions of issues related to liquidity.

3.3 Market Risk of Stablecoins

3.3.1 Measuring Volatility

Let $X_1, \dots, X_T$ be a discrete time series with T prices for some financial asset. Moreover, let $r_t := \ln X_t - \ln X_{t-1}$ with $1 < t \leq T$ be the **logarithmic returns** of the asset. We define the **mean** log-returns at time $t \leq T$ for a period of length $n \leq T$ as

$$\mu_t := \frac{1}{n} \sum_{i=t-n+1}^t r_i. \quad (3.1)$$

Correspondingly, we define the time series **volatility** at time t for period length n as

$$\sigma_t := \sqrt{\frac{1}{n-1} \sum_{i=t-n+1}^t (r_i - \mu_t)^2}. \quad (3.2)$$

Popular cryptocurrencies like Bitcoin are very volatile in comparison to other types of value stores like currencies or gold; a figure comparing the three can be found in [Blo19a]. This is one of the main issues that stablecoins are trying to resolve, so our main emphasis will be to analyze how stablecoins measure up in terms of volatility. Since our analysis only includes a time period of only a few months, we introduce a modified volatility estimator based on the previous one. More precisely, the previous estimator (3.2) is not particularly suitable to display short term changes of volatility. For this reason we use the estimator proposed by RiskMetrics (*cf.*, Section 5.2 in [JL96]), with a small adaptation for the initial value. We recursively define the **EWMA volatility**

$$\sigma_{t,\lambda} := \sqrt{(1-\lambda)r_{t-1}^2 + \lambda\sigma_{t-1,\lambda}^2}, \quad (3.3)$$

where as before, r_t are the log-returns and $\lambda := 0.94$ is a somewhat arbitrarily chosen decay factor. Moreover, we recursively define $\sigma_{t,\lambda}$ only for $t > t_0 := 30$ and set $\sigma_{t_0,\lambda} := \sigma_{t_0}$, where σ_{t_0} is as in Equation (3.2) and we use a period length of $n = 30$ days. In this way, we obtain a volatility estimator that assigns a higher weight to recent events and decays exponentially when going back in time.

3.3.2 Measuring Market Risk of Stablecoins

The major goal of a stablecoin issuer is to provide a coin whose value is stable. Nonetheless, to measure stability (or rather instability) a formal definition is needed establishing boundaries in which it is possible to determine levels of stability or instability. One question that arises in this context is with respect to what we should measure the stability of a stablecoin. As an example, simply measuring prices in USD is insufficient, because a stablecoin pegged to an other currency will automatically be considered unstable due to the fluctuations in currency exchange rate. As another example, some stablecoins are pegged to gold, which itself is somewhat volatile in comparison to certain exchange rates (see the figure in [Blo19a]). So by simply measuring the denominated price of a gold pegged stablecoin (in some currency) we would not be making any statement about the quality of the underlying stablecoin mechanism. To this end, we define the **stablecoin exchange (SX) rate** as

$$X_t := \frac{S_t}{P_t},$$

where S_t denotes the value of the stablecoin and P_t denotes the value of its peg at a given time t . The definition of SX rates is an adaption of foreign exchange (FX) rates, which measure the exchange rate between two fiat currencies. Note, however, that the SX rate is not an exchange rate between two currencies. Rather, it defines the rate at which the stablecoin can be redeemed. As an example, if the SX rate falls below 1, then coin holders are incentivized to redeem because they can liquidate the deposited collateral and make a profit. Note also that there are some stablecoins that by design do not have an explicit peg; an example is given in Section 2.3. We will however not analyze these cases. To quantify stability of stablecoins we apply the EWMA volatility estimator (3.3) to the SX rate log-returns. This will be among the contents of Chapter 4.

3.3.3 Stablecoin Price Distributions and Our Data Set

Our data set consists of the end of day prices as well as daily trade volume and end of day market capitalization of the following six stablecoins: Tether (USDT), USD Coin (USDC), Digix Gold (DGX), Paxos Gold (PAXG), DAI and Synthetix USD (sUSD). The time period ranges from the 19th of November 2019 (when the multi-collateral version of DAI was released [Pul19]) to the 1st of May 2020. The data was obtained from [coingecko.com](https://www.coingecko.com).

According to Section 2.3, these six coins can be grouped into three pairs. USDT and USDC are off-chain fiat collateralized stablecoins pegged to the USD; DAI and sUSD are on-chain collateralized stablecoins based on leveraged loans and pegged to the USD; and DGX and PAXG are off-chain gold collateralized stablecoins pegged to the gold price. So essentially our stablecoin sample set comprises three different collaterals (fiat, gold and cryptocurrency), two different pegs (USD and gold) and two different stability mechanisms (off-chain reserve and leveraged loans).

Classical models from stochastic calculus suggest a lognormal distribution for asset prices such as stocks and currencies (*cf.*, Section 6.2 in [BR96]), hence, we compare the distribution of our SX rate data to this model. More precisely, for a given stablecoin let r_t , $t > 1$ be the log-return of the SX rate X_t at time $t > 1$. Then, one could assume that $r_t \sim \mathcal{N}(0, \sigma^2)$, where σ^2 is constant at all times. In this case, σ is estimated according to Equation (3.2) using all data points, so the volatility of the whole sample is computed.

We argue that stablecoins behaving according to this model are favourable. If stablecoin log-returns are distributed with a constant standard deviation, then there are no extreme events where the SX rate deviates significantly from 1. Moreover, due to symmetry and the centering at zero, it would then be equally probable for stablecoin returns to be positive or negative. These two attributes would speak for the stability mechanism.

To see how well stablecoins fit into this model we use a boxplot. Recall that a boxplot consists of the following elements: the mean value (marked as an $\times$ in the box), the median value (line within the box), the 25% and 75% quantile (boundaries of the box) as well as the whiskers (whose length below / above the quantiles corresponds to 1.5 times the height of the box) and lastly the outliers (data points outside the whisker range).

The boxplot of normally distributed values is symmetrical and one can calculate that only 0.7% of the data should be classified as outliers, which in our case would correspond to no more than one to two outliers. In Figure 3.3 we can see that none of the stablecoins in our data set matches this second criterion, the closest being USDC with only three outliers. We must mention at this point that the boxplot of sUSD is incomplete as there are six more outliers (half on each side of the $[-0.1, 0.1]$ interval) that are not being displayed. The high number of boxplot outliers for all of the depicted stablecoins indicates that their log return distributions have heavier tails than a normal distribution. Concerning the symmetry, none of the distributions appears to be significantly skewed. We forego technical analysis of skewness and kurtosis as it is not central to our main questions.

Apart from comparing the distributions against a normal distribution it is also interesting to compare the different stablecoins among themselves. It is apparent that USDT and USDC are less volatile than the other four coins. Although the box for USDT is slightly narrower than for USDC, the latter has fewer outliers and therefore narrower tails in the distribution. PAXG is less volatile than its competitor DGX, and DAI is less volatile than its competitor sUSD for which not even all outlier values are displayed.

A boxplot of Tether and DAI in comparison with other cryptocurrencies can also be found in [DB19] (Chart 4). The time series there is different but the findings are in accordance with ours.

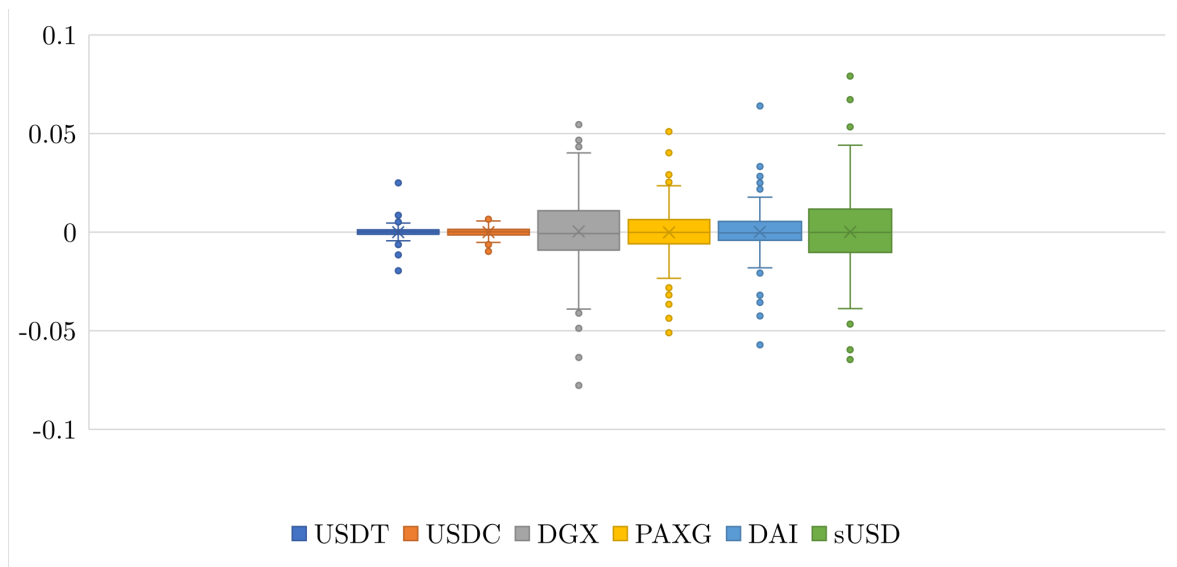


Figure 3.3: Boxplot of stablecoin log-returns of six stablecoins, prices from 19th Nov 2019 to May 1st 2020. Data from coingecko.com on 1st of May 2020.

4 Stablecoin Performance during the 2020 Global Financial Crisis

We begin this chapter with a general discussion of market performance during the start of the 2020 financial crisis. Then, we focus on market performance of stablecoins with particular attention to the market volatility of stablecoins and their popularity during the financial crisis. The data on stablecoins used for all figures was obtained from `coingecko.com` as already mentioned in the previous section. Economic key figures regarding financial market performance are published by various market data providers, for example on `reuters.com`.

4.1 General Market Performance during the 2020 Financial Crisis

Global financial market data shows a significant market downturn in March 2020. Major stock indices from the USA, Asia and Europe dropped around 30% in mid March 2020, with some reporting historical daily losses on the 12th of March [FI20]. On the one hand, with measures of nation-wide economic and social lockdowns taking effect due to the global Covid-19 pandemic, crude oil prices also dropped more than 50% in March 2020. On the other hand, gold, which had been on the rise for more than a year, also dropped more than 10% but quickly recovered within a few days and went on to rise, thereby providing a store of value during this period of global economic distress. Starting in February 2020, exchange rates for major currency pairs such as USD/EUR showed significant increases in volatility.

Concerning the cryptocurrencies' world, the two largest ones - Bitcoin and Ether - both dropped by around 50% from beginning to mid March 2020, with losses of around 30% on the 12th of March. Since then, both Bitcoin and Ether rallied to original levels from the beginning of February. The significant daily drop in mid March resulted in heavy strains on blockchain infrastructures and service applications, such as cryptocurrency exchanges [KMM20]. As a particular event, we mention the network congestion experienced by DAI holders. The congestion was caused by an increased amount of collateral liquidations of the DAI due to the Ether price crash on the 12th of March. Due to the leveraged loans stability mechanism deployed by DAI, there are automatic liquidations in case of large devaluations of the cryptocurrency collateral (*cf.*, Section 2.2.3). The result of the many liquidation actions was a failure of the liquidation system, with some liquidations being carried out at almost zero prices [Mak20a].

4.2 Market Performance of Stablecoins

In the following section we analyze how stablecoins performed during the start of the 2020 global financial crisis. After having a look at SX rates during the period, we consider data on trade volume and then analyze the stability of the stablecoins using the stability measure from the previous chapter. Then, this helps to interpret the market capitalization of our selection of stablecoins. As a basis, we use the end of day prices of the six stablecoins Tether, USD Coin, Paxos Gold, Digix Gold, DAI and Synthetix USD, as introduced in Section 3.3.3. From the same source, we also obtain daily trade volume and end of day market capitalization numbers. In our figures we label the 12th of March "Black Thursday".

4.2.1 Stablecoins SX rates

We start by considering seven-day averages of SX rates of the selected stablecoins. The seven-day averages are used to smoothen the data. In Section 3.3.3 we discussed SX rate distributions and found that most SX rate log-returns followed a symmetric distribution during the period. However, from Figure 4.1 we can see that this is

4 Stablecoin Performance during the 2020 Global Financial Crisis

only half the truth. There is not much to say about USDT and USDC; their SX rate seven-day averages are within 1 ± 0.01 at all times, meaning that their stability mechanism to maintain the peg works well. However, all other stablecoins are seen to deviate from their peg during time periods sometimes as long as multiple months. This is particularly pronounced for the two stablecoins using a leveraged loans stability mechanism. The DAI mostly traded below 1\$ before the market crash and then above 1\$ at all times afterwards. The gold stablecoins both show a similar trend, although less pronounced. Concerning sUSD, its seven-day average SX rate is below 1 at all times before and during the market crash, with SX rates surprisingly close to 1 afterwards.

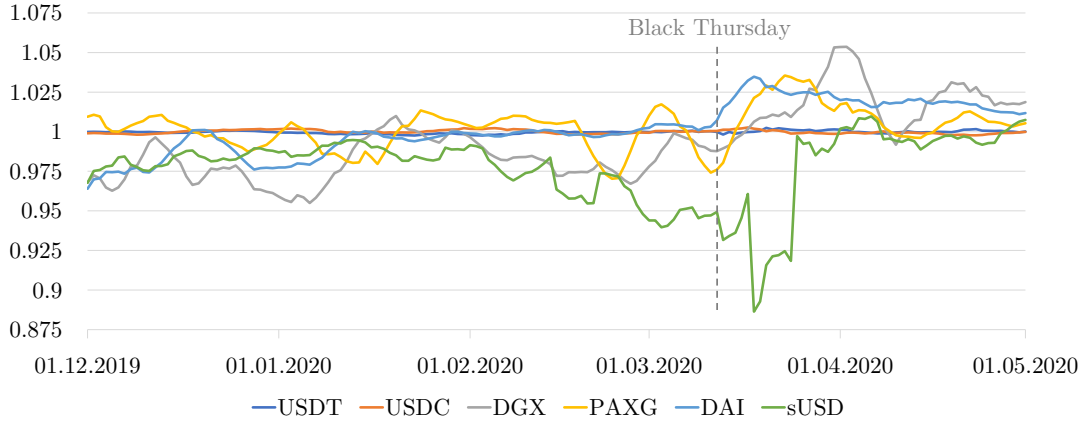


Figure 4.1: Seven-day mean of six stablecoin end of day SX rates, before and during the financial crisis of 2020.

4.2.2 Trade Volume and Volatility

In order to analyze changes in trading volume, we normalized reported daily trading volume in two ways. Firstly, we calculated 7-day trading volume to smoothen the curves. Secondly, we normalized values by dividing 7-day volumes by the individual stablecoins trading volume in the preceding week and including the 1st of December 2019. This starting point is not too arbitrary, since the 2020 financial crisis is often discussed in connection with uncertainty and measures related the global Covid-19 pandemic, news around which first surfaced in December 2019 [CCM⁺20].

One can see that throughout December and January 7-day trade volume does not increase more than three-fold for any stablecoin until mid January 2020. The interesting aspect is that there seems to be a clear difference between the different groups of stablecoins. For USDT and USDC, 7-day trade volume is largely constant throughout December before showing increased volume in January and February throughout April. Until mid March, USDC 7-day trading volume has increased more than fivefold compared to the volume in December, while Tether trade volume shows a slight decrease starting mid February. Compared to the two previous examples, PAXG and DGX trade volume changes only moderately. 7-day trade volume mostly varies between 50% and 200% of volumes from December, with no obvious trends. However, we should mention that PAXG saw its highest daily trade volume one day after Black Thursday (around 10 times the normal daily trade volume), so during the financial market crash. For DGX we did not observe any such increase.

In contrast to the four off-chain collateralized stablecoins in our sample, DAI and sUSD show much larger fluctuations in daily trade volume. This makes sense intuitively since these two systems use leveraged loans as a stability mechanism, which results in automatic liquidations. The large amount of automatic liquidations for DAI can also be observed in Figure 4.2. In mid March, 7-day DAI trade volume was around 10 to 20 times the levels of December, with historical highs of daily trade volume reported on the 13th and 14th of March. For sUSD we see a big increase in trade volume at the end of January. Although we are not aware of the reason for this jump, we assume that it is unrelated to global economic events since other stablecoins did not present a similar behavior.

4 Stablecoin Performance during the 2020 Global Financial Crisis

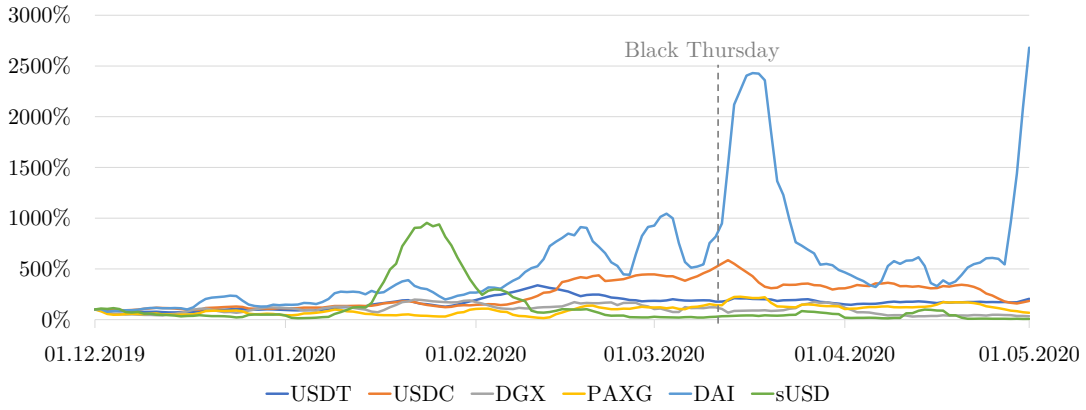


Figure 4.2: Mean weekly trade volume relative to the week of 1st of December 2019.

There are findings in literature showing that for the exchange of currency pairs, trade volume and volatility are correlated [UAM90]. However, if we compare Figures 4.2 and 4.3, we see that this is not necessarily the case for all of the stablecoins in our sample.

For DAI it can be safely assumed that the mass triggering of automatic liquidations lead to instability in its price, hence increased volatility. As to sUSD, prices dropped to around \$0.4 in a single day (*cf.*, Figure 4.1) but this anomalous event did not seem to have a significant impact on trade volume. Concerning Tether, we see a sharp increase in volatility during the financial market crash, but trade volume shows a tendency to decrease. One possible explanation is that since Tether mainly functions as a means of liquidating Bitcoin, the trade volume (which is measured in USD) decreased due to the significant decrease in the Bitcoin price. As far as USD Coin is concerned, a possible explanation is that trade volume profited from an increase in popularity as a means of Bitcoin liquidation (*cf.*, [Cry20]).

With the exception of USDC, which appears exceptionally stable at all times, the other three USD-pegged stablecoins in our sample show a significant jump in volatility during the financial market crash. This holds for both Tether, which is off-chain collateralized, as well as DAI and sUSD, which are on-chain collateralized. On a relative scale, the increase in volatility is pronounced for Tether, which showed almost no volatility in the months foregoing the crash. On a relative and absolute scale, the price crash of sUSD is the most dramatic, with EWMA volatility levels reaching almost 30% (Figure 4.3 is truncated at this point). What is also interesting is that during the financial crisis, EWMA volatility of Tether behaved similar to the one of DAI, in the sense there is one large spike in the same time period during the market crash and a convergence to previous levels after that.

As opposed to these three USD stablecoins, the gold stablecoins do not show such pronounced volatility increases during the financial market crash. There are moderate increases in volatility, which we attribute to the fact that gold price volatility itself increased during the period, making it more difficult to keep track of its exact price. From this we conclude that gold collateralized stablecoins can also function as a reliable value store even in times of economic downturn, just like gold. Nonetheless, we acknowledge that overall volatility levels of these two stablecoins are generally higher than those of the two USD collateralized stablecoins (USDT and USDC), which are the undisputed winners with respect to stability during the financial crisis.

4.2.3 Market Capitalization

To gain additional insights into stablecoin performance during the 2020 financial market crisis we consider their changes in market capitalization. In Figure 4.4, we present the market capitalization of our stablecoin samples from February to April 2020. We have again normalized the data by expressing the market capitalizations as a percentage of the capitalization on the 1st of February 2020. We chose not to display the market capitalization figures from between December 2019 and January 2020. The reason is the migration of an earlier version of DAI (now called SAI) to the current version [Pul19]. This migration resulted in an increase in the the market

4 Stablecoin Performance during the 2020 Global Financial Crisis

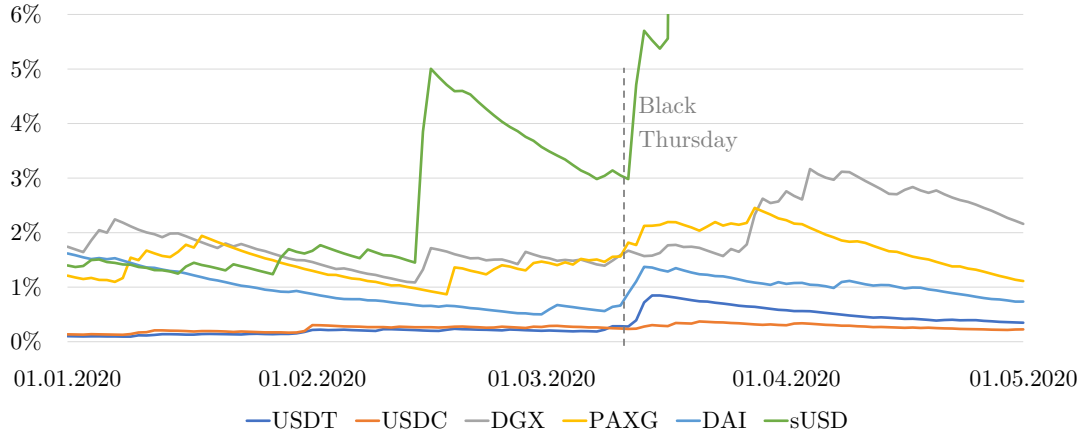


Figure 4.3: SX rate daily log-return EWMA volatilities before and during the 2020 market crash.

capitalization of DAI from zero in mid November to over \$100 Million by the end of January, which means that around 80% of SAI was migrated to DAI by that time. This migration is irrelevant in our analysis, which is why we chose to narrow the observation window at this point. The market capitalizations of other stablecoins are constant during this period except for sUSD, which shows the same downwards trend that still persisted throughout February. Unfortunately, we have not been able to obtain market capitalization data for Paxos Gold.

Firstly, we observe that by the end of April, market capitalization of both USDC and Tether increased by more than 60% compared to the beginning of February. Both coins had relatively stable market capitalizations throughout February and March until the financial market crash. At that point, USDC experienced a surge in market capitalization of around 50% within one week. It appears in this scenario that Tether follows up only about three weeks later. However, we suspect that the unnatural looking kinks in the USDT market capitalization plot are artefacts of some reporting mechanism and that the USDT market capitalization plot in March and April should look similar to the one of USDC.

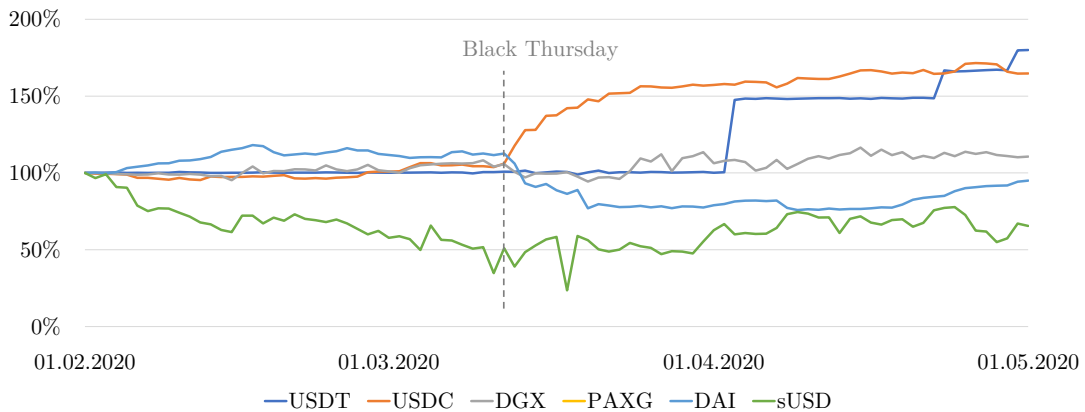


Figure 4.4: Stablecoin market capitalization relative to the 1st of February 2020.

When looking at the plot of DAI, we notice that market capitalization fell by roughly 30% in the days during and following the financial market crash. This is in accordance with the large amount of automatic DAI liquidations described before.

Concerning sUSD, we observe an overall decrease in market capitalization. What stands out is the fall of market capitalization on the 18th of March from approximately 60% to just around 25% relative to the 1st of February. At this point we recall that market capitalization of a stablecoin is directly influenced by its price. Knowing that

on the 18th of March the sUSD price dropped from roughly \$1.0 to around \$0.4, we have a logical explanation for the short term decrease in sUSD market capitalization.

Lastly, DGX market capitalization was relatively constant throughout the whole period. More precisely, DGX market capitalization fluctuated around $\pm 5\%$ in February and increased by roughly 10% in April 2020. This corresponds with a relative increase in the gold price during this period. So if one divides by the gold price, one can see that the number of DGX coins in circulation was stable during the observed period.

As mentioned before, `coingecko.com` unfortunately does not provide any market cap data for PAXG. However, data accessible at `coinmarketcap.com` shows that PAXG market capitalization followed a pattern similar to the one of DGX during the time period in question.

4.2.4 Discussion

In our analysis, the most stable stablecoins in terms of volatility and price stability were USDT and USDC. They also outperformed the other stablecoins in terms of growth, both increasing their market capitalization by more than 50% during the financial crisis. This is in accordance with the view from [JS18] and [Cho19] that trust in a stablecoin system depends on how well the stablecoin can maintain its peg. Of these two stablecoins, USDC performed better than Tether, which showed a spike in volatility. We have not found a reason as to why USDC was able to maintain its peg within 1% on all days and Tether was not. It would be interesting to know if this still holds when intraday prices (in particular daily lows and highs) are also considered.

Comparing Tether to DAI, both stablecoins show an increased volatility during the market crash, with a rapprochement to lower levels afterwards. Like Tether, the DAI did not crash, so the DAI was able to withstand the price crash that its collateral suffered. This robustness is also one of the findings in [DB19]. Indeed, instead of crashing the DAI rose and stayed a few percent above its peg in the first weeks of the financial crisis (*cf.*, Figure 4.1), whereas Tether only shows fluctuations around its peg. So the designs of Tether and DAI worked similarly well for stabilizing SX rates, but not equally well for accurately maintaining the peg.

The behavior of the DAI is in contrast to the behavior of sUSD, which uses a conceptually similar stability mechanism. On the one hand, sUSD suffered a major price crash shortly after the financial market crash. On the other hand, sUSD prices recovered within a week and the stablecoin was able to maintain its peg in the weeks after the crash. What is more, as opposed to DAI, the market crash did not result in a permanent loss of market capitalization for sUSD.

Compared to the USD pegged stablecoins, the two gold backed stablecoins appeared to be less affected by the market crash. They only showed moderately increased volatility in SX rate log-returns that could be attributed to increased price volatility. Interestingly, market capitalization of gold backed stablecoins did not significantly increase although the increase in gold price implies an increased demand for gold during the period.

We also think it is worth pointing out that apart from sUSD, all of the observed stablecoins traded at prices at or above their peg after the financial market crash. This shows an increased demand for stablecoins after the financial market crash. Also, it shows that stablecoins are a valid option for cryptocurrency investors looking to secure their holdings during times of economic distress.

5 Final Considerations

After distinguishing between different types of stablecoins and gaining an overview of the stablecoin market landscape, we have established a framework to measure stability of stablecoins. A crucial step was the introduction of SX rates, which enable the measurement of stablecoin price volatility independently of the pegs. We then used these measurement techniques as well as our understanding of stablecoin design variants to assess the performance of six stablecoins during the start of the 2020 financial crisis. Our main findings are that market performance during this period was individual and we have provided reasoning based on the different stablecoin designs.

We found that Tether and USDC performed best. Both coins are pegged to the USD and are off-chain collateralized. These two stablecoins enjoyed the most trust by investors as their market capitalization each grew by over 60% in the first weeks during and after the financial market crash. At the time of analysis they were also the most largely capitalized stablecoins.

All in all, the two on-chain collateralized stablecoins we analyzed both compared unfavourably during the financial crisis and during the market crash in particular. The DAI was able to avoid a price crash, but it lost around a third of its market capitalization due to automatic liquidations triggered by a price drop of its main collateral Ether. The price drop and subsequent liquidations came with an increase in trade volume, followed by network congestion and collateral liquidations at near zero prices. The sUSD stablecoin showed a different behavior: it traded for less than half its peg on one day during the crash. Interestingly, it did not suffer from a permanent loss of market capitalization, although it uses the same leveraged loans stability mechanism and its underlying collateral (Synthetix Network Token) also suffered a price crash during the financial market crash.

The two gold backed stablecoins have neither performed particularly well nor particularly bad. Volatility increased slightly during the market crash. Moreover, when accounting for the price increase in gold we found that the number of stablecoins in circulation was not affected by the market crisis. A positive aspect is that they rose in value during the market crisis. Compared with their fiat-collateralized counterparts, their SX rate volatility was higher at all times.

5.1 Conclusion

Regarding our objectives stated in the introduction, we have been able to assess stablecoin performance during the market crisis. Moreover, additional data on market capitalization and trade volume helped us understand stablecoin popularity. We were also able to relate our observations to different features of stablecoin designs, in particular stability mechanisms and pegs. However, we did not manage to explain the behavior of sUSD, which behaved differently than the DAI although it uses the same design. It would be interesting to gain further insight into the particularities of these two stablecoins that accounted for the differences in behavior. Furthermore, using end of day prices we could not explain why - unlike Tether, DAI and sUSD - USDC did not seem to deviate from its peg at any point during the market crash.

With dozens of active stablecoins available, one of the main challenges was choosing a suitable selection of stablecoins. We think that our sample has enabled us to perform a meaningful analysis, but clearly there are many stablecoin implementations that could not be discussed and whose behavior during the crisis would have provided further insights. One aspect that we were not able to investigate with our sample was the connection between market capitalization and stability. For instance, it would be interesting to know whether fiat collateralized stablecoins with smaller market capitalizations also achieved the same stability as USDC and Tether during the crisis. A second aspect that we did not investigate was the level of collateralization.

Another challenge was finding a suitable way of measuring stability. We chose EWMA volatility of daily SX rate log-returns to measure price stability due to similar models already being used for other financial assets. Apart from the volatility estimator, our analysis was shaped by the granularity and the range of the available data

and in particular the prices that we used (one price per day, end of day). Intraday prices or at least daily lows and highs might provide further insights, in particular during the days of the financial market crash in mid March. Furthermore, we have only used data from November 2019 to the beginning of May 2020. The financial market crisis was however still ongoing throughout May and June, presenting an opportunity to extend the time window and evaluate ongoing effects of the financial market crisis on stablecoin performance.

Lastly, we would like to point out that we omitted the price information oracle from our analysis, apart from a brief mention in Section 2.2. In times when prices are changing rapidly, as is the case during a market crash, the methods used to determine the current price will surely affect market dynamics. While our analysis was mostly centered around stability mechanisms and pegs, we think that the price information oracle would be another interesting starting point for further investigations into stablecoin market performance.

5.2 Outlook

After the financial market crash, DAI users have voted on different measures to enhance stability of the stablecoin [Mak20a]. One of the outcomes was to allow Tether and USD Coin as a collateral for mining DAI [Mak20b]. Leveraged loans stablecoins of course profit from more stable collaterals such as other stablecoins in terms of stability. In some sense, this vote could be considered a defeat for DAI; if one already owns Tether or USD Coin, why should one use it to mine DAI? However, it is an example of what we think could be a trend to use multiple collaterals for a stablecoin instead of just one (both Tether and DAI have introduced additional collaterals over the time). The use of multiple collaterals helps to diversify risk and it also gives more possibilities to users who like to mine stablecoins, presumably at the cost of complicating the stability mechanism.

In our analysis we found that the two largest capitalized and fiat collateralized stablecoins were able to provide liquidity and stability during the crash of the cryptocurrency market in the 2020 financial crisis. The on-chain stablecoins have displayed too many flaws during the crisis for us to believe that the leveraged loans design will ever win a larger market share. For this reason we see a potential for future developments following the approach of tokenized funds. In particular, we see a potential for implementations of government backed cryptocurrencies in the form of digital fiat money for large economies. The US federal reserve has recently mentioned researching this opportunity [Bra20]. Should such a government backed digital fiat currency ever be launched, this would surely change the stablecoin market landscape.

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