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1. Abstract

In this study, in order to determine if all stablecoin designs achieve the objective of minimizing their price swings to the same extent, I examine the average volatility that distinguishes the major stablecoin designs. My research recreates and extends Jarno and Kołodziejczyk's (2020) study. In the introduction section, I clearly outline what is a stablecoin and the purpose of it. In the literature review section, I explain and compare the three stablecoin designs, namely the tokenized, on-chain collateralized and algorithmic ones. Then I chose a common measure of volatility, the standard deviation of return rates corrected for autocorrelation, and use a variety of nonparametric tests, including the Kruskal-Wallis and the Games-Howell nonparametric post-hoc tests to find differences between the distributions of the measure in three stablecoin groups. I also divided the samples into time series, in order to have a better and more significant outcome. I established that while tokenized funds are better at delivering stable market value than the other two category, stablecoins as a whole fall short.

1.2 Zusammenfassung

In dieser Studie untersuche ich, ob alle Stablecoin-Designs das Ziel erreichen, ihre Preisänderungen in gleichem Maße zu minimieren, indem ich die durchschnittliche Volatilität analysiere, die die verschiedenen Stablecoin-Designs unterscheidet. Meine Forschung reproduziert und erweitert die Studie von Jarno und Kołodziejczyk (2020). Im Einleitungsteil erläutere ich klar, was ein Stablecoin ist und wofür er verwendet wird. Im Abschnitt der Literaturrecherche erkläre und vergleiche ich die drei Stablecoin-Designs, nämlich die tokenisierten, die durch On-Chain-Besicherung gedeckten und die algorithmischen Stablecoins. Dann wähle ich ein gängiges Maß für Volatilität, die Standardabweichung von Renditeraten, korrigiert für Autokorrelation, und verwende verschiedene nichtparametrische Tests, einschließlich des Kruskal-Wallis-Tests und des Games-Howell nichtparametrischen Post-hoc-Tests, um Unterschiede zwischen den Verteilungen des Maßes in den drei Stablecoin-Gruppen zu finden. Ich unterteile auch die Stichproben in Zeitreihen, um ein besseres und aussagekräftigeres Ergebnis zu erhalten. Dabei habe ich festgestellt, dass zwar tokenisierte Stablecoins besser darin sind, einen stabilen Marktwert zu liefern als die anderen beiden Kategorien, insgesamt jedoch alle Stablecoins diesem Ziel nicht vollständig gerecht werden.

2. Introduction

Stablecoins are digital assets that aim to minimize price fluctuations with respect to their reference asset, typically the US dollar, in the highly volatile cryptocurrency market. They are defined in Bullmann's (2019) ECB Occasional Paper on Stablecoins as units of value that are not tied to a specific currency, but rather use stabilization tools to reduce volatility. Stablecoins represent a major trend in the cryptocurrency market, with three of the top 10 largest cryptocurrencies by market capitalization being stablecoins and the stablecoin economy comprising over 15% of the $900 billion industry as of December 2022 (CoinGecko, 2022a).

2.1 Volatility in the crypto-asset market

To understand the inherent volatility in the space, we have to understand the value of cryptocurrencies first, let us try to attempt to explain it through the example of bitcoin. For that we have to first understand fiat money, which is an unbacked currency that has no intrinsic value other than being a legal tender by a single or multiple governments. (Hans-Hermann Hoppe, 2021) It can be used to buy goods and services, such as the euro or the US dollar, and most impotently citizens have to settle their tax obligation in the country's legal tender. While on the other hand, fiduciary money is a type of money that is accepted as a medium of exchange due to the trust that exists between the payer and the payee. Fiduciary money, just like fiat money has no intrinsic value, and its worth comes from the confidence people have in the issuer of the currency. Therefore, one could say that fiat money has no underlying value, except the trust in the government, that supplies it, hence it is a fiduciary/trust based monetary system. So commonly used tenders, like the euro is both a fiat and a fiduciary money system. (Skaggs, 2012)

Let us look at bitcoin the same way for the moment and assume that it does not have any intrinsic value, hence a form of fiat money, where the issuance is based on a predetermined algorithm. Or one could even say that its value is based on the trust in the blockchain system, therefore it is a fiduciary money system. Recently bitcoin even fulfills the requirement to be a legal tender, since El Salvador formally adopted it as their currency next to the USD, and taxes can be settled in the digital currency. (Sinclair, 2021) The difference between the fiat money we use and bitcoin is the lack of stabilization mechanism in the latter. The Bitcoin blockchain is operated by an open-source code that predetermined the distribution and caps its supply to 21 million bitcoins. (Satoshi, 2008) This rigid supply does not leave a lot of space for the continuously and rapidly changing aggregate demand to give it a stable value. The demand based on future value, speculation and the predetermined slowly expanding supply results in high volatility. While traditional fiat money has central banks in their corner to back the value of the currency and using stabilizing monetary policy mechanisms to maintain a fairly stable value. These monetary policy tools influencing the supply and the market value of a currency includes open market operation, reserve requirement or base interest rate. So, while the traditional moneys' aggregate demand fluctuates too, a central authority can influence the aggregate supply hence creating a somewhat 'elastic currency' that is rather stable. (Berentsen, 2019)

2.2 Purpose of stablecoins

The most important use of stablecoins are conversion and exchange of other cryptocurrencies (Wei, 2018). If we compare the total crypto market 24-hour trading volume on any given day, with the stablecoin market's trading volume, we can conclude that approximately 75% of the trades happens between any cryptocurrency and a stablecoin. Even in time of distress or high volatility in the cryptocurrency market, many stablecoins are proven to have deep liquidity, nonetheless the economic uncertainties. (Kyriazis and Prassa, 2019).

In the cryptocurrency economy, many wallets and exchanges use bitcoin, as the reference currency of a portfolio or an investment. But due to the volatile nature of the internet economy the reference currency could lose or gain value each day, hence it is hard to comprehend prices denominated in bitcoin. This is another place where stablecoins provide a solution, because by using them as a reference, one uses the world reserve currency, the US dollar for dominating prices and positions. This also makes inherent sense, since the crypto economy is not bound to one specific jurisdiction or geographical place, and today approximately 40% of global international trade is denominated in USD. (Georgiadis et al. 2021)

Most of the exchanges happen between a given cryptocurrency and a stablecoin pair, there is also another reason for this phenomenon, other than just trading cryptocurrency against traditional fiat money on centralized exchanges. In some jurisdiction, where crypto trading has some regulatory ground, exchanging cryptocurrencies, such as bitcoin to ether is not a taxable operation. (Vámhivatal, 2021) Since stablecoins are also cryptocurrencies, exchanging bitcoin into USDC is also not a taxable event. While on the other hand, when an investor sells their bitcoin for traditional fiat money, they have to pay tax on that. So, an added benefit of using stablecoins in the world of blockchains is the simplification of taxation for every user and investor.

While domestic payments and remittances in developed countries is increasingly cheaper and more convenient with instant transfer and 24/7 availability, it is not necessarily the case in developing countries, especially in the case of cross-border retail transactions. 38% of the adults do not have an account at a bank or even through mobile money services worldwide. (Demirguc-Kunt et al, 2018) Even if those who can use a mobile phone, in some cases they lack the authentication documents, such as an ID or passport to even open an account. If somebody wants to send money in their home country to their family, for transfers under $10, Western Union may charge up to 35% of the total amount. (Chapiro, 2021) It is unequivocal that financial inclusion has an immense area to improve, that is where the blockchain technology can help.

2.3 What is a stablecoin

The most important characteristic of any stablecoin is their volatility, since their main purpose is to minimize price fluctuation in their respected currency of reference. Stablecoin performance can be measured by comparing their volatilities through time, meaning to what degree can they maintain stable market value. (Chohan, 2019)

An important thing to understand about the cryptoasset industry, that it is not mature and changing very rapidly. While I am writing this study and using Bullmann's taxonomy for stablecoin it is plausible that a new stablecoin type is being invented. According to CoinGecko.com (2022a), there are currently over 85 stablecoin projects, even though most of them have lost their pegs or are not used by anyone. Yet it is really hard to be exact about this number, due to the decentralized nature of permissionless blockchains. Meaning most of the projects are open source and easy to recreate, since the most used blockchains do not need any permission to be used, to create a token or project, causing so many scams in the cryptocurrency economy (Massimo et al. 2021).

On the other hand, the upside of the permissionless nature is that anybody can create a new stabilization mechanism, that can work and create tremendous value in the stablecoin economy. This value can be created by, for instance the stablecoin being decentralized instead of a centralized entities and third-parties imposing monetary policy. The value can also come from different experimental algorithmic stablecoins, which use under-collateralization or no collateral at all. Another reason why this number is not precise, is the amount of failed stablecoin projects.

Stablecoins can be categorized on many levels. According to Moin et al. 2019's taxonomy, we could divide them based on what type of collaterals they use, like fiat money, debt, commodity, other cryptoassets, a basket of any or even no collaterals at all. They can also be categorized based on the amount of collateral they use, such as stablecoins with full reserve, partial reserve, overcollateralized or again no collateral at all. One of the most relevant factors of an underlying project of a stablecoin is the governance model in particular the scope of decentralization they use. Such as it could be a centralized entity, like Tether's USDT with traditional management or it could also be a decentralized autonomous organization also known as a DAO. A DAO represents an innovation in the design of organizations, in its emphasis on computerized rules (Usman, 2017). So, the project runs on predefined rules that can be seen in the open-source code, and the governance token holders of a DAO can vote on changing aspects of the organization, the code or even receive dividends. A DAO's governance token is essentially equivalent to a share in a traditional public company, but every token holder can participate in every vote, no matter the size. Other aspects of design choices include which blockchains they operate on, the scale of adoption on centralized and decentralized exchanges, country of origin of the project and type of issuer. (Bullmann, 2019)

But for us the most important distinction in this research is the stabilization mechanism it uses. This design choice is the most influential for low volatility since this is the mechanism that tries to reach a stable value for the cryptocurrency with respect to its peg. There are four groups which we can distinguish, tokenized, off-chain collateralized, on-chain collateralized and algorithmic stablecoins (Jarno and Kołodziejczyk, 2021).

Tokenized stablecoins are backed by a single currency (or a basket of currency) which needs a third-party custodian. Just like off-chain collateralized stablecoins, which use other traditional assets – or it could be cryptoassets too – for backing and therefore it needs a custodian entity for redemption. On the other hand, on-chain collateralized stablecoins are only backed by cryptoassets that are recorded on a distributed ledger, and therefore it needs no third-party custodian for any claim to be satisfied. Last but not least the algorithmic stablecoins, which are creative use of computer algorithms that affect either the supply, demand or even both sides of a stablecoin, in order for the price to remain stable. This is done by using secondary stabilization tools implemented by smart contracts[1] on blockchains. All of them can be found on the market, yet not all of them has the same sample sizes neither with respect to project length nor daily observations data. Tokenized and on-chain collateralized stablecoins are the most frequent and are around for the longest time, so the amount of observation is bigger than any other. Due to not having any active off-chain

[1] A smart contract is a low-level automated code scripts running on a blockchain platform. (Weiqin et al., 2019)

collateralized stablecoin in the set, I group it together with tokenized stablecoins, so I only do my analysis on 3 groups. Out of the three, the major stablecoin categorie is the tokenized in number of projects, in aggregated market capitalization and also in traded and transacted volume.

The goal of the stabilization mechanisms is to incentivize the users and holders of the token to contract and expand the supply until the price reaches the pegged asset's price. The most straightforward way to do it is by having a fully collateralized system, where the pegged asset is the collateral one-to-one, so tokenizing the underlying asset. This way the users can expand the supply if the price is under the peg, by purchasing more and increasing the demand, or they could redeem their assets if the price is above the underlying asset's. So, if the token, e.g., USDC is above 1 dollar, the user should go to the issuer and purchase the token for the promised one-to-one rate, and she/he could instantly sell it on the market, by taking advantage of the arbitrage opportunity. Vice versa if the price is below the pegged asset's value, so buying on the market and redeeming at the issuer. This process should happen, till the price of the USDC finds equilibrium.

3. Literature Review

3.1 Tokenized stablecoins

3.1.1 What are tokenized stablecoins and why do we need them?

The biggest category in stabilization mechanisms, is tokenized stablecoin. Based on market capitalization the top 3 stablecoins are in this category, and more than 85% of the market share is dominated by them. (CoinGecko, 2022a)

Tokenized stablecoins are created by a centralized entity, a company that controls the monetary policy of the token. The company acts as a custodial service for the underlying collateral, backing the stablecoin. The company gets $1 from a customer and in exchange provides 1 stablecoin. In theory, the company holds that 1$ in a vault, and for every stablecoin out in the circulation, there is 1$ worth of commercial money, e-money or central bank money backing it up in the company's vault. (ECB, 2019) But in practice, this collateral barely stays in 100% money equivalent.

The introduction of a third-party entails many advantages and risks into the stablecoin stabilization process. While there is a real-world representation of the project, through the management and owners of the company – unlike in a DAO, where that is not necessary – there are not many clear and transparent regulation and supervision for these companies. Since the company that safekeeps the underlying dollar of the stablecoin is not transparent and due to the lack of regulations, they do not need to disclose their holdings in detail.

Of these reserve-backed stablecoins most are backed by treasury bills, commercial papers, and cash-equivalent reserves. (Liao and Caramichael, 2022) The soundness of these custodial stablecoins have been challenged many times. Some companies have a tendency of disclosing attestations of their holdings, while others have been sued before for potential misconduct of the reserves. (ag.ny.gov, 2019)

The issuance of new tokens starts with the customer registering with the stablecoin company. They have to go through KYC/AML procedures. After that the user deposits money into an account the issuer company made with a custodian who will safekeep it, for instance a bank. Once the funds are confirmed the issuer party mints[2] new tokens through the smart contract, that is transferred to the user's digital wallet. The transaction happens based on the predefined rules of the blockchain, where participants in the network confirm that the transfer complies with the initiative's guidelines and validate the transfer. The stablecoin effectively works as a receipt on the issuer and the redemption works almost like the issuance, just in reverse. The user sends the redeemable amount of tokenized funds to an address specified by the issuer, who burns[3]

[2] Creating new tokens inside a blockchain infrastructure like Ethereum, through the use of smart contracts is referred to as crypto minting. (Beganski, 2022)
[3] The process of burning tokens removes digital assets from circulation permanently and lowers its supply. (Beganski, 2022)

the cryptoassets. As the tokens are burned the custodian will transfer the stated amount of money back to the user. (ECB, 2019)

The users who act as arbitragers are incentivized to help keeping the peg on the market through this issuance and redemption mechanism. Just like discussed above, if the stablecoin trades above the peg, the user can utilize the issuance function to earn profit. As well as if it dips below the peg, the user can purchase the stablecoin cheaper and take advantage of the redemption function to create financial gain.

In conclusion, this mechanism's success is based on a third-party and their trustworthiness, as well as the trust in efficient market functions, with the assumption of sufficient level of arbitragers. With respect to other mechanism, there is a high level of centralization and in case of credibility loss there is a high risk of bank run. With sufficient level of regulation this could be mitigated, yet there is none in place for now.

3.1.2 The case of Tether

Tether was founded in 2014 under the name 'Realcoin', as the very first stablecoin initiative. (Messari.io, 2022b) USDT – Tether's dollar pegged stablecoin – is currently the dominant stablecoin on the market both in terms of market capitalization and volume. Back in February of 2018 it was responsible for 99% of the market capitalization in the stablecoin market. (ECB, 2019) Since Tether had the first mover advantage of stablecoins, most of the exchanges used it to create trading pairs, mainly to lower or do away with the requirement to retain external banking relationships.

However, it has been through a steady and long decline throughout the years in terms of market dominance. By the end of 2022, this share dropped below 45%. (CoinGecko, 2022a) Tether Inc. – the company behind the stablecoin – has been through many controversies throughout the years.

Here is a brief summary of how Tether became the most controversial stablecoin, maybe cryptocurrency company ever. In 2019, the website of Tether claimed, that the backing of every tether is done by traditional fiat currencies held in their reserves. (web.archive.org, 2019) But the language around the statement has changed and the reserve was guaranteed by traditional currencies, cash equivalent and most importantly other assets and receivables from loans made by Tether to third parties, which may include connected organizations. (Lopatto, 2021) The affiliated entities turned out included Bitfinex, which is a cryptocurrency exchange that had a partnership with Tether, but through the 'Paradise Papers' it turned out to be controlled by the same people. (offshoreleaks.icij.org, 2022) An investigation by the New York state Attorney General determined, that Bitfinex and Tether had participated in a cover-up to conceal the alleged loss of $850 million in funds that were mixed with customer and company cash. (ag.ny.gov, 2019) Not long after that, Tether's lawyer admitted that the stablecoin was only backed by 74% of cash and cash equivalent. (De, 2019) The case was settled, Tether has admitted no wrongdoing and as a result they have to provide quarterly reports about their reserves for two years. (ag.ny.gov, 2021) However, the controversy does not stop there. After the first breakdown of the reserves, it turned out that only 75% of the reserve was in cash or cash equivalent, which also included unspecified commercial paper, that is responsible for 49% of the stablecoin's full reserve. (De and Hochstein, 2021) The breakdown also included 12.5% of other loans – to affiliated entities – bonds, precious metal and 'other investments' that include digital tokens. A more recent report of their reserve showed that the most obscure part, the commercial paper number went to around 12.5%, while more than 43% of the reserve consists of U.S. treasury bills. (Tether.to, 2022)

Despite the increasing transparency, and better risk management, a result of the years of controversies and lying is that the industry started to shift to other stablecoins. This is the main reason behind the significant fall of market dominance.

3.1.3 The case of Circle

USD Coin (USDC) is a stablecoin with tokenized stabilization mechanism, launched in 2018 by the CENTRE consortium, which is a partnership between Circle – a financial technology company – and Coinbase – one of the largest cryptoasset exchange. (Messari.io, 2022a) USDC possesses around 33% of the market capitalization of stablecoins, which puts it to second place after Tether's USDT. (CoinGecko, 2022a) However, the total daily volume of USDC is around 5% of all the stablecoins, while USDT is on average above 50%. This is a clear indication, that while USDC is widely adopted, and used to store value in the digital asset space, USDT is the dominant cryptoasset used for trading.

The most significant distinction between the transparency of the two assets, is that USDC provides a weekly reserve reports and monthly attestation of capital in the reserve, which also includes a breakdown of their assets backing the stablecoin. The breakdown only includes two categories, cash – which is around 20% of the reserve – and short-duration U.S. treasuries. (Circle, 2022) It is also important to mention, that attestation is more like a snapshot, that the company has the equivalent dollar value, but not a deep audit. (Gallagher, 2022)

3.1.4 The case of Paxos

Paxos is a financial institution regulated in New York, they launched their first USD pegged stablecoin PAX (now rebranded as USDP) in 2018. (Paxos, 2022a) Unlike the two top stablecoins, Paxos's tokenized US dollars' reserves consist of 100% cash and cash equivalent i.e., consumer deposits are always kept secure and readily redeemable. Also, The New York State Department of Financial Services maintains strong monitoring of USDP, which complies with the highest levels of consumer protection.

Similarly, to USDC, Paxos publishes attestations every month, but unlike their counterparty, it is more detailed. In the Circle's attestations, there is a balance of the circulating USDC amount and the value of the custody accounts. (Centre, 2022) On the other hand Paxos discloses a more detailed description, that also includes the amount and exact type of U.S. treasuries with their maturity, and a current market value of the cash equivalents and the breakdown of the cash's deposits. (Paxos, 2022)

While USDP is only the 6th biggest stablecoin with respect to market capitalization, that is not the only USD pegged product of Paxos. The company is also responsible for the third biggest stablecoin on the market, which is the Binance USD (BUSD). (Paxos, 2022c) Combined they have more than 15% of the total market dominance in the stablecoin market, but in terms of size, BUSD is more than 20 times bigger than USDP. (CoinGecko, 2022a) In the beginning of 2021, they consisted less than 5% of the market, so in the recent years they gained a more and more preferable place in the eyes of the market.

3.1.5 Off-chain collateralized stablecoins

Off-chain collateralized stablecoin are backed by other conventional asset classes that must be kept secure by a custodian and are in the issuer's control only for the duration that the user does not redeem it. (Bullmann, 2019) Similarly to tokenized stablecoin, this initiative calls for dependable custodians and issuers to hold collateral securely and permit its redemption. These stablecoin could represent commodities or even real estates, and the underlying collateral could be any type of securities or even other digital asset, controlled by the custodian party.

In the reference study, Jarno and Kołodziejczyk (2020) grouped this category together with on-chain collateralized stablecoins. But since many of the tokenized stablecoins are known to be backed by securities – such as government bonds or commercial papers in the case of Tether – I find it more suitable to be grouped with the tokenized stablecoin category. Also, it needs the same reliable third-party for the mechanism to work. This decision does not affect the end result of the study, since no off-chain collateralized stablecoin was included in the sample.

3.1.6 Concluding tokenization

As established, the most important part of the tokenization stabilization mechanism is the issuance and redemption of the assets by centralized companies. If trust falters, the asset holders would get their positions out of the token – even if this just means that they transfer the value into a stablecoin that is perceived safer – and the market price would fall, which means the arbitrageurs could purchase it at a discount and redeem it at the centralized entity for a profit. Yet in case of for instance Tether when it was not fully backed, if a big enough portion of the USDT wants to be redeemed at once and if the underlying investments could not be liquidated at par or fast enough, there could be a case of bank run. That is why the name of the game in case of tokenized stablecoins is trust.

This is where regulation fits into the picture. Stablecoins should be subject to thorough, standardized, risk-based, flexible regulation with an emphasis on their structural characteristics and use. (Bains et al., 2022) If every company that issues tokenized digital assets would be supervised and would follow clear guidelines and rules, the whole ecosystem would be much safer. It is very interesting to note, that while still the first mover USDT is the dominant, the value is slowly but steadily flowing to other stablecoins that are perceived safer. If this trend continues, as the stablecoin with the lowest risk parameters will be the dominant.

3.2 On-chain collateralized stablecoins

3.2.1 What are on-chain collateralized stablecoins, and why do we need them?

Permissionless open blockchains offer the possibility of a peer-to-peer transaction form, that is decentralized and cannot be controlled by any one company, government or entity. This is a very important part of the ethos of the cryptocurrencies, because the idea is to have a decentralized alternative solution for our centralized financial systems. (Konashevych, 2017) This includes an alternative payment system, currency system, financial intermediary system and much more. As we already established the gravity of stablecoins, it is very important to have a stablecoin that works in a decentralized fashion. (Jarno and Kołodziejczyk, 2020) Decentralization eliminates most of the risks of tokenized stablecoins, like custodial risk, through open-source code and the transparency of open blockchains. The most important characteristic of a decentralized stablecoin is that the issuance of new token and burning of existing – meaning the control of the supply – is done through autonomous smart contracts.

First to dissect what on-chain means. The phrase refers to the blockchain, for instance if we think about a transaction of a digital asset, an on-chain payment happens recorded and confirmed on the blockchain. Whilst the opposite of it, meaning an off-chain transaction of a cryptoasset is everything that is confirmed outside of the main blockchain network. Being on-chain offers higher security through finality[4], full pseudonym[5] transparency, high privacy and the exclusion of any third-party in the process due to decentralization of the network, while off-chain transactions happen on average in a much faster, scalable and cheaper way. (Soares, 2022)

3.2.2 The case of MakerDAO

MakerDAO was founded in 2015, and it is one of the longest running DAO. It launched the DAI on-chain collateralized stablecoin in 2017. (Messari.io, 2021) MakerDAO is the largest Decentralized Finance[6] (DeFi) protocol by the end of 2022. The way to measure the size of a protocol in the DeFi ecosystem is by total value locked (TVL). This in the case of MakerDAO is the collateralized debt position (CDP). Currently MakerDAO's TVL is around 7.5 billion US dollar, while at the highest point in 2021 it was almost $20 billion. MakerDAO is around 14% of the whole DeFi ecosystem in terms of size. (DeFiLlama, 2022)

The organization uses collateral to maintain the value of the stablecoin DAI, but not just one-to-one collateral, but an overcollateralized portfolio of cryptocurrencies, which is the underlying value of the token. To create new supply of DAI a user has to create a collateralized debt position, that will serve as the name suggests the collateral for the stablecoin. (Kozhan and Viswanath-Natraj, 2022) The CDP in MakerDAO consists of mainly ether (ETH), but it can include other cryptocurrencies, like bitcoin (BTC) or even other stablecoins like GUSD[7]. The user can borrow a fraction of their CDP in DAI – therefore creating new supply – which maintains a soft peg to the US dollar. Since DAI works in a completely decentralized on-

[4] Finality in a blockchain means a relative X confirmation, from which a double-spend attack is generally accepted as infeasible. When a transaction is final, it is perceived as secure and immutable.
[5] Pseudonym is a name someone uses instead of their real name. In cryptocurrencies a wallet's address is pseudonym, but the owner can reveal itself. (Androulaki et al. 2013)
[6] Decentralized Finance is an alternative way of finance, which focuses on the elimination of third-parties and centralized entities from financial systems. (Zetzsche et al. 2020)
[7] GUSD is the Gemini dollar, a tokenzied stablecoin.

chain way, it gets rid of custodial risk all together, however, it is nevertheless subject to hazards related to changes in the value of the collateral currencies.

Since the CDP can be highly volatile, due to the nature of the underlying cryptoassets, it has to be overcollateralized by a significant margin. In general, users can borrow up to 2/3 of their CDP. For example, if somebody lock up 1 ETH at the price of $1000, they are able to borrow DAI up to $666. So, the CDP has to be at least 1.5x of the borrowed amount, but usually users lock up even more, than just the bare minimum. Since the underlying asset is unpredictable, there would be a high probability of a margin call or even liquidation of the CDP, if the ratio is not higher than 1.5x. (Brennecke et al., 2022) The minimum collateral ratio can vary dependent on the underlying cryptoasset, also the ratio can be changed by the protocol.

Many early investors in bitcoin and other cryptocurrencies believe that the market prices of their holdings will worth multiple times as much in the future as it did when they bought it. Partially for this reason somebody who bought ether early on and who has a lot of value on paper might have a liquidity problem. When somebody looks at a CDP, they could think of it as a mortgage with a more volatile underlying asset. Just like a traditional organization, a DAO also has a revenue model, and a part of that revenue is from these DAI loans. Just like a bank has an interest rate on a mortgage loan, MakerDAO has an interest rate on the loan a user takes against their CDP. This in part solves the liquidity problem long-term crypto holders have, since if they borrow a portion of their CDP, they have dollar liquidity.

This interest rate is called Stability Fee. (MakerDAO, 2022a) The annual interest rate changes based on what cryptoassets a customer is using in their CDP. If the underlying asset is something riskier the Stability Fee is higher, 4.50% annually. On the other hand, if the cryptocurrency a more established coin or even another stablecoin, the fee could be 0.50% or it could even go to 0%. (Oasis Borrow, 2022)

If the market price of a DAI deviates from the equilibrium and decreases, it is an indicator that there is too much outstanding supply and too little demand. If this happens, the protocol increases the rates on the CDP loans, therefore incentivizing the users to pay down their borrowed amount, which decreases the outstanding supply, hence stabilizing the equilibrium. In order to close a loan, the customer has to repay the principal and the accrued fee in DAI. While the borrowed amount gets burned, the fee goes into the Maker Protocol's internal balance sheet, where it is stored in a vault and can be decided by the community what happens to it. If there is surplus the remaining tokens are sent to a Surplus Auction, where people can bid in MKR for DAI. After this the MKR gets burned – which is essentially a share buyback. (MakerDAO, 2022a)

If the market price of the DAI token deviates the other way – meaning it is traded above $1 – the protocol adjusts the Stability Fee into a lower rate. This incentivizes customers to borrow more which in effect increases the supply of the token and helps it to reach parity once again. The Stability Fee acts as an interest rate on money implemented by a central bank, which affects the supply of the currency. But while a central bank's monetary policy is decided in a centralized manner the protocol uses a decentralized, continuous-voting system that approves every change in the Stability Fee. (Kozhan and Viswanath-Natraj, 2022)

Another way how a CDP can be closed is by the means of liquidation. When the CDP dips below the predefined minimum collateral ratio of the borrowed amount, the underlying asset gets liquidated. This ensures that DAI is always backed by an adequate quantity of collateral. If a liquidation occurs, the Liquidation Penalty is added to the CDP's total outstanding produced DAI, increasing the amount of collateral that must be sold at auction. Proceeds from the Liquidation Fee are used to buy back MKR and burn it – meaning the equivalent of share buyback. (MakerDAO, 2022b) The fee from the penalty could be up to 15% of the borrowed DAI, but users could avoid margin calls, by putting up additional collateral or paying DAI back.

It is important to note, that MakerDAO in the category of protocols that mint their own stablecoin using collateralized lending dominates the market with more than 75% of market share based on TVL. (DeFiLlama, 2022) Out of the 54 CDP protocols recorded on DeFiLlama – which is the largest on-chain

TVL aggregator, it analyzes over 145 different blockchains and thousands of protocols – only 5 has a TVL of above $100 million. Thanks to the network effect and active prudent governance of the MakerDAO, it produces the longest and safest decentralized stablecoin. This data also suggests that it is a winner takes all category, which creates safety in the robustness of the protocol, but also a single point of failure for the stablecoin category.

3.2.3 Concluding on-chain collateralized stablecoins

To conclude on-chain stablecoin mechanisms, it is a project where the collateral is stored on-chain, and the organization is owned and run by the governance token holders. This facilitates high level of transparency and decentralization.

In case of a sudden downward movement in the price of the collateral asset, the liquidation of CDP happens automatically through smart contracts, when the minimum collateral ratio is reached. This gives the investors a reliable failsafe, since the code of the smart contracts is transparent, and unless a bug appears, the liquidation will happen. (Levine, 2020) The DAI stablecoin has a lifespan of over 5 years, and while there are cases of bugs, the fact that it is still standing, just strengthens the argument that a safe product has to be battle tested. Not to mention, that MakerDAO has the biggest bug bounty program – project that pays people for finding and reporting problems in software – in the tech place with $10 million. (Asmakov, 2022)

On the other hand, the liquidation further escalates the downward pressure of the collateral asset, and could lead to an even lower valuation of the underlying collateral. The rates on borrowing can induce change in the supply that pushed the price of the stablecoin towards the desired peg, however there is clear empirical evidence, that volatile collateral increases the riskiness of the peg. (Kozhan and Viswanath-Natraj, 2022) So the lower the risk on the collateral, the lower the volatility of the stablecoin.

3.3 Algorithmic stablecoins:

3.3.1 What are algorithmic stablecoins and why do we need them?

As it is established with the on-chain collateralized stablecoins, decentralization and trust in the system is very important, especially in the long term. So why are on-chain collateralized tokens not enough? A decentralized stablecoin is a very needed element for the digital asset market, but if investors would not have to lock up billions of dollars worth of assets would be the ideal solution. That is where tokens with algorithmic stabilization mechanism come to the picture.

A type of cryptocurrency known as an algorithmic stablecoin is controlled by algorithms (i.e., smart contracts) to dynamically reduce the volatility of its price in relation to a particular form of asset, such as the US dollar. Typically, algorithmic stablecoins' money supply is controlled in an automated fashion, which is comparable to how central banks produce and destroy money. Algorithmic stablecoins have been expanding quickly in recent years, while their volatility has increased significantly too. (Zhao et al., 2021)

3.3.2 Types of algorithmic stablecoin mechanisms

Algorithmic stablecoins could be further classified into three categories, based on Zhao et al. (2021). It could use a rebase algorithm, seigniorage shares or partial-collateral algorithm.

3.3.2.1 Rebase

If a stablecoin is using a rebase algorithm, to stabilize its value, the supply of the currency is elastic, so unlike other cryptoassets, it is not fixed. While for instance bitcoin has a fixed supply programmed into the code, fiat currencies like the US dollar have a similar inelastic supply. (Satoshi, 2008) But unlike how the Federal Reserve controls the money supply of the dollar through monetary policy, a rebase stablecoin has a preprogrammed algorithm that affects the changing supply based on the demand. (Federal Reserve, 2022)

In practice, this means that if a person would have 100 tokens in their wallet that is worth $100 one day, and the next day the token's price would depreciate to $0.9 per token, the balance in the wallet would become 111.11 after the rebase process. This makes the value of the cryptocurrency owned constant at $100. However, if the next day, the demand for the token increases significantly, and the price appreciates to $1.1, the token held in the wallet after the rebase process would be equivalent to 90.9. (Kuo et al., 2019) A currently working example of a rebase stablecoin is Ampleforth, that has a market capitalization of just $39 million dollar, that is a fraction of the overall stablecoin market, which is added up to around $147 billion. (CoinGecko, 2022b)

3.3.2.2 Seigniorage share

The seigniorage share model for algorithmic stablecoins introduces two different forms of cryptocurrencies, namely a stablecoin and shares token as ownership of seigniorage. In general, when a coin's price exceeds the intended peg, shares are utilized to expand the supply of coins. In addition to these two cryptocurrencies, stablecoins with a seigniorage-style peg sometimes provide redeemable bonds as well. Zhao et al. (2021) use the cryptocurrency project Basis Cash as an example for the seigniorage share based stablecoin model.

The project has 3 cryptocurrencies, the BAC, which is the stablecoin that is ideally pegged to $1, BAS, which is the Basis Share token, and the BAB, which is the Basis Bond token. There are two phases in the quest to keep the peg, the first one is expansion. As the demand grows for the BAC stablecoin, the price of it goes above $1, therefore to reduce the price, more supply is created. The newly minted tokens are distributed to the 'share' holders, meaning the wallets which own BAS. On the other hand, in the contraction phase, if the BAC drops below the peg, the investors are incentivized to purchases bonds, so BAB tokens with their BAC tokens, effectively removing supply from the market, hence increasing the price. Investors do this, because they get the BAB on a discounted price, and if the price of the BAC goes above $1 again, they can exchange it back with a profit.

However, in the contraction phase, a so called ‘death spiral’ can happen, when all the printed coins are sold. And due to lower prices, investors just keep on selling, and the stablecoin is not able to recover to its peg. Seigniorage based stablecoins usually do not have a strong track record, and end up failing. According to Fu et al. (2022) a rational Ponzi game is essentially, a financial mechanism that uses money raised by new investors to compensate old investors. However, as long as the game can be continuously rolled over, running a Ponzi does not necessarily mean that any player is losing out in any way. When the rollover fails, the ‘death spiral’ begins and the project fails. That is why stablecoins based on the seigniorage model are usually referred to as Ponzi schemes.

3.3.2.3 Partial-collateral

The last category of algorithmic stablecoins are the ones, that are only partially collateralized. In contrast to the previous solution, this model actually has collateral behind the stablecoin, but unlike DAI, it does not need overcollateralization, and hence less capital would be locked up.

To understand the algorithmic model, just like Zhao et al. (2021), I use the Frax Protocol. The DAO has two tokens, FRAX, which is the stablecoin pegged to $1, and FXS, which is the governance token, similar to MKR at the MakerDAO project. The collateral ration is $0 \leq r \leq 1$, that is hourly dynamically set with a step of 0.25 percent in the protocol to regulate the amount of peg the collateral must accept to maintain the value of FRAX. The stablecoin is purely algorithmic when r is 0, and completely collateralized when r is 1. It is basically a hybrid model between the two, that frees up more collateral. If the price of FRAX is above or equal to $1, the collateral ratio decreases by 0.25%. If the stablecoin is below the peg, the collateral ratio increases by one step, every hour. (Frax.finance, 2022)

The stabilization mechanism works with the similar incentivization model through arbitrage. When the stablecoin is above the peg, an arbitrageur could mint a new stablecoin for $1 worth of value, and sell it for a profit. If the token is below the peg, one could buy it in the market on a discount and redeem it for the $1. (Kazemian, 2022)

If the collateral ratio is for instance 0.96, when an investor mints a new stablecoin, they pay 1$ for 1 stablecoin, and the 96% of that dollar goes into the reserve, while the remaining 4% is used to buy FXS that gets burned. (Frax.finance, 2022) On the other hand, when the investor is redeeming the stablecoin, at $r = 1$, they would receive the $1 worth of collateral. But if the collateral ratio is for example $r = 0.92$, they would receive $.92 of the collateral asset and $.08 of FXS token.

3.3.3 Concluding algorithmic stablecoins

As algorithmic stablecoins promise high decentralization and capital efficiency, it is yet to be seen to have a widely adopted, battle tested solution. Thanks to some of their Ponzi scheme-like characteristics, some of the biggest scams happened in the algorithmic stablecoin space, where investors lost most or all of their capitals. (Fu et al. 2022) Such as the story of LUNA token and its algorithmic stablecoin UST, that erased $50 billions of value just in two weeks. (Uhlig, 2022) Or the DeFi protocol, Iron Finance, that had a bank-run-like incident, where a shock sent the value of their tokens into a downward spiral, leaving investors with close to nothing. (Saengchote, 2021)

Zhao et al. (2021) researched the design of an algorithmic stablecoin affecting its volatility. Their conclusion included, that the contracture design is essentially more significant and difficult, this is because it is inherently simpler for cryptocurrencies to decline in value than grow. Therefore, a strong design of contraction should be well-incentivized while taking into account investors' fear and hesitation. Another result from the research states, that the quantity and the frequency of intervention by the algorithm is very crucial for the effective operation of the stablecoin. A flexible and reliable model is preferred.

4. Methodology

I start my research by recreating Jarno and Kołodziejczyk's (2021) research, titled "Does the Design of Stablecoins Impact Their Volatility?". I extend their sample by adding approximately an additional 2 years of data and exclude irrelevant and failed projects and include new relevant data. I also extend their research with a different approach by adding moving windows to the sample, in order to have higher sample sizes and more significant data.

4.1 Data collections

In this research project, the data used is gathered from CoinGecko.com, (2022a) a widely used and highly respected platform for tracking and analyzing cryptocurrency prices and market trends. In this case, the research is specifically examining US dollar-pegged stablecoins, and the top 19 biggest ones in terms of market capitalization are included in the study. It is important to note that all of the selected stablecoins have a market capitalization of at least 30 million dollars, indicating their significant size and influence in the cryptocurrency market. The data used in the research consists of the end of day closing prices of the stablecoins, covering the period from the earliest available data until November 23, 2022. This allows for a detailed examination of the stability and performance of these stablecoins over an extended time frame, providing valuable insights into their potential usefulness. In order to ensure the reliability and validity of the data, certain measures were taken to exclude any stablecoins that may have compromised the integrity of the study. Specifically, stablecoins that had already lost their peg or had an average price that was below the peg by at least 5% in the previous 30 days were excluded from the analysis. This helps to ensure that the results accurately reflect the stability and performance of the selected stablecoins.

The number of daily prices observed for each of the stablecoins varies, with some having around 200 daily price observations and others having over 1800. There are 7 stablecoins that use tokenization, a method in which the value of the stablecoin is derived from the value of a physical asset that is held in a secure, transparent manner. There are 8 stablecoins that use on-chain collateralization, in which the value of the stablecoin is backed by collateral that is held on the blockchain, often in the form of other cryptocurrencies. The remaining 4 stablecoins use algorithmic stabilization, in which the value of the stablecoin is maintained through the use of complex algorithms and smart contracts. By examining the stability and performance of these stablecoins over a prolonged period of time, and taking into account the different stabilization mechanisms they use, it is hoped that valuable insights can be gained into the potential usefulness of stablecoins as a medium of exchange and store of value.

4.2 Statistical models

4.2.1 Statistical models for stablecoins

Once the data is collected, the logarithmic return of the daily prices is calculated in order to analyze the performance of the stablecoins. This is done by taking the natural logarithm of the daily change in price, which is calculated by dividing today's price by yesterday's price. The logarithmic return allows for a more accurate representation of the relative change in price, as it accounts for the compounding effect of percentage changes.

After the logarithmic returns are calculated, the next step is to calculate the standard deviation (SD) of the returns, which is a measure of the dispersion of the data around the mean. In order to accurately calculate the standard deviation, it is necessary to correct for autocorrelation, which is the correlation between the values of a time series at different times. Autocorrelation can affect the standard deviation calculation if it is not accounted for, leading to an overestimation or underestimation of the dispersion of the data.

Once the standard deviation of the returns is calculated, the variance of each stablecoin can be determined by squaring the standard deviation. The variance is a measure of the spread of the data, and is useful for comparing the dispersion of different stablecoins. To obtain the standard deviation in percentage points, we take the square root of the variance and multiply it by 100. This allows us to express the standard deviation in a more easily interpretable format, as it represents the percentage of the mean that the data points typically deviate from.

Once the standard deviation of each stablecoin has been calculated, the next step is to group the stablecoins into different categories based on Bullmann's (2019) taxonomy. This taxonomy divides stablecoins into three main categories: tokenized, on-chain collateralized, and algorithmic. After the stablecoins have been grouped into these categories, the goal is to run an ANOVA (analysis of variance) test to determine the average difference in volatility between the different stablecoin designs. Similarly to Jarno and Kołodziejczyk, (2021) by running an ANOVA test on the volatility of the stablecoins, we can gain insight into which stablecoin design is most effective at maintaining price stability and minimizing volatility.

In order to prepare the data for statistical analysis, it is necessary to test it for normality and homogeneity. Normality refers to the distribution of the data, and it is important to ensure that the data follows a normal distribution in order to use certain statistical tests, such as ANOVA. There are several tests that can be used to assess the normality of the data, including the Shapiro-Wilk test and the Kolmoforov-Sminrov test. Homogeneity, on the other hand, refers to the equality of variance between the groups being compared. It is important to test for homogeneity in order to ensure that the variance of the data is similar between the groups, as this can affect the validity of the statistical test being used. There are several tests that can be used to assess the homogeneity of the data, including the Bartlett test, the Fligner-Killeen test, and the Levene test.

If the requirements for ANOVA are not met, either due to non-normality or non-homogeneity of the data, a nonparametric procedure may be used to identify differences in the distribution of the standard deviation of daily returns between the different stablecoin design groups. One common nonparametric procedure for comparing multiple groups is the Wilcoxon–Mann–Whitney U test, which can be used to determine whether there are significant differences between the medians of two groups. To compare multiple groups, the Pairwise Wilcoxon–Mann–Whitney U test can be used, with Holm correction to adjust the p-values. Another option is the Dunn test, which is a nonparametric multiple comparison test that can be used to identify which groups differ from one another and by how much. To adjust the p-values in the Dunn test, the Benjamini–Hochberg method can be used.

4.2.2 Statistical models for stablecoins monthly observed

One potential extension of the model is to adopt a dynamic approach and analyze the data using time series techniques. Time series analysis involves the modeling and forecasting of data that is collected over a period of time, and is particularly useful for understanding trends and patterns in data that change over time. As De Gooijer and Hyndman (2006) have noted, one of the challenges of using ANOVA with small sample sizes is that it can be difficult to meet the requirements for the test, such as normality and homogeneity of variance. To address this issue, one approach is to use moving windows to slice the data into smaller time periods, such as months. By using moving windows, it is possible to increase the sample size in each group, making it more likely that the requirements for ANOVA will be met.

To implement this approach, the logarithmic returns of each stablecoin can be analyzed by slicing the sample sets into months. It is important to ensure that the sample sizes for each group are sufficient for statistical analysis, so months with less than 10 observations should be excluded. By using this dynamic approach, it is possible to gain a more detailed understanding of the differences in price volatility between the different stablecoin design groups over time, and to identify any changes or trends in the data.

For example, consider a stablecoin like BUSD, which has more than three years of observations. Previously, this stablecoin may have been analyzed as a single sample in the tokenized category. However, by using time series techniques and slicing the data into smaller time periods, such as months, it is possible to increase the sample size significantly and now it accounts for 38 samples in the tokenized category. So instead of the previously counted 19 samples, I have 628 samples. By using time series and having the number of SD samples multiplied, the requirement for ANOVA will be more likely to be fulfilled.

The next step is to redo the statistical analysis of the variance assumption procedure, following all of the steps previously outlined. If the requirements for ANOVA are not met, it may be possible to rely on the central limit theorem (CLT) to assume normality of the data. The CLT states that the distribution of the sample mean approaches a normal distribution as the sample size increases, regardless of the underlying distribution of the data. (Kwak and Kim, 2017) This means that, even if the data is not normally distributed, it is likely to be approximately normal if the sample size is large enough. Therefore, if the sample size is significantly large, it may be appropriate to assume normality of the data based on the CLT, and to focus on testing for homogeneity of variance between the different stablecoin design groups.

If the homogeneity requirement is fulfilled, I do a one-way ANOVA. However, if the homogeneity requirement is violated, meaning that the variance of the data is not equal between the groups a modified version of the ANOVA known as Welch's one-way ANOVA can be used instead. Welch's ANOVA is a robust test that is less sensitive to violations of the homogeneity assumption than the standard one-way ANOVA. If the null hypothesis of the ANOVA test can be rejected, this indicates that there is a statistically significant difference between the means of the different stablecoin design groups. In other words, the stablecoin design groups differ significantly in terms of their price volatility, as measured by the standard deviation of the daily returns.

The next step is to identify which groups differ significantly from one another in terms of their price volatility. To do this, a post-hoc test is typically used, which is a statistical procedure that is used to compare the means of specific groups to one another, in order to identify which groups differ significantly and by how much. One common post-hoc test that can be used in this situation is the Tukey test, which is a parametric test that is based on the assumption of equal variances between the groups. The Tukey test compares the means of all possible pairs of groups, and provides an estimate of the size of the difference between the groups. However, if the homogeneity assumption has been violated, a nonparametric post-hoc test may be more appropriate. What I use in this case is the Games-Howell test, which is a nonparametric multiple comparison test that can be used to identify which groups differ significantly from one another, even when the assumption of equal variances is not met. (Lee and Lee, 2018)

5. Results

5.1 Results for stablecoins

As a first step in the analysis, the individual volatility of each selected stablecoin was calculated based on the daily return data. The results of this calculation are presented in Table 1, which shows the standard deviation of the daily returns for each stablecoin. As the table illustrates, there is a high degree of dispersion in the values, with the lowest volatility being 0.33% for a stablecoin that had only 7 months of observations, and the highest being 6.54%. These values provide a clear indication of the differences in price volatility between the different stablecoins, and highlight the importance of understanding the factors that influence the stability of these digital assets.

Table 1. Ranking of the 20 stablecoins in the research based on the standard deviation of daily returns (in percentage points)

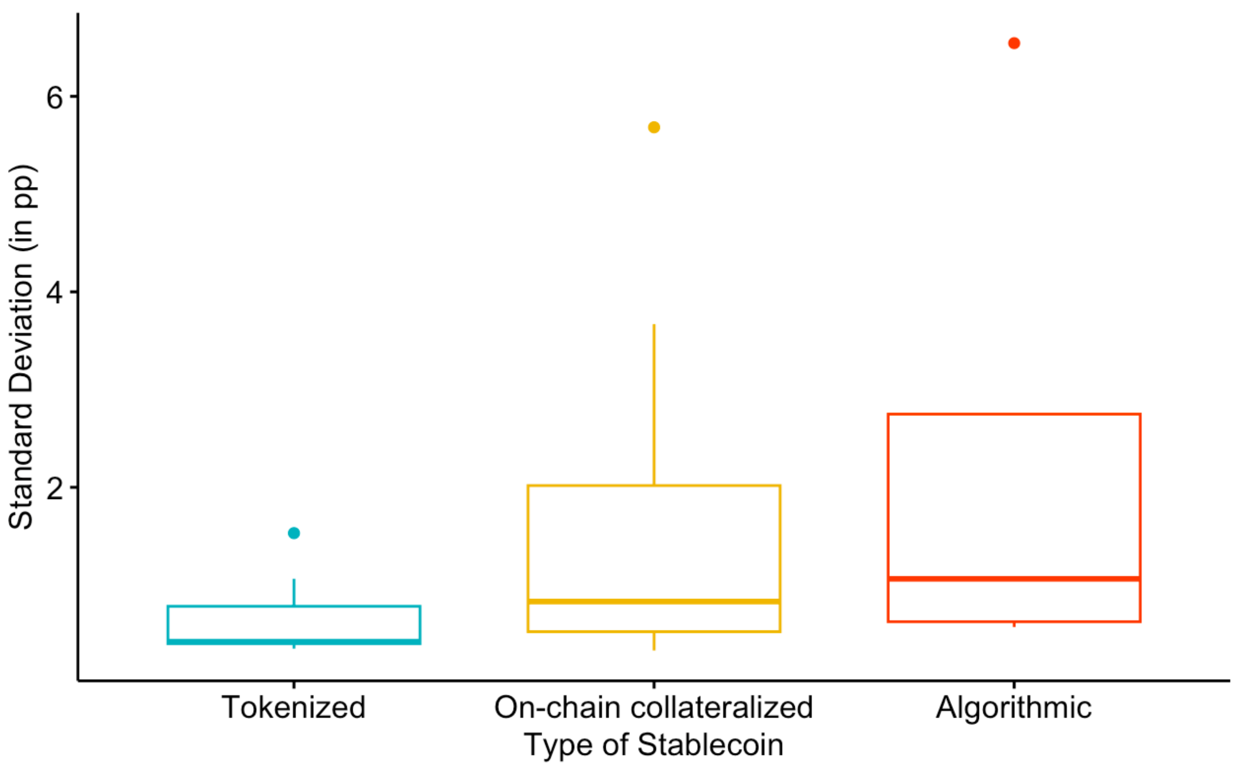
Name	Volatility in p.p.	Type
USDD	0.330795151	On-chain collateralized
USDC	0.350202389	Tokenized
USDK	0.391339994	Tokenized
MIM	0.398682056	On-chain collateralized
BUSD	0.409245418	Tokenized
USDP	0.421203206	Tokenized
TUSD	0.500771609	Tokenized
DAI	0.565041064	On-chain collateralized
CUSD	0.570707049	Algorithmic
FRAX	0.643318752	Algorithmic
LUSD	0.695857767	On-chain collateralized
OUSD	0.96719369	On-chain collateralized
USDT	1.06443398	Tokenized
MIMATIC	1.467970143	On-chain collateralized
FEI	1.483970874	Algorithmic
GUSD	1.531353887	Tokenized
SUSD	3.668546017	On-chain collateralized
ALUSD	5.683267355	On-chain collateralized
BEAN	6.544234124	Algorithmic

Source: Author’s own calculation based on data from CoinGecko.com

Once the individual volatility of each stablecoin had been calculated, it was possible to plot the results on a boxplot in order to visualize the distribution of the data. The boxplot in Figure 1 displays the standard deviation of the daily returns for the three categories of stablecoins, which include tokenized, on-chain collateralized, and algorithmic.

From the plot, it is clear that the groups with the highest outliers, or extreme values, are the on-chain collateralized and algorithmic stablecoins. The boxplot also provides a general overview of the distribution of the data, with the middle line representing the median, and the upper and lower lines representing the upper and lower quartiles, respectively. From this plot, it is possible to see that the tokenized stablecoins generally have the lowest volatility, with fewer extreme values and a more tightly clustered distribution. Overall, the boxplot in Figure 1 provides a clear and visual representation of the differences in price volatility between the different stablecoin design groups.

Figure 1. Autocorrelation estimates for stablecoins



Source: Author's own calculation based on data from CoinGecko.com

Table 2. Results of tests for normality of residuals and homogeneity of variances.

Null hypothesis	Normality of Residuals		Homogeneity of Variances		
Test	Shapiro-Wilk normality test	Kolmogorov-Smirnov test	Bartlett test	Fligner-Killeen test	Levene test
Value of the test statistic	0.63867	0.6296	11.637	3.2887	1.1842
df	-	-	2	2	2
p-value	1.126E-05***	8.052E-08***	0.00297***	0.1931	0.3314

Source: Author's own calculation based on data from CoinGecko.com

The results of the statistical analysis indicate that the null hypothesis of the samples coming from a normally distributed population is rejected, as shown by the results of the normality tests. This means that the data does not meet the assumption of normality, which is a requirement for ANOVA. In addition, the homogeneity null hypothesis, which states that the multiple samples are from populations with equal variance, is supported by the results of two out of the three tests that were conducted. However, the third test did not support the assumption of homogeneity, indicating that the variance of the data is not equal between the different stablecoin design groups.

Table 3. Result of the Kruskal-Wallis test

Test	Kruskal-Wallis test
Value of the test statistic	2.8945
df	2
p-value	0.2352

Source: Author's own calculation based on data from CoinGecko.com

Since the data did not meet the assumption of normality, it was not possible to use ANOVA to compare the differences in price volatility between the different stablecoin design groups. Instead, a nonparametric statistical test, such as the Kruskal-Wallis test, was used to determine whether the samples came from the same distribution. The Kruskal-Wallis test is a widely used nonparametric technique that is used to compare the means of multiple groups when the assumptions of normality and homogeneity are not met. It is based on the ranks of the data, rather than the actual values, and is therefore less sensitive to violations of the assumptions of parametric tests.

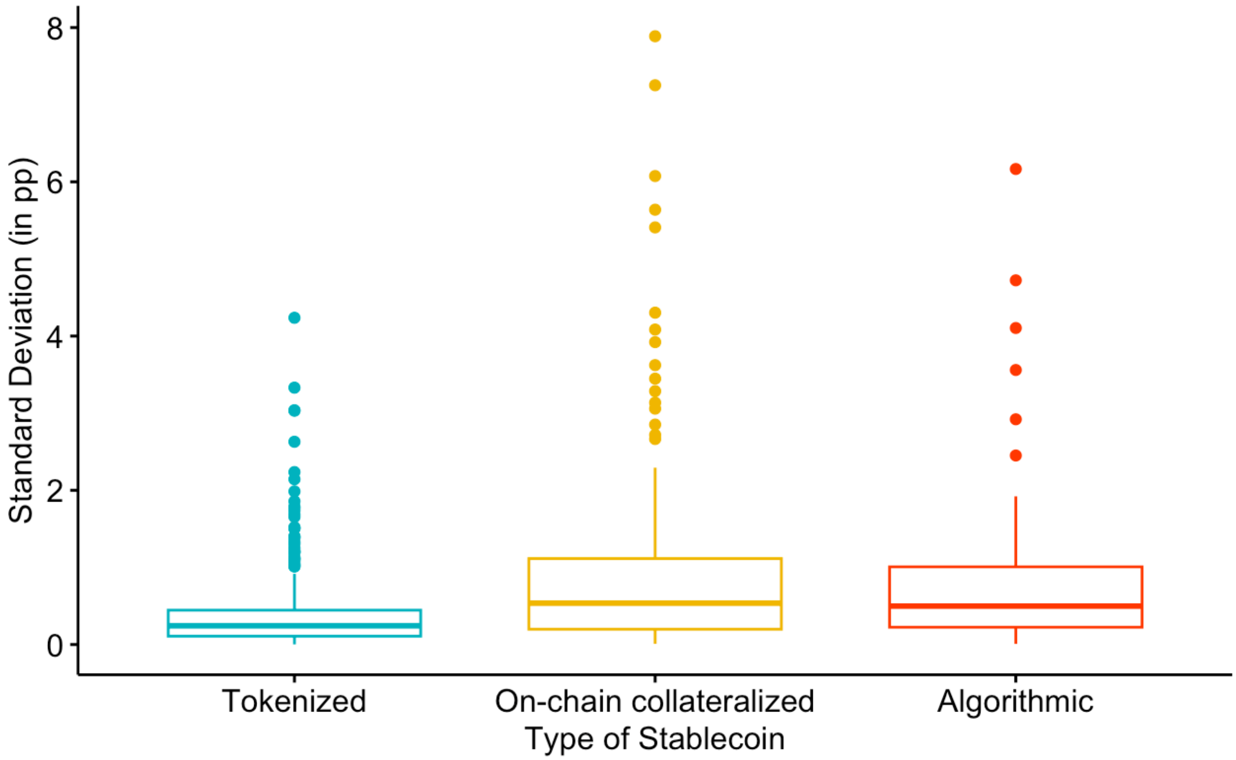
In this case, the p-value obtained from the Kruskal-Wallis test was not below the 5% threshold, which means that the null hypothesis could not be rejected. This indicates that there was no statistically significant evidence from the data that any of the three stablecoin design categories is more volatile than the others. As a result, it was not possible to use the nonparametric post-hoc tests, such as the Pairwise Wilcoxon-Mann-Whitney U test or the Dunn test, which were originally planned to identify which stablecoin design category is more volatile.

5.2 Results for stablecoins monthly observed

To address the statistical limitations of the initial analysis, the moving window approach was introduced, in order to increase the sample size and improve the statistical power of the analysis. The moving window approach involves slicing the stablecoin data into smaller time periods, such as months, and calculating the standard deviation of the daily returns for each time period. This allows for a larger number of samples to be included in the analysis, which may be more likely to meet the assumptions of statistical tests such as ANOVA.

Figure 2 displays the standard deviation of the daily returns for each month that has at least 10 observations for each stablecoin design category. From the plot, it is once again clear that the on-chain collateralized and algorithmic stablecoins tend to have higher outliers, or extreme values, compared to the tokenized stablecoins. In addition, the average volatility appears to be lower for the tokenized stablecoins, as indicated by the smaller spread of the data and the lower median value. These findings are consistent with the results of the initial analysis, and suggest that the tokenized stablecoins may be more effective at maintaining price stability and minimizing volatility compared to the other stablecoin design categories.

Figure 2. Autocorrelation estimates for stablecoins monthly observed



Source: Author's own calculation based on data from CoinGecko.com

The results of the statistical analysis indicate that both the normality and homogeneity assumptions are violated, as indicated by the p-values obtained from the tests that were conducted. However, the introduction of the moving window approach significantly increased the sample size from 19 to 628, which may allow for the assumption of normality to be applied through the use of the central limit theorem (CLT).

Table 4. Results of tests for normality of residuals and homogeneity of variances for stablecoins monthly observed

Null hypothesis	**Normality of Residuals**		**Homogeneity of Variances**		
Test	Shapiro-Wilk normality test	Kolmogorov-Smirnov test	Bartlett test	Fligner-Killeen test	Levene test
Value of the test statistic	0.6074	0.5008	197.03	74.499	19.629
df	-	-	2	2	2
p-value	≈ 0***	≈ 0***	≈ 0***	≈ 0***	≈ 0***

Source: Author's own calculation based on data from CoinGecko.com

Since the homogeneity assumption was not fulfilled, it was not possible to use the traditional one-way ANOVA test to compare the differences in price volatility between the different stablecoin design groups. Instead, the Welch's one-way ANOVA test, which is a modified version of ANOVA that is specifically designed to handle data with unequal variances, was used.

The null hypothesis of the Welch's one-way ANOVA test is that there is no difference among the group means, which means that the stablecoin design categories do not differ in terms of their price volatility. This null hypothesis was rejected based on the low p-value obtained from the test, which indicates that there is statistically significant evidence of a difference in the means of the stablecoin design groups.

Table 5. Result of the Welch's one-way ANOVA test for stablecoins monthly observed

Test	**Welch's one-way ANOVA**
Value of the test statistic	21.389
df1	2
df2	162.64
p-value	5.6E-09***

Source: Author's own calculation based on data from CoinGecko.com

As a last step I use the Games-Howell test to identify which groups have statistically significant difference in terms of volatility. The results of the Games-Howell test indicated that the tokenized stablecoins were

0.54% more stable, on average, than the on-chain collateralized stablecoins. In addition, the tokenized stablecoins were found to have 0.43% less volatility, on average, than the algorithmic stablecoins. However, the Games-Howell test did not find any statistically significant differences in volatility between the on-chain collateralized and algorithmic stablecoins. Overall, these findings suggest that the tokenized stablecoins are more effective at maintaining price stability and minimizing volatility compared to the other stablecoin design categories.

Table 6. Result of the Games-Howell test for stablecoins monthly observed

Games-Howell test			
Category pairs		p-value	Estimate
Tokenized	On-chain collateralized	6.1E-08***	0.549
Tokenized	Algorithmic	0.003***	0.432
On-chain collateralized	Algorithmic	0.722	-0.118

Source: Author's own calculation based on data from CoinGecko.com

6. Conclusion

The goal of a stablecoin is to provide a stable value with lower price volatility in the respected currency of reference. In my study I analyzed the top stablecoins by market capitalization to find out which stabilization mechanism is the most efficient to reach price stability. I compared the standard deviation of daily returns using a variety of non-parametric statistical methods. My research has shown that different stablecoin kinds are not equally volatile.

The result of my study clearly shows that tokenized stablecoins are less volatile than on-chain collateralized and algorithmic stablecoins. Yet there is no statistically significant difference between the latter two category. In the reference research, the result was only significant between tokenized and on-chain collateralized, with tokenized being more stable as well. This could be partially because during the 2 additional years of data, the market matured, and I was able to have more algorithmic stablecoins in my sample. Also, since I applied time series to my data, I was able to have much more samples.

An important insight can be concluded by comparing parts of the reference research and mine. In general, the individual stablecoin volatilities were way higher on average and the max values as well. In Jarno and Kołodziejczyk's (2021) research the maximum volatility observed for stablecoins was 16.01%, while in my research this number was significantly less, 6.54% to be exact. Comparing the reference research conducted 2 years ago with mine, out of the 20 samples, the 12 most volatile stablecoins are not in my samples. This means they do not fulfill the criteria for my study – having $30 million in market capitalization and/or the average price not deviating from the peg in the last month more than 5% – in fact, none of them can be found on CoinGecko's stablecoin list. (CoinGecko, 2022a) This shows that as the industry matures, the high volatility stablecoins have less value in the market and they die out. So, in general, the higher the volatility of a stablecoin, the less likely that it will withstand the test of time. Hence for long term usage, stablecoins using tokenized stabilizing mechanism are better in terms of low volatility and likelihood to survive.

Tokenized stablecoins in general perform better in the long-term, because they are backed by usually the same asset as they represent. There is no volatility of the reserves and therefore investors could be sure, that they will be able to redeem the exact amount.

However, there is a counterparty risk present with tokenized stablecoin, that could be mitigated with decentralized stablecoins. As described in the literature review part, the biggest and most used tokenized stablecoins, are subject to scandals and lies about the one-to-one backing of their stablecoin. Creditworthiness is in question for some of the tokenized stablecoin and they are also subject to high level of verification cost. If centralized entities would be subject to rigorous regulations that forces them to have reliable periodic audits, their transparency would greatly develop, making the whole ecosystem safer.

On the other hand, on-chain collateralized decentralized stablecoin, like DAI, has a fully transparent reserve, that can be audited by anyone on the blockchain. Also, the decentralization and transparency ethos stay close to the blockchain ecosystem, creating additional value to this possibility, even if there is a higher volatility present, that could be partially attributed to the underlying assets' volatility.

Algorithmic stablecoins also promise the benefit of decentralization and no counterparty risk towards a centralized entity, with even lower or no capital being locked up. However, I believe algorithmic stablecoins are the most dangerous – even if according to the result they are less volatile compared to tokenized stablecoins than on-chain collateralized ones are. Comparing my list with the reference study's list, none of the algorithmic stablecoins survived the 2 years. This could be attributed that no algorithmic stablecoin prooved yet that they could withstand an endogenous death spiral, even if some were able to survive exogenous shocks. Also, since they have the lowest reputation in terms of long-term survival, users and investors are more likely to leave the sinking ship if the shadow of a death spiral is on the horizon, therefore accelerating the loop.

This study's subject is open to additional research. An interesting study would be if this result is replicable through time. Some of the stablecoins were fairly new and not battle tested compared to others. Just like I was able to find additional conclusion through comparing the reference study with mine, a replica at a later date could offer more insights. Another interesting outcome could be if the samples were filtered or weighted by either the market capitalization of the stablecoin or the daily volume. This could disregard less used or smaller stablecoins and could focus the findings on the most commonly transacted stablecoins inside each category. Since the only big one from on-chain collateralized stablecoins is DAI, the volatility between the tokenized and their category might be lower or non-significant. Different research could focus on the correlation between the volatility of the stablecoin market and the wider cryptoasset market. Also, to see if there is correlation between price volatility and market capitalization. A hypothesis could be that stablecoins with higher capitalization would have lower volatility, since they are more commonly used, potentially have more arbitrageurs and tend to have a longer history. Future research could also concentrate on the findings from the standpoint of risk management. The foundation for that has already been laid in the works by Baur and Hoang (2020) and Wang et al. (2020).

7. References

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