Analyzing Key Events & Causal Factors Impacting Cryptocurrency Lending Rates

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An Undergraduate Research Thesis Submitted in fulfillment of the requirements for the:

WHARTON RESEARCH SCHOLARS PROGRAM

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MAY 2023

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Abstract

Digital asset markets reached peak valuations of more than 3 trillion in 2021. However, the strong growth in crypto asset value in 2021 was met with turmoil and value destruction in subsequent years with a series of bankruptcies of cryptocurrency-related businesses in a period dubbed the "crypto winter." This study considers the impacts of the events of the crypto winter on decentralized lending protocols, specifically using the Aave protocol as a case study. Looking at data centered on interest rates, available liquidity, and the total value of invested funds on the Aave protocol, this study seeks to better understand how investors' perceptions of the safety of borrowing cryptocurrencies have changed after the events of the crypto winter. The study will aim to look at predicting spreads between variable and stable interest rates with an OLS regression and analyze the impacts of the crypto winter using historical Aave lending data.

Keywords: Cryptocurrency, Aave, DeFi Lending, DeFi Protocols, Crypto Winter, Stable Borrow Rate, Variable Borrow Rate, Lending Pool, Total Value Locked, Available Liquidity

Disciplines: Finance, Economics, Statistics

Introduction

Overview of Decentralized Finance

With the intention to address the inherent limitations and inequalities of legacy financial institutions, decentralized finance (DeFi) was introduced as a means for a new financial ecosystem where products and transactions could exist in a borderless manner. From the invention of the Bitcoin blockchain by Satoshi Nakamoto in 2008 and the subsequent Ethereum blockchain in 2013 by Vitalik Buterin, Ethereum-based 'smart contracts' would become the foundation of DeFi and allow for financial transactions without human intermediaries. Offering investors the opportunity to lend, exchange, and tokenize cryptocurrencies, DeFi became recognized as a technology of inclusion where transactions could be openly facilitated without the need for prior clearances or regulatory bodies. With growing investor interest, DeFi reached a peak of 45 billion USD in total value locked (TVL) in 2021 across Aave, Compound, and Maker, the most prominent lending protocols that comprise 90% of the DeFi ecosystem. Valuations for cryptocurrencies also soared in 2021, with Bitcoin reaching over a trillion dollars in market capitalization while Ethereum reached half a trillion dollars in market capitalization. Given the outstanding growth within crypto markets, President Biden issued Executive Order 14067 in November 2021, noting that the entire non-state-issued digital asset market had reached a market capitalization of $3 trillion and expressing the need for a greater understanding of how crypto assets can coexist in traditional financial markets.

However, the strong growth in crypto asset value in 2021 was met with turmoil and value destruction throughout 2022. Dubbed the "crypto winter," this period saw a loss of 2 trillion USD in cryptocurrency market value. At the same time, the TVL in DeFi protocols declined to nearly 14 billion in February 2023, losing more than 50% of its value in just a year and a half.

Cornerstone events that led to the declining value of cryptocurrencies and crypto markets include the crash of Terra's UST stablecoin, the bankruptcy filing of multibillion-dollar cryptocurrency exchange FTX, the fall of cryptocurrency lending platforms Celsius Network, Genesis and BlockFi, and the insolvency of cryptocurrency hedge fund Three Arrows Capital among other events in 2022. These events underpin the need for an understanding of how investors reacted to the events of the crypto winter and how they can anticipate and protect against the risks associated with cryptocurrency investments moving forward.

Research Question and Significance

This paper delves deeply into the cryptocurrency lending ecosystem and investor reactions to the events that unfolded in the crypto winter. A study of cryptocurrency lending returns on Aave, the largest and most prominent DeFi lending protocol, will be conducted to understand how investors' risk appetite for DeFi investments changed with greater market instability. The study will investigate a comparison of the amount of cryptocurrency borrowed and the spreads of interest rates between stable and variable rates. The research question explored in this paper is two-fold. The first question is, how do investors view and protect against risks by borrowing cryptocurrencies during market instability? This question will be explored by understanding a borrower's preference for paying a premium and taking out a loan with a guaranteed, stable rate compared to a variable rate during periods of volatility in cryptocurrency markets. The second question is how do DeFi lending protocols protect the liquidity of their assets during unstable market conditions, and what are the lasting impacts of changes in available liquidity that resulted from the crypto winter?

A better understanding of the topic will add to existing research on DeFi lending and investing risks. Many previous academic studies have attempted to create models to quantify liquidity risks within lending protocols, and this study will complement the academic research by looking at DeFi investor's reactions to the events of the crypto winter in real-time. The study will aim to look at patterns of how lending protocols protect against liquidity risks with their interest rate models while also considering investors' preference for borrowing cryptocurrencies during a period of great instability in cryptocurrency markets.

There is currently little research in the DeFi space related to the growth and development of Aave since its introduction to DeFi markets in 2020. This study will document the dramatic growth and increase in TVL that Aave has experienced while also noting how the events of the crypto winter impacted the platform. This study will therefore aim to educate future investors on the key differences between DeFi lending/borrowing and traditional loans within centralized financial institutions, while providing an outlook on DeFi lending based on historic Aave data. The study will also add to the existing literature on the specifics of lending using the Aave protocol.

The paper will be structured into a section focusing on the review of current literature that will establish the foundation for how DeFi fits into the broader cryptocurrency market landscape, the importance of Aave as a DeFi protocol, how cryptocurrency is borrowed and loaned out on different platforms, how the interest rates are calculated, and a more detailed outline of recent events in cryptocurrency markets that motivate the study. Subsequent sections will then go over the data collection process and methodology while ending with a discussion of limitations and potential interesting future studies.

Literature Review

Decentralized Finance Foundations and Principles

The Ethereum blockchain is the birthplace of DeFi. The invention of smart contracts enabled primitive financial transactions to be facilitated through executable code on the blockchain, providing a distributed public database of all transactions. Harvey and Santoro (2020) consider the origins of DeFi and similarities/differences to traditional financial markets. The study concludes that fintech initiatives that embrace current banking infrastructures will likely be fleeting. At the same time, those that rely on decentralized methods have a chance to define the future of finance.

Within the DeFi-focused research field, studies on DeFi and its developments throughout the past few years continue to be fragmented. In June 2022, Meyer, Welpe, and Sandner published a literature review focusing on integrating 83 peer-reviewed DeFi-related publications for an overview of the available research. Their work focuses on narrowing the scope of the definition of DeFi to refer to finance protocols built with smart contracts in a trustless and permissionless public blockchain. It provides for a review of micro, macro, and regulatory implications of current research related to DeFi.

Fisch et al. (2019) further considers the promises and values that serve as the foundation for the decentralization of finance. Through evaluating challenges and potential limitations, the study speaks to the benefits of open access and the lack of a controlling party to facilitate combinatorial innovation, where new financial technologies can serve as the building blocks for future innovations. In addition to creating open networks for innovative products, decentralized finance also can decrease the disproportionate amount of market power and profits accumulated by legacy financial institutions. Fisch et al. defend the ability of decentralized networks to reduce

transaction costs and create network effects as no single entity will be able to gain sufficient monopoly power, allowing for greater transaction possibilities. Other key principles mentioned within the study include the benefits of transparency, given transactions are recorded on public blockchain-based ledgers with open-source code, and borderlessness as decentralized transactions are not tied to a specific geographic location or fiat currency.

Lending in Decentralized Finance Protocols

Specifically looking at lending within DeFi protocols, we can understand several differences between traditional financial markets. With a traditional bank loan, there is a centralized system in place where a lender deposits funds into a bank, and the bank can lend out those funds in exchange for a claim on the borrower. The lenders will then safeguard their funds through margin requirements and rely on regulators to monitor counterparty risks, such as defaults on contractual lending agreements (Heimbach et al., 2023). Margin requirements and regulatory oversight aim to reduce the likelihood of defaults and instability in financial markets.

However, risks of lending crypto assets include counterparty risks between borrowers and lenders, price volatility, and monetary instability. Since the system is decentralized, no mechanisms exist to measure the borrower's riskiness with soft information such as a credit rating. DeFi lending protocols account for these risks with the requirement of over-collateralization for borrowers of cryptocurrencies, removing the need for a central clearing house in lending transactions. Many DeFi lending protocols will vary the loan-to-value ratio for collateral on crypto loans by currency and structure the collateral to dynamically measure any borrower's default risk. Bertomeu et al. (2022) consider these differences between crypto and traditional loans in a study measuring DeFi risk. The study notes how with cryptocurrency loans,

coins must serve as collateral. In contrast, in many traditional loans, a physical asset such as real estate may be the underlying collateral. Bertomeu et al. then discuss this as a potential limitation of lending in cryptocurrency as the primary purpose of crypto loans will be leveraged investment or arbitrages in other currencies.

DeFi protocols may operate through Peer-to-Peer (P2P) lending mechanisms or lending pools where funds are pooled together, and interest rates are derived systematically given the supply and demand for the type of currency. DeFi lending structures, therefore, eliminate the intermediaries that provide a prior clearance for transactions and a market for loanable funds (Gudgeon et al., 2020).

Overall, the motives of lending protocols are two-fold: offering rates that are competitive for borrowers while providing low risks for lenders. Though these protocols function autonomously, they are still governed by a decentralized autonomous organization (DAO) that focuses on making decisions in a bottom-up approach. These DAOs are token holders that collectively cast votes on any updates to their respective protocol, with voting power often decided based on a distributed number of tokens held. For example, AAVE DAO comprises the native token on the Aave protocol titled AAVE, while Compound DAO comprises the protocol's separate token entitled COMP. Heimbach et al. consider the power of DAOs in initiating changes and updates to DeFi protocols and note that one of the most important decisions that DAOs are involved with is defining and changing the risk parameters of each protocol and their respective assets. Fritsch et al. conducted an empirical study analyzing how voting power is distributed among DAOs. Though the focus on governance among DeFi protocols should emphasize the equal distribution of governance tokens among active users, Fritsch et al. find that the voting

power is generally very concentrated when looking at the spread of DAO owners on the three most prominent lending protocols.

Many previous studies have focused on different elements of DeFi loans to assess inherent risks and returns. Saengchote (2020) examined investor sentiments on liquidation risk by examining the relation between daily loan amounts and stable coin price volatility. Perez et al. conducted an empirical study of liquidations to find that excessive borrowing can lead to higher liquidation risk among positions. A small percentage drop in price can trigger high aggregate values of liquidated loans. Many other studies, such as Gudgeon et al., also attempt to create a stress-testing framework for systematic insolvency risk centered on different currencies across several lending protocols.

Lending Pools and Interest Rate Models

Looking closely at the concept of lending pools, DeFi protocols allow anyone to become a lender by depositing funds into open pools of cryptocurrencies. Anyone can also borrow funds if the amount of assets they deposited exceeds their borrowed funds. These structures allow for over-collateralization margins that protect against fluctuations in the value of currencies, as any under-collateralized position risks liquidation. Bertomeu et al. sought to develop a framework to assess the position of a pool relative to lenders and borrowers while looking at the risk of liquidation for borrowers and the risk of collateral loss for lenders. The paper claims that DeFi deposits are perceived as low-risk products, given the general collateral and liquidation requirements on cryptocurrency loans. In contrast, realistically, deposits face exposure to significant declines in coin prices.

Interest rate models between crypto loans and traditional loans also greatly vary. Central banks play an integral role in setting rates in conventional financial markets, and then those rates become key to managing credit within the economy. Comparatively, interest rates within decentralized financial markets are usually determined by the specific protocol founders and then updated through DAO votes (Gudeon et al., 2020). Heimbach et al. consider general characteristics of interest rate models with DeFi, explicitly looking at Aave and Compound. Their study notes that interest payments are made periodically on lending protocols, but the loans are generally for an indefinite period. The actual rate offered also depends on a model that factors in the asset borrowed and the utilization, which compares the total outstanding loans to the total amount deposited on a certain protocol. Gundgeon et al. also presents a study that analyzes the methodologies used to set interest rates across three main DeFi protocols. The study groups interest rate models into linear and non-linear rates. Overall, interest rates among DeFi protocols aim to offer borrowers flexibility while protecting liquidity within the platform.

Aave Protocol

Since this study will mainly focus on the Aave protocol, it is worth noting previous studies that specifically focused on the protocol and their findings. Aave was first made available as a DeFi protocol in January 2020 and has grown to more than $4.5 billion in total value locked as of February 2023. Sun et al. present a study measuring liquidity risks on lending protocols, using Aave as their case study. The study finds that increased liquidity can negatively impact the growth of AAVE, the platform's DAO currency.

Furthermore, Sun et al. find that Aave can suffer from illiquidity when the available liquidity on the platform reaches a certain threshold. Heimbach et al. also conducted a study

focused on Aave and Compound, looking at how the lending landscape changed with the switch from proof-of-work to proof-of-stake on the Ethereum blockchain, making a note of Aave's unique interest rate offering with a stable borrow rate and variable borrow rate. Lehar et al. also conducted a study with liquidation data from Compound and Aave, considering the number of loans on each platform that reached a health factor of below 1 in each period. The study reveals the systematic fragility within decentralized markets as they note clear price impacts of collateral asset sales for a specific type of currency on each of the two platforms. Overall, a handful of studies analyze liquidity positions, interest rate models, and liquidation data on Aave.

Recent Events

Many studies have also considered the events of 2022-2023, and their larger significance for the future of crypto markets. Arner et al. (2023) give an overview of each of the events within the crypto winter to then argue for regulation systems that would aid in the supervision and coexistence of crypto markets with traditional finance. Looking specifically at FTX, Arner et al. compare the cryptocurrency exchanges' collapse to the fall of Enron and Lehman Brothers, citing how the liquidity crisis that FTX faced was reminiscent of the solvency crisis many banks faced in the 2008 financial crisis. The study notes how FTX was valued at 32 billion within the company's January 2021 funding round, with records of exponential revenue growth from 90 million in 2020 to over one billion in 2021, adding to the magnitude of the firm's bankruptcy. Beyond FTX, the study also looks chronologically at the various bankruptcy filings throughout 2022 to 2023, including a variety of cryptocurrency exchanges, lending platforms, and ventures. capital firms, and hedge funds.

Overall, Arner et al. note that there is widespread institutional instability in the crypto industry, regardless of business model, and that there is a clear pattern of centralized crypto intermediaries reaching the point of bankruptcy due to mismanagement, fraud, and lack of transparency, among other aspects. Trautman (2023) also conducts a deeper study into FTX, considering the speed at which the company faced insolvency and the collateral damage for other investors within the cryptocurrency community.

Data and Methods

Data Collection Overview

To analyze the impacts of events in 2022 on lending rates within DeFi protocols, lending data from Aave will be collected. Aave holds the highest TVL among lending protocols, with over 5 billion invested within the platform in February 2023. Calling the function 'getReserveData' through Python scripts allows for the following spread of data points from the Aave protocol: availableLiquidity, totalStableDebt, totalVariableDebt, liquidityRate, variableBorrowRate, stableBorrowRate, averageStable BorrowRate, liquidityIndex, variableBorrowIndex, lastUpdateTimestamp. These values are taken directly from the blockchain ledger when getReserveData is called and are associated with the assets on the Aave protocol.

For this study, the data acquired spans from 12/2/2020 to 2/23/2023, allowing for a thorough understanding of how borrowing rates changed on Aave since the protocol first became available. Within the study, three main cryptocurrencies will be analyzed, including USD Coin (USDC), Wrapped Bitcoin (WBTC), and Wrapped Ethereum (WETH). USD Coin is a popular stablecoin that holds a substantial TVL on Aave. Bitcoin, Ethereum, and USD Coin are three

currencies holding a considerable market share of available cryptocurrencies, with Bitcoin having a 47% market share and Ethereum holding a 19% market share as of February 2023.

Looking at USDC, WETH, and WBTC, a complete picture of how the value of the currency and its relative interest rate has changed over time can be understood as each of these currencies had already been trading on crypto markets when Aave was first introduced. These currencies will also enable a broader outlook on how the events that unfolded in the crypto winter impacted lending rates as the study considers widely traded popular coins on the DeFi lending protocol with the highest amount of value invested.

Key Metrics within the Aave Dataset

This study will specifically focus on the following variables within the getReserveData dataset: USD price, date, available liquidity, total stable debt, total variable debt, variable borrow rate, and stable borrow rate. The currency price will measure the coin's market value on the day of the transaction. Available liquidity will calculate the current amount of a currency available to borrow within existing lending pool. Available liquidity will then be factored into the Aave utilization rate, characterized as total outstanding loans over total deposits in lending pools.

Aave stable interest rates are defined by the following model

$$R_s^t = \begin{cases} M_r + \frac{U}{U_{optimal}} R_{slope1}, \text{ if } U \leq U_{optimal} \\ M_r + R_{slope1} + \frac{U - U_{optimal}}{1 - U_{optimal}} R_{slope2}, \text{ if } U > U_{optimal} \end{cases}$$

With:
- M_r the average market lending rate.
- R_{slope1} the interest rate slope below $U_{optimal}$, increases the rate as U increases.
- R_{slope2} the interest rate slope beyond $U_{optimal}$, increases as the difference between U and $U_{optimal}$ increases.
- U is the utilization rate.

While the variable borrow rate is determined through a similar model:

- Base variable borrow rate R_{v_0}
- Interest rate slope below optimal utilisation R_{slope1}
- Interest rate slope beyond optimal utilisation R_{slope2}

The current variable borrow rate is:

$$R_v = \begin{cases} R_{v_0} + \frac{U}{U_{optimal}} R_{slope1}, \text{ if } U \leq U_{optimal} \\ R_{v_0} + R_{slope1} + \frac{U - U_{optimal}}{1 - U_{optimal}} R_{slope2}, \text{ if } U > U_{optimal} \end{cases}$$

These models consider the utilization of a specific currency and then factor in an optimal utilization rate to determine whether the interest rate should encourage lending or slow the lending rate, given the amount of available liquidity in the lending pool.

Methodology Overview

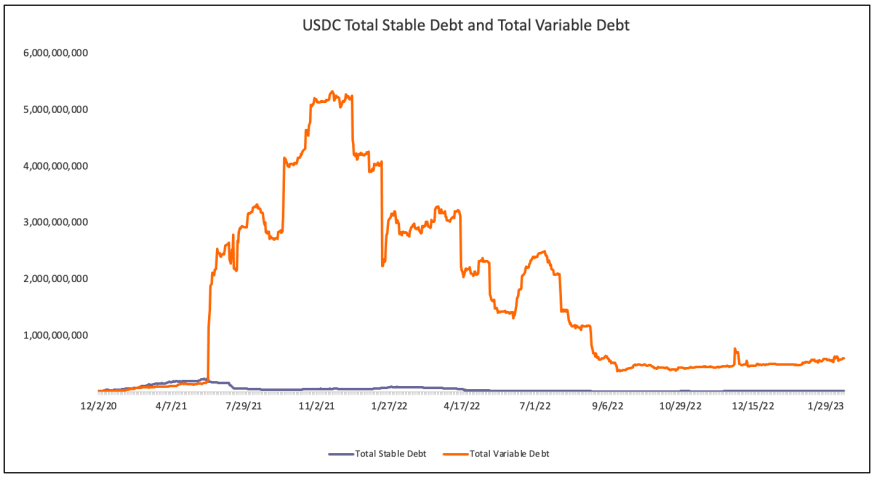
To analyze the relationships between preference for stable or variable interest rates and the relation available liquidity and price volatility, an Ordinary Least Squares (OLS) regression model will be applied. This model is commonly used to determine a causal relationship between a dependent variable and a series of independent quantitative variables and has been shown to be relevant in many empirical studies focused on cryptocurrency returns.

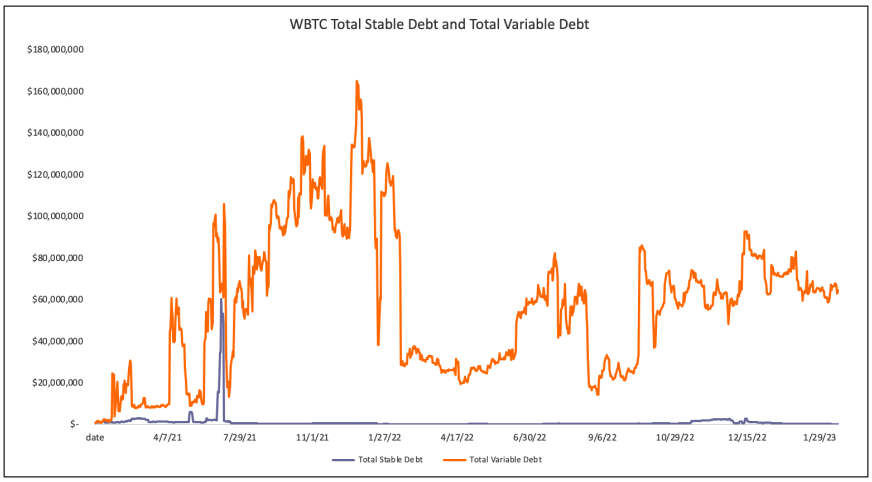
Specifically, this study will reference the OLS regression in a similar model to the one applied by Hafner, Schierreck, and Buxmann (2020) in a study that analyzed the relationship between average bid and ask volumes of various cryptocurrencies to the best bid or ask price. The study considered volumes as their independent variable and applied three models focusing on logarithmic, square-root, and linear regressions to determine the relationship between price and volume. The study concluded that the linear OLS regression served as the best fit compared to a logarithmic or square-root model when analyzing sets of independent quantitative variables to pricing returns.

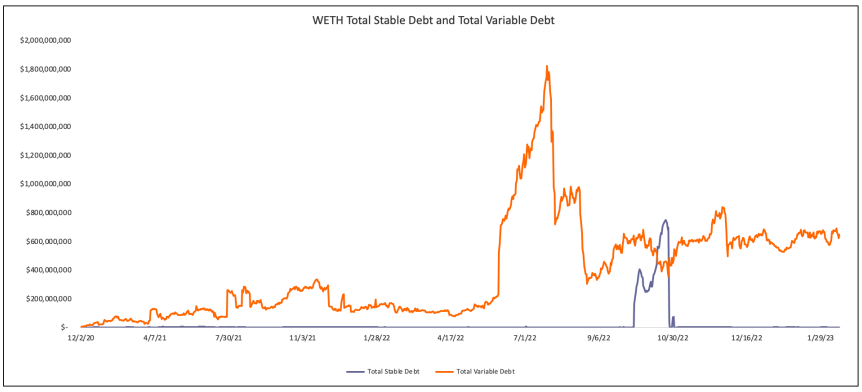
Results and Findings

Data Overview

Figure One: Comparison of Total Stable Debt and Total Variable Debt

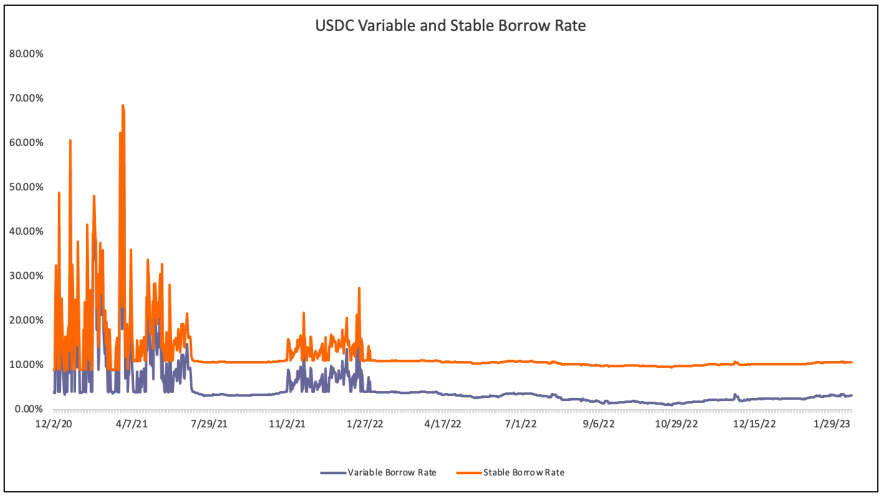


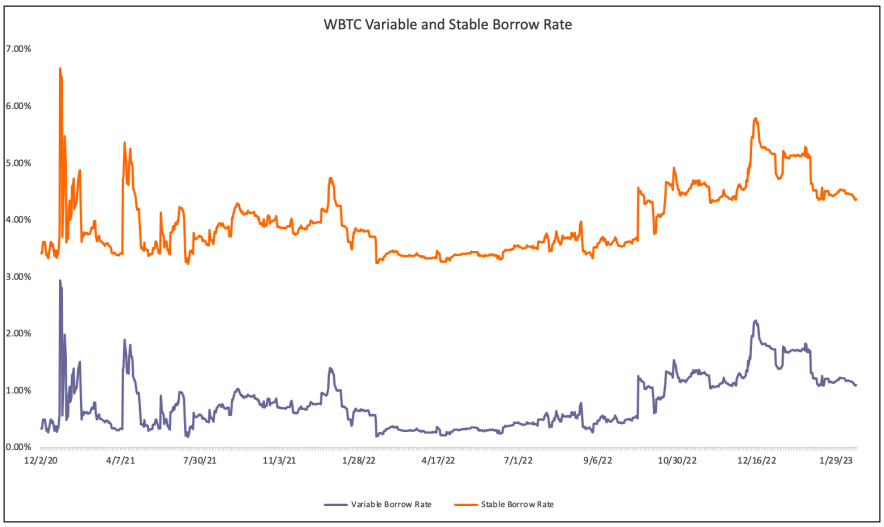


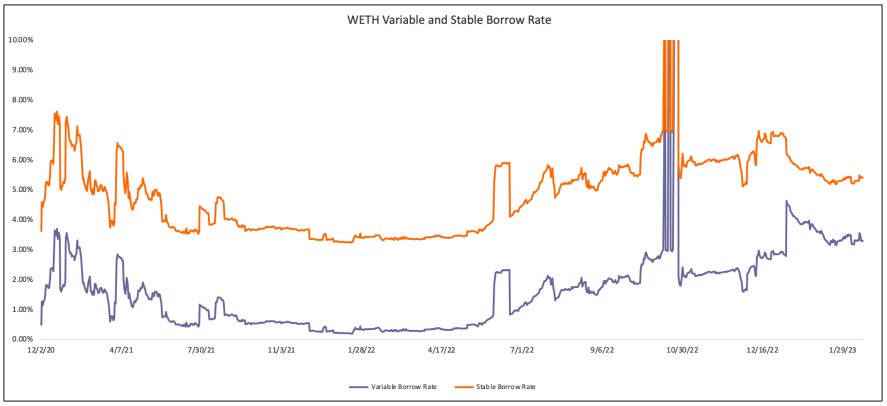


Historically, the data shows how investors prefer to borrow cryptocurrencies with variable interest rates, choosing to pay a lower assumed interest rate in return for the potential risk of interest rate fluctuations with their crypto loans. Within each chart, we can see that there is a clear drop in total variable debt for each currency during the month of July 2022. This time was a known period of instability within cryptocurrency markets given the bankruptcy filings of Celsius Network, Voyager Digital Capital, and Three Arrows Capital. Looking specifically at the WETH data, we can also see that more value was placed into borrowing at a stable rate rather than the variable rate leading up to the FTX bankruptcy filing in November 2022. Overall, the dramatic decreases in variable borrowing and preference for borrowing at a stable rate show investors increased risk aversion to cryptocurrency lending during periods of known instability within crypto markets.

Figure Two: Comparison of Variable and Stable Borrow Rates





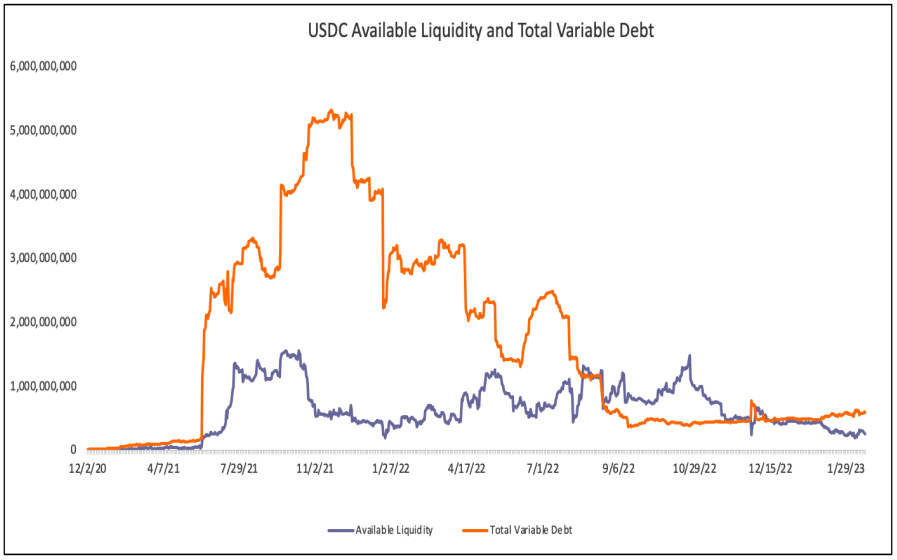


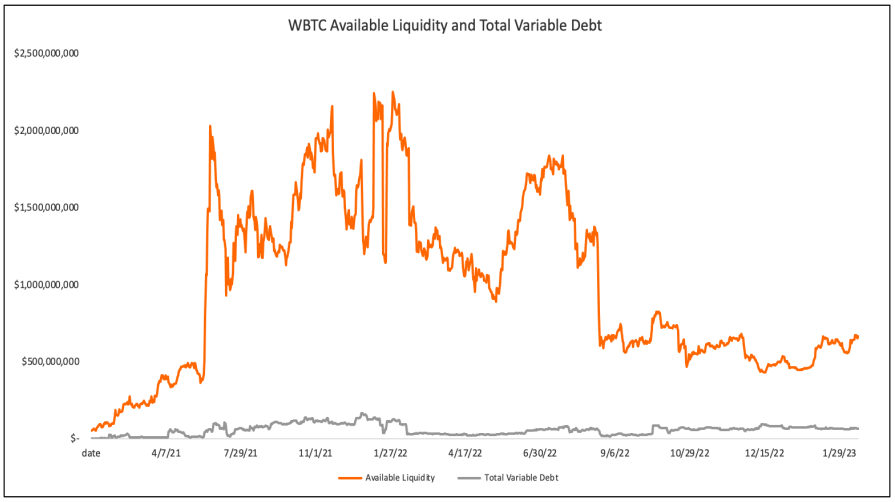
Furthermore, the changes in variable and stable borrow rates for each currency outline the reaction of Aave's interest rate model to periods of volatility within crypto markets. From the Aave interest rate model, variable and stable rates will only change because of the utilization and perceived market-based lending rate of the specific currency. Looking at USDC, the stable coin's variable and stable rates remained relatively consistent within 2022-2023, showing that the market base lending rate and optimal utilization ratio was generally unaffected throughout the events of the crypto winter. WBTC and WETH, on the other hand, both show some drastic changes in stable and variable rates leading up to the FTX collapse in November 2022. The sharp rise in both variable and stable rates within WETH at the end of October 2022, leading up to the first initial leaked report of FTX and Alameda fraudulent relations released on November 2,

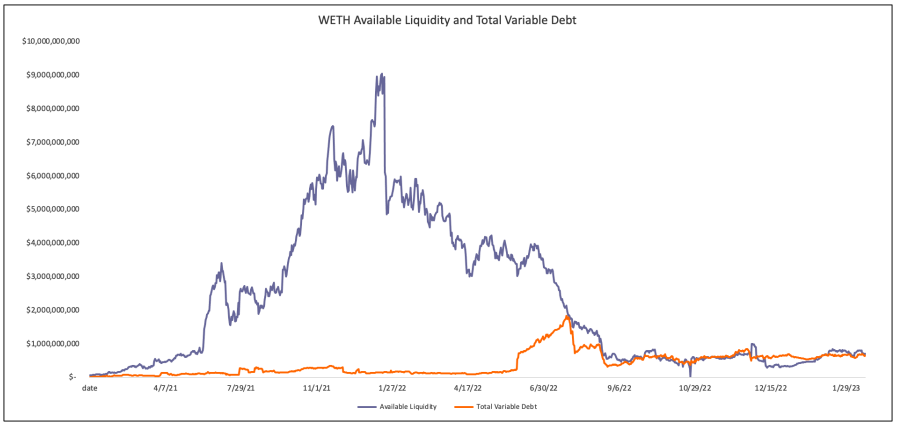
2022, show how investors may have anticipated instability in crypto markets and preferred borrowing at a stable rate given Ethereum price fluctuation.

Holistically, borrowers benefitted from having a stable rate during the time period preceding news of the FTX liquidity crisis in early October 2022. During this time, there was a greater amount of loans taken out at the stable rate, and the total stable debt was greater than the total variable debt. Given the spike in both the stable and variable borrowing rates in late October 2022, it can be understood that borrowers preferred to pay a premium for a stable rate loan as a form of insurance against future rate spikes. This strategy works well when the expected rate spike is much higher than the current difference between the stable and variable borrow rate. With the currencies in this study, stable and variable borrow rates returned to their pre-FTX amounts in the starting months of 2023. Similar patterns are also followed by rate spikes in July 2022 and other periods of volatility within crypto markets. Given the historic Aave data, it can be concluded that stable rate borrowing is only valuable as a form of insurance against interest rate spikes in the short term. This can be seen in the above graphs as existing patterns show interest rate spreads returning to historic levels within weeks or months after a period of rising rates. Since there is no set maturity on a cryptocurrency loan then it can be understood that borrowing with a stable rate will mostly benefit investors who seek short-term protection against immediate interest rate spikes. Otherwise, investors would prefer a variable rate when assuming that their loan will be held over a long period of time.

Figure Three: Comparison of Available Liquidity and Total Variable Debt







Looking at available liquidity, there is a sharp decrease of available WETH, WBTC, and USDC starting from July 2022. The amount that available liquidity decreases is not matched by the amount that total variable debt increases, and there is a clear reduction in the TVL of each of these currencies on Aave. Within the data set, it is also worth noting that the decrease in available liquidity did not go toward investing in stable debt as Figure One showed that total stable debt is almost always less than the amount of total variable debt at any given time. Overall, decreased available liquidity directly relates to a decrease in the amount of the currency available within lending pools on Aave. Available liquidity continues to decrease in late October and early November 2022 at the time of the FTX bankruptcy filing.

Since BTC, ETH, and USDC are the tokens with the largest market share among all cryptocurrencies then the data shows a clear trend where investors are less likely to place their tokens in Aave lending pools specifically as the TVL of each of these currencies continues to drop throughout 2022.

Regression Analysis

Appendix three shows the summary statistics for the data set focused on each of the three currencies. Using an ordinary least squares regression model, figure four shows the regression outputs when testing for causation between spreads of variable and stable borrow rates compared to price and available liquidity.

Figure Four:

WETH Data Regression Results

```
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                    3.370e-02  2.333e-04 144.455  < 2e-16 ***
WETH_data$`Available Liquidity` -4.708e-13  7.383e-14  -6.377 2.72e-10 ***
```

```
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)      3.457e-02  4.093e-04  84.460  < 2e-16 ***
WETH_data$Price -8.506e-07  1.635e-07  -5.203 2.36e-07 ***
```

WBTC Data Regression Results

```
                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                   3.277e-02  6.808e-05  481.29   <2e-16 ***
WBTC_Data$`Available Liquidity` -8.444e-13  6.028e-14  -14.01   <2e-16 ***
```

```
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)      3.342e-02  8.585e-05  389.25   <2e-16 ***
WBTC_Data$Price -4.077e-08  2.198e-09  -18.55   <2e-16 ***
```

USDC Data Regression Results

```
                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                  6.474e-02  3.928e-04  164.83   <2e-16 ***
USDC_Data$`Available Liquidity` 1.316e-11  5.402e-13   24.36   <2e-16 ***
```

```
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)      0.22928    0.09508   2.411   0.0161 *
USDC_Data$Price -0.15635    0.09500  -1.646   0.1001
```

Given Aave's interest rate formula, changes in available liquidity should impact both the variable and stable rate offering to maintain an ideal utilization rate. Yet, when looking at figure three, specifically the WETH data, there is a clear period in July 2022 when available liquidity dramatically drops yet the spread between variable and stable borrow rates remains relativity unchanged. The OLS regression will consider the true causal impact between available liquidity and price on the spread between stable and variable debt.

From the regression results, price and available liquidity are statistically significant measures of the spread between stable and variable rates. These two measures have a negative relationship with the interest rate spread. However, USDC holds a different relationship as the regression outputs show that available liquidity is a statistically significant measure of interest

rate spreads but not price. This would logically make sense as USDC is a stable coin that is pegged to the US Dollar and is not subject to the same price volatility of Bitcoin and Ethereum.

Overall, the regression results confirm the equation for Aave's interest rate model, where available liquidity and token price increases cause a decrease in the spread between stable and variable interest rates, leading to interest rates that match the ideal token utilization.

Further Discussion

Potential limitations within the sample data include the lack of independent variables used to determine the spread between the stable and variable interest rates. As most of the outputs from calling the getReserveData function will be tied to existing interest rate models from the Aave protocol, then additional data points related to specific lending transactions on the blockchain could be useful in analyzing new independent variables. In addition to an OLS regression, tests such as the Granger causality test could be conducted to access the direct quantitative impact of different qualitative measures that are ingrained in existing data.

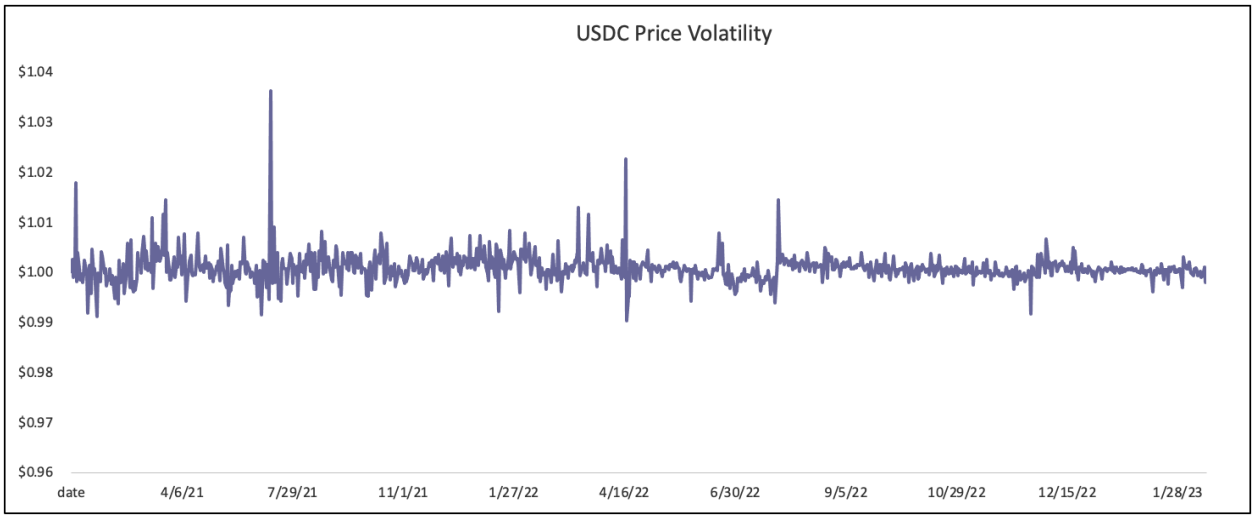
Next Steps to continue this study could focus on looking at how decreased available liquidity within Aave will impact the protocol's ability to offer competitive borrowing rates in the future. An additional study that looks at similar data from Compound and other lending protocols with sizeable market share could be interesting as a comparison of investor behavior among different lending platforms. Overall, continuing to collect new data points with the getReserveData function will further enable for a better understanding of the prolonged impacts of the instability within cryptocurrency markets during the past year.

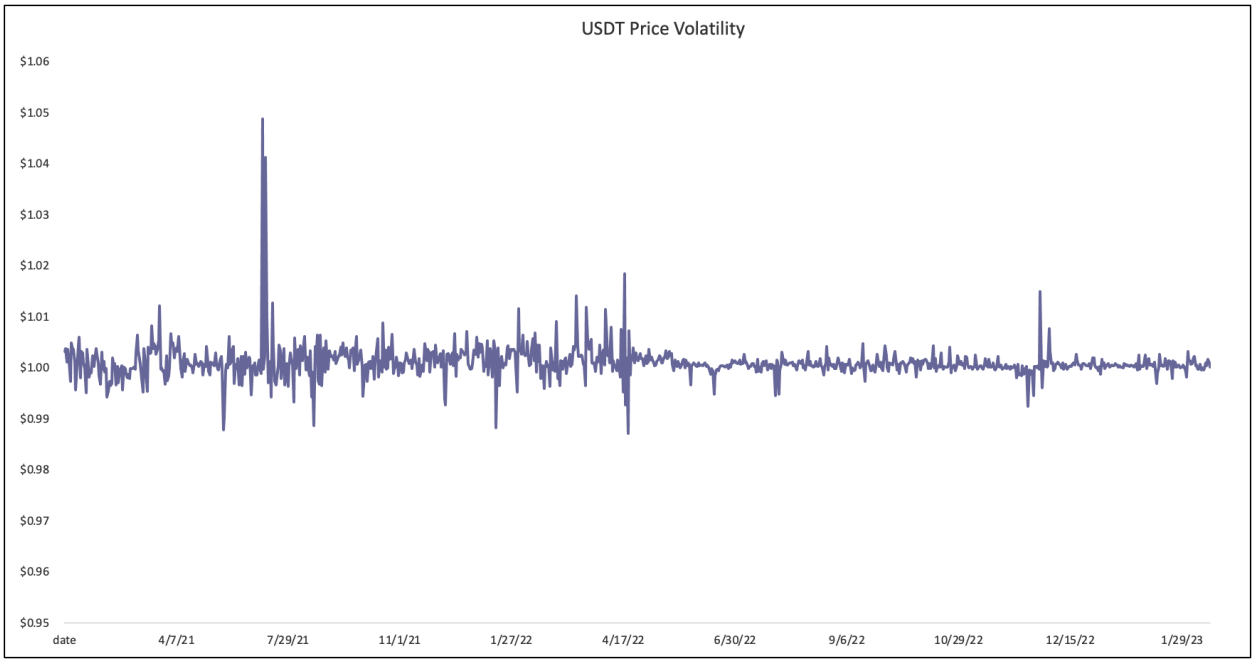
Conclusion

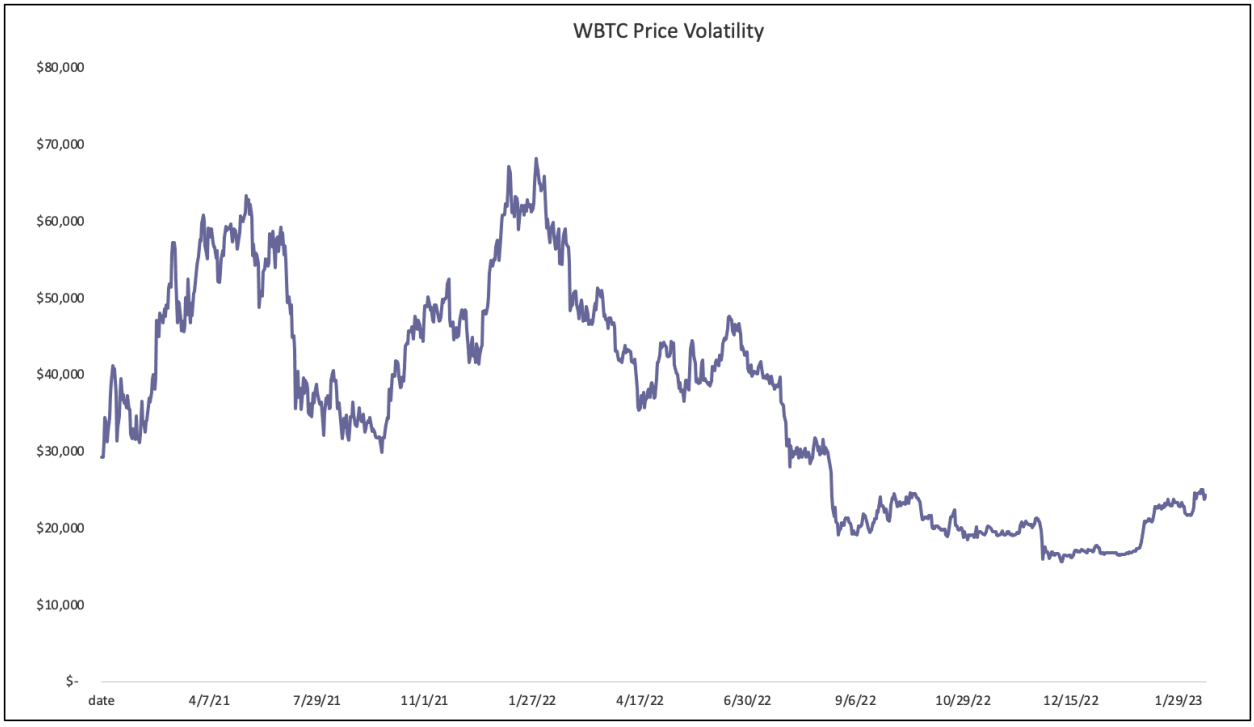
This study sought to consider existing research on lending within DeFi protocols and specifically consider characteristics of lending on Aave. Through looking at historical data on interest rates, available liquidity, and loan preferences, an analysis of investors risk aversion in time periods of instability within cryptocurrency markets was able to be completed. A further regression analysis confirmed the interest rate model that Aave applies on the protocol, while outlining key differences between lending using traditional cryptocurrencies and stablecoins. From the historical data, Aave is losing available liquidity on their protocol within some of the most popular cryptocurrencies on the market, and these trends were further escalated by the many bankruptcy filings of fintech industry peers in 2022. Overall, the study will add to existing literature that considers the risks of investing cryptocurrencies in DeFi lending pools, borrowing cryptocurrencies within lending protocols, and understanding how investors price in market risk with their preference for stable or variable interest rates.

Appendix

Appendix 1: Price Volatility

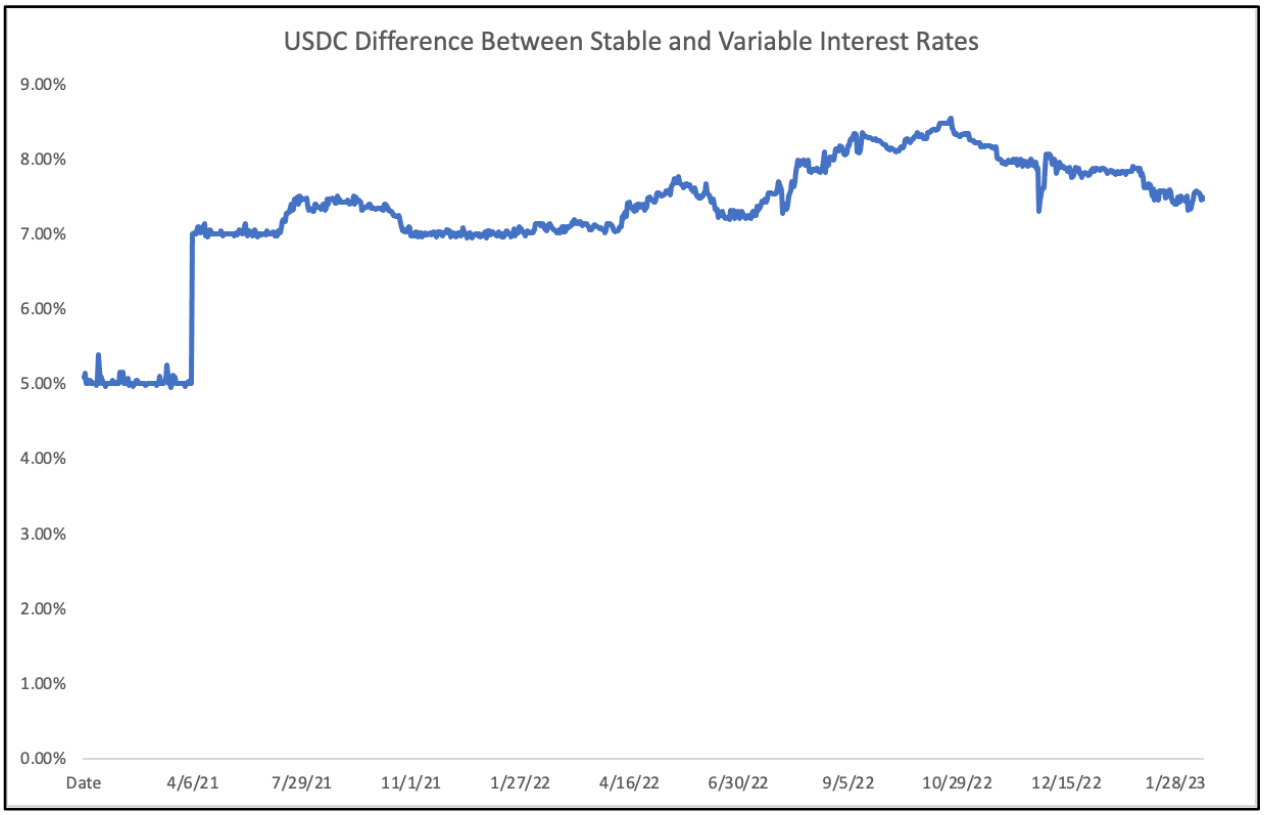


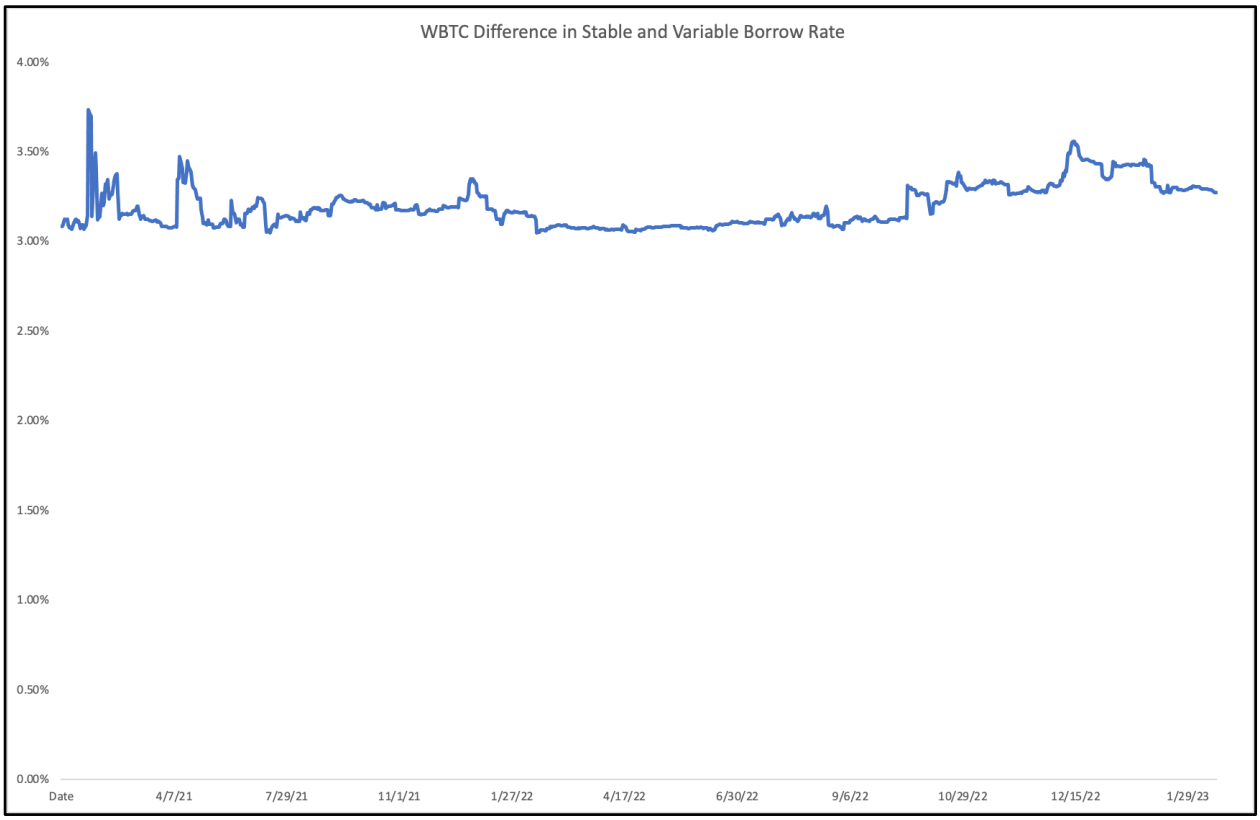


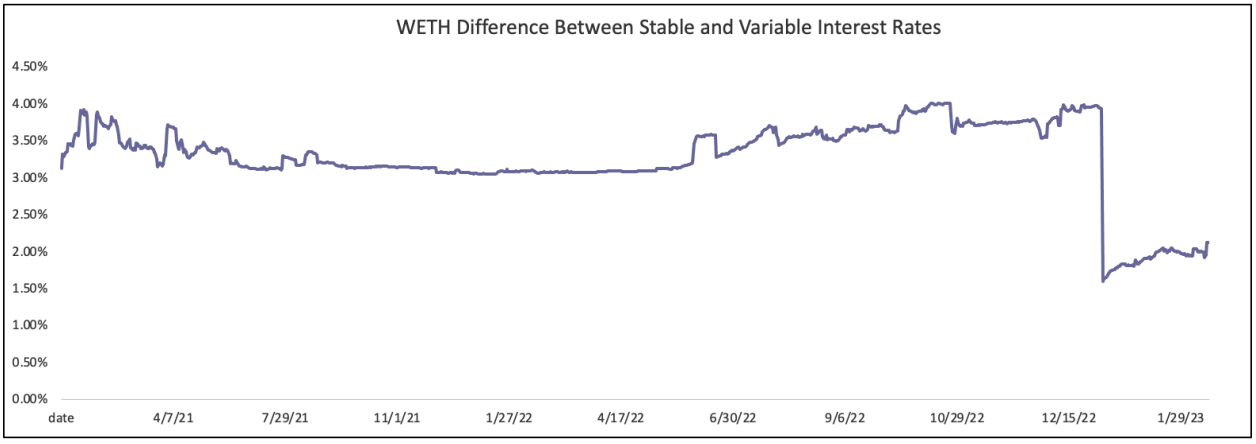

WBTC Price Volatility
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$-
date
4/7/21
7/29/21
11/1/21
1/27/22
4/17/22
6/30/22
9/6/22
10/29/22
12/15/22
1/29/23


WETH Price Volatility
$6,000.00
$5,000.00
$4,000.00
$3,000.00
$2,000.00
$1,000.00
$-
date
4/7/21
7/29/21
11/1/21
1/27/22
4/17/22
6/30/22
9/6/22
10/29/22
12/15/22
1/29/23

Appendix 2: Difference Between Stable and Variable Interest Rates







Appendix 3: Summary Statistics

Summary Statistics for WETH Data

```
 variableBorrowRate  stableBorrowRate    averageStableBorrowRate     Price             Date
Min.   :1.843e+24   Min.   :3.230e+25   Min.   :0.000e+00       Min.   : 725.2   Min.   :2020-12-02 03:34:16.0
1st Qu.:5.237e+24   1st Qu.:3.655e+25   1st Qu.:3.997e+25       1st Qu.:1504.2   1st Qu.:2021-09-24 06:40:19.5
Median :1.547e+25   Median :4.972e+25   Median :4.841e+25       Median :1992.8   Median :2022-04-26 05:00:43.5
Mean   :1.787e+25   Mean   :5.048e+25   Mean   :4.937e+25       Mean   :2304.2   Mean   :2022-03-23 23:38:18.9
3rd Qu.:2.263e+25   3rd Qu.:5.753e+25   3rd Qu.:5.761e+25       3rd Qu.:3062.5   3rd Qu.:2022-10-14 22:46:26.0
Max.   :1.030e+27   Max.   :1.070e+27   Max.   :3.770e+26       Max.   :4816.1   Max.   :2023-02-08 17:54:35.0
Available Liquidity Total Stable Debt   Total Variable Debt Variable Borrow Rate Stable Borrow Rate Average Stable Borrow Rate
Min.   :0.000e+00   Min.   :       0   Min.   :2.045e+06   Min.   :0.001843     Min.   :0.03230    Min.   :0.00000
1st Qu.:5.452e+08   1st Qu.:   662197   1st Qu.:1.190e+08   1st Qu.:0.005237     1st Qu.:0.03655    1st Qu.:0.03997
Median :1.368e+09   Median :  1342125   Median :2.611e+08   Median :0.015468     Median :0.04972    Median :0.04841
Mean   :2.310e+09   Mean   : 21523555   Mean   :3.876e+08   Mean   :0.017872     Mean   :0.05048    Mean   :0.04937
3rd Qu.:3.851e+09   3rd Qu.:  2231163   3rd Qu.:6.088e+08   3rd Qu.:0.022630     3rd Qu.:0.05753    3rd Qu.:0.05761
Max.   :9.036e+09   Max.   :749737144   Max.   :1.823e+09   Max.   :1.030000     Max.   :1.07000    Max.   :0.37700
Difference in Stable v Variable
Min.   :0.01590
1st Qu.:0.03086
Median :0.03286
Mean   :0.03261
3rd Qu.:0.03633
Max.   :0.04000
```

Summary Statistics for WBTC Data

```
 variableBorrowRate  stableBorrowRate    averageStableBorrowRate     Price             Date
Min.   :1.804e+24   Min.   :3.225e+25   Min.   :3.338e+25       Min.   :15621   Min.   :2020-12-02 21:56:02.00
1st Qu.:3.962e+24   1st Qu.:3.495e+25   1st Qu.:3.601e+25       1st Qu.:21768   1st Qu.:2021-09-24 06:40:19.50
Median :6.379e+24   Median :3.797e+25   Median :3.989e+25       Median :37295   Median :2022-04-26 05:00:43.50
Mean   :7.727e+24   Mean   :3.966e+25   Mean   :4.067e+25       Mean   :36407   Mean   :2022-03-23 23:18:40.13
3rd Qu.:1.108e+25   3rd Qu.:4.385e+25   3rd Qu.:4.523e+25       3rd Qu.:47091   3rd Qu.:2022-10-14 22:46:26.00
Max.   :2.930e+25   Max.   :6.663e+25   Max.   :5.444e+25       Max.   :68170   Max.   :2023-02-08 17:54:35.00
Available Liquidity Total Stable Debt  Total Variable Debt Variable Borrow Rate Stable Borrow Rate  Average Sta
Min.   :5.134e+07   Min.   :   22498   Min.   :   459152   Min.   :0.001804     Min.   :0.03225    Min.   :0.03338
1st Qu.:5.512e+08   1st Qu.:  173509   1st Qu.: 28080278   1st Qu.:0.003962     1st Qu.:0.03495    1st Qu.:0.03601
Median :9.584e+08   Median :  367285   Median : 58869645   Median :0.006379     Median :0.03797    Median :0.03989
Mean   :9.887e+08   Mean   :  938270   Mean   : 57145545   Mean   :0.007727     Mean   :0.03966    Mean   :0.04067
3rd Qu.:1.396e+09   3rd Qu.:  869014   3rd Qu.: 74632771   3rd Qu.:0.011079     3rd Qu.:0.04385    3rd Qu.:0.04523
Max.   :2.251e+09   Max.   :60241163   Max.   :165042820   Max.   :0.029301     Max.   :0.06663    Max.   :0.05444
Difference in Stable and Variable Borrow Rate
Min.   :0.03045
1st Qu.:0.03099
Median :0.03159
Mean   :0.03193
3rd Qu.:0.03277
Max.   :0.03733
```

Summary Statistics for USDC Data

```
 variableBorrowRate  stableBorrowRate    averageStableBorrowRate     Price             Date
 Min.   :9.070e+24   Min.   :8.610e+25   Min.   :6.880e+25       Min.   :0.9902   Min.   :2020-12-02 03:34:00.00
 1st Qu.:2.322e+25   1st Qu.:1.010e+26   1st Qu.:9.730e+25       1st Qu.:0.9996   1st Qu.:2021-09-23 12:13:00.00
 Median :3.240e+25   Median :1.060e+26   Median :1.030e+26       Median :1.0006   Median :2022-04-26 05:00:00.00
 Mean   :5.001e+25   Mean   :1.228e+26   Mean   :1.034e+26       Mean   :1.0008   Mean   :2022-03-23 15:10:13.32
 3rd Qu.:3.937e+25   3rd Qu.:1.100e+26   3rd Qu.:1.090e+26       3rd Qu.:1.0018   3rd Qu.:2022-10-14 10:12:00.00
 Max.   :6.350e+26   Max.   :6.850e+26   Max.   :1.270e+26       Max.   :1.0362   Max.   :2023-02-08 17:54:00.00
 Available Liquidity Total Stable Debt   Total Variable Debt Variable Borrow Rate Stable Borrow Rate
 Min.   :1.988e+05   Min.   :  4309184   Min.   :5.260e+06   Min.   :0.00907      Min.   :0.0861
 1st Qu.:3.767e+08   1st Qu.:  6672667   1st Qu.:4.389e+08   1st Qu.:0.02322      1st Qu.:0.1010
 Median :5.482e+08   Median : 19938712   Median :1.158e+09   Median :0.03240      Median :0.1060
 Mean   :6.120e+08   Mean   : 42573316   Mean   :1.685e+09   Mean   :0.05001      Mean   :0.1228
 3rd Qu.:8.810e+08   3rd Qu.: 53816817   3rd Qu.:2.848e+09   3rd Qu.:0.03938      3rd Qu.:0.1100
 Max.   :1.552e+09   Max.   :251171249   Max.   :5.318e+09   Max.   :0.63500      Max.   :0.6850
 Difference Between Stable and Variable Interest Rate
 Min.   :0.04950
 1st Qu.:0.07030
 Median :0.07390
 Mean   :0.07279
 3rd Qu.:0.07850
 Max.   :0.08543
```

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