How to assess the bad debt risk for DeFi lending protocols?

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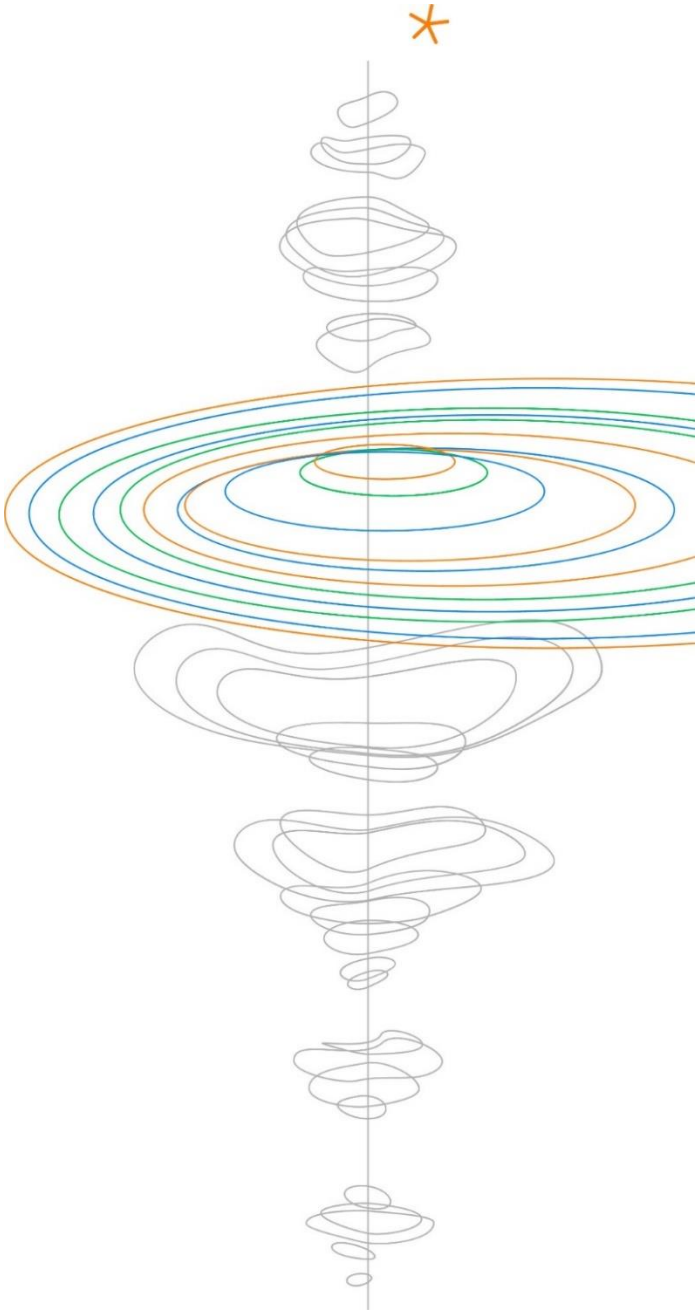

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Key Highlights:

- DeFi offers an alternative to the traditional centralized financial system and removes intermediaries from financial transactions, thus enabling faster, cheaper, and more secure transactions.

- TOBAM has been developing its DeFi investment capabilities and research on the topic for several years. The assessment of collateral risk is one of the key components of the rating we assign to lending protocols.

- Decentralized lending applications enable cryptocurrency holders to lend their digital assets to other users, earning interest on the loaned amount.

- While this technology provides numerous benefits, there are also some risks associated with it that should be taken into consideration before engaging in any type of decentralized lending activity.

- One of the main risks is the potential negative impact of borrower defaults. Although liquidation mechanisms are in place to mitigate this impact, bad debts and therefore insolvency may still occur in some cases.

- Our study focuses on the quantitative assessment of this risk. To achieve our goal, we analyze what can happen using a wide range of scenarios.

Introduction

Based on transparent and decentralized blockchain technology, **Decentralized Finance (DeFi) is a new peer-to-peer financial system (the internet of value).** DeFi offers a variety of financial services in an open environment that does not rely on intermediaries like custodians, central clearing houses or escrow services, as these roles are assumed by smart contracts. Most of the time, these services are provided through Decentralized Applications (DApps).

The financial needs generated by the accumulation of wealth in crypto led to the development of, amongst many other applications, lending DApps. This was necessary as crypto holders were and still are not serviced by traditional financial institutions: it is not possible to take a loan at the biggest banks by posting cryptocurrencies as collateral. On the other side, in DeFi, everybody can be a lender (provided they have assets to lend) and everybody can be a borrower (provided they have the assets or resources to collateralize) via smart contracts.

Lending represents, along with decentralized exchanges (DEX), liquidity providing and liquid staking, **one of the biggest DeFi activities** with big actors like Compound or AAVE. Lending protocols enable **cryptocurrency owners** to **lend their digital assets to other users, earning interest** on the loan in the process. However, there are also numerous risks associated with it that should be taken into consideration before engaging in any type of decentralized lending activity. Apart from dangers such as technological risk or governance risk, one of the most important risks that a lender should take into account when making the decision to place their crypto on a lending platform is the risk of under-collateralization of the loan: the risk that the value of the borrower's collateral becomes lower than the value of the debt, rendering the borrower insolvent.

Despite the efforts put in place by the lending protocols to set up the right risk controls, history has shown us that abnormal situations with over-leveraged actors may endanger the lending ecosystem. The objective of this paper is to define and quantify the under-collateralization risk for DeFi lending protocols. One of the main challenges faced by users is the lack of an agency rating system like Moody's, S&P or Fitch to help investors assess credit risk. **Unlike traditional interest rate markets**, there is currently **no way to assess the creditworthiness of borrowers** or lending/borrowing platforms in the world of DeFi.

In the following, we will first provide a brief introduction to DeFi lending mechanisms followed by a description of our under-collateralization or bad debt analysis. **Our study focuses on Aave and Compound**, the two most popular DeFi protocols, which offer cryptocurrency lending services. They are leading the field in their category in terms of Total Value Locked (TVL), which is a metric used to measure the amount of cryptocurrency assets locked in protocols.

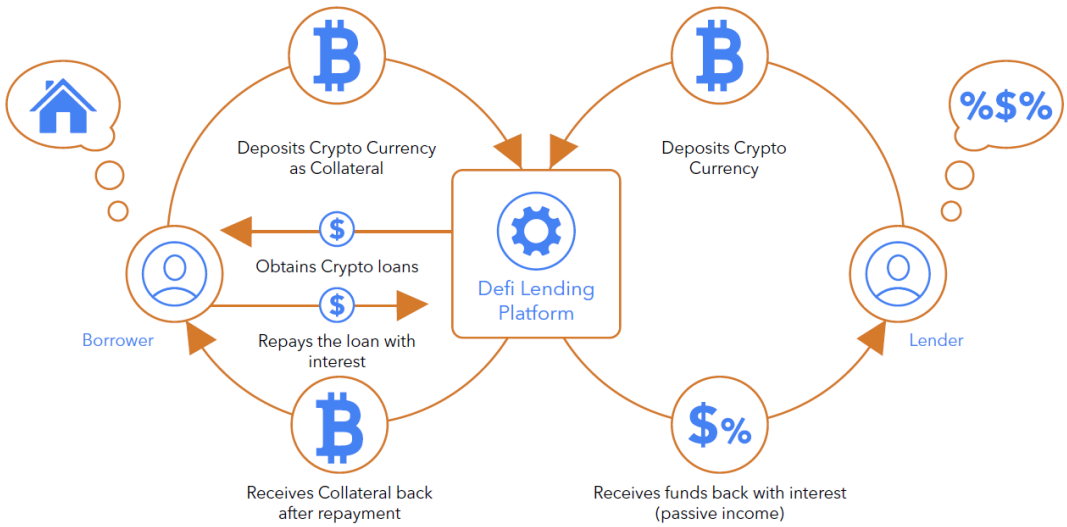
I. How does a lending protocol work?

Key take-aways of this section

- Cryptocurrency lending works by connecting borrowers and lenders through smart contracts.
- As the cryptocurrency market is highly volatile, many DeFi platforms enforce over-collateralization.
- The borrowable amount is the sum of deposits in each token adjusted by their collateralization factor (<1, depending on the protocol).
- To monitor bad debt risk, protocols control the Health Factor of every borrower (Health Factor = borrowable amount / borrowed amount).
- If the health factor drops below 1, liquidators are incentivized to liquidate the position, limiting the risk of bad debt in the protocol.

Cryptocurrency lending works by connecting borrowers and lenders through smart contracts. Lenders deposit cryptocurrencies they wish to lend in a liquidity pool, which borrowers can draw upon when taking out a loan. Collateral in the form of cryptocurrencies is provided by the borrower in exchange for the loan. For instance, a borrower can deposit Bitcoin (BTC) as collateral to borrow Ether tokens (ETH).

Figure 1: What are Crypto Loans?



- **Loans must be over-collateralized.**

Borrowers deposit collateral in cryptocurrencies that should back the loan they obtain from a lending pool on the DApp they want to use. As the cryptocurrency market is highly volatile, many DeFi platforms enforce over-collateralization, meaning the borrower must provide more than the loan amount. The collateralization factor represents the fraction of the deposit that can be borrowed. It is token specific and would typically be determined as a function of its volatility, liquidity or market cap to name the most important factors.

For instance, AAVE has set a *collateralization factor* of 80% for ETH. The parameters can also be adjusted over time if judged necessary by the Decentralized Autonomous Organization controlling the protocol (DAO, i.e. those who own the protocol's governance token and can vote for the proposals). This was for instance the case after the Mango hack, where a group of hackers successfully managed to manipulate the price of a poorly liquid token (Mango token MGO) to increase their borrowing capacity virtually. After this event, AAVE suspended 17 markets by setting the collateral factor of the corresponding tokens to zero. On their side, Compound also froze the borrowing capacity for 4 tokens in October 2022.

To summarize, the total amount that can be borrowed by an individual is the sum of deposits in each token adjusted by their collateralization factor, which is determined by the protocol, and can be adjusted over time:

$$borrowable\ amount = \Sigma_i \text{ collateral factor (i)} \times deposit\ amount(i)$$

For a lender, it is therefore highly relevant to assess the quality of the collateral pool to manage the potential risk related to a sudden major drop in the value of the collateral. While the lending platforms try to define the collateral requirements based on their own risk assessments of the respective collateral used, we think it is crucial for an investor to go beyond what the platforms do and to put additional layers of risk assessment in place, TOBAM has developed a methodology for quantifying risks associated to DeFi loans since it actively invested in 2021.

- **What happens if the collateralization level drops?**

The liquidity provider faces the risk of bad debt, i.e., the risk that the value of the borrower's collateral becomes lower than the value of the debt, making the borrower insolvent. This can happen if the value of the collateral decreases relative to the amount borrowed. For instance, when:
- the value of the collateral drops while the borrowed amount remains the same or
- the value of the borrowed assets increases while the value of the deposits does not change
To mitigate this risk, the protocol takes the necessary steps to close the borrower's position as soon as the amount borrowed exceeds the borrowable amount. As collateral factors are smaller than 100%, the protocol has some room before bad debt is created (when the borrowed amount exceeds the deposit) unless the under collateralization happens to quickly for the protocol to react or the closure of the position creates a large market impact. The protocol usually monitors the health factor of every borrower, which corresponds to the ratio of the amount borrowable divided by the borrowed amount.

$$Health\ Factor = \frac{borrowable\ amount}{borrowed\ amount}$$

If the health factor drops below one, then the protocol gives everybody the right to repay a fraction of the loan and seize some collateral. The fraction of the loan that can be reimbursed is called the close factor. It is typically 50% on AAVE and Compound. In order to incentivize actors to perform the task, which are called liquidators, the protocol lets them seize more collateral than the reimbursed debt. The liquidation incentive is the extra amount seized by the liquidators. This incentive typically ranges from 5% to 15%. Liquidators are usually robots, as liquidations operate on a first come, first serve basis.

Once liquidated, three outcomes are possible:

- The borrower's health factor becomes greater than 1 again. This is the ideal scenario.
- The borrower's health factor remains below 1 but there is still collateral to liquidate. The wallet can be liquidated one more time. It is not the perfect scenario but there is still no bad debt for the protocol.
- The borrower's health factor remains below 1 and there is no more collateral to liquidate. This is a serious situation for the protocol as bad debt is created. Our objective is to evaluate the likelihood of this scenario and its associated magnitude.

Delaunay *et al*. [1] has demonstrated that the ratio of borrowed to deposited assets decreases after a liquidation if and only if this ratio was under $\frac{1}{Liquidation\ Incentive}$ before the liquidation. This means that if the liquidation process starts when the situation has already significantly deteriorated $\left(\frac{Borrowed}{Depositted} > \frac{1}{Liquidation\ Incentive}\right)$, then it can only deteriorate further and lead to a bad debt position: we know in advance the final result of the second possibility.

- **What could go wrong?**

When a wallet is available for liquidation, liquidators will start competing against each other in a race to be the first to liquidate the position if it is profitable to do so. In the following we assume that liquidators are greedy: they only look for quick profits and consequently:

- They are not speculators and they do not hold anything prior to liquidation, and thus they need to buy the assets that have been borrowed to repay the debt.
- They sell the seized crypto assets immediately after the seizure.

Selling and buying cryptos can be costly especially in volatile conditions. Liquidators must pay particular attention to the market impact of their trades amongst other trading costs. They must wisely choose what cryptos they want to seize (if the borrower has pledged different crypto assets) and what crypto they want to use to repay the debt (if the borrower has borrowed different cryptos) to minimize their costs of trading.

Market impact is a very important consideration. Ignoring it may lead to negative consequences.

In early 2022, for example, Celsius was a CEFI platform promising very high returns for depositors on different assets. They managed to achieve this for Ethereum by depositing the client's ETH in liquid staking solutions (Lido Finance) and using the proof of deposit (Lido staked ETH or stETH) as collateral to borrow more ETH, that was subsequently deposited again. They repeated this loop many times and finally ended up building a highly leveraged position with deposits in stETH and borrows in ETH. Now, stETH was not listed on big, centralized exchanges but only on a few decentralized ones, the liquidity for the stETH token was relatively small when compared to the size of the position that had been built by this actor.

As such, Celsius built from the start a difficult to liquidate long stETH/short ETH position. Now, when stETH 's price started to decline relatively to ETH's, Celsius ran into significant losses with stETH trading at as low as to an 7% discount to ETH. Compounding woes, Celsius' clients started to withdraw their ETH, which Celsius could only get back realizing significant losses. Celsius answer ended up blocking withdrawals to limit the damage. At that point, we were in a situation where an additional decline in stETH/ETH price could lead to undercollateralized loans on lending platforms. This dangerous situation happened because liquidating Celsius position would have been too costly to sell its illiquid stETH position vs buying ETH.

In the following, we will assume that liquidators immediately sell the seized collateral, this means that the price of this token will be impacted negatively and may trigger liquidations for other borrowers who have used the same crypto asset as collateral. These so called "cascading liquidations" are an important feature considered in our risk assessments.

II. Our approach to assess the under-collateralization risk

Key take-aways of this section

- To assess the possible under-collateralization or bad best issue, we use different stress test scenarios.
- We then compute for each scenario the amount of generated bad debt. For Monte Carlo simulations, we analyse statistically the bad debt distribution.
- Protocols may have in some cases a reserve that can be used to reimburse lenders if bad debt is generated in the protocol.

• Methodology

To assess the possible under-collateralization or bad debt issue, we use the following scenarios:

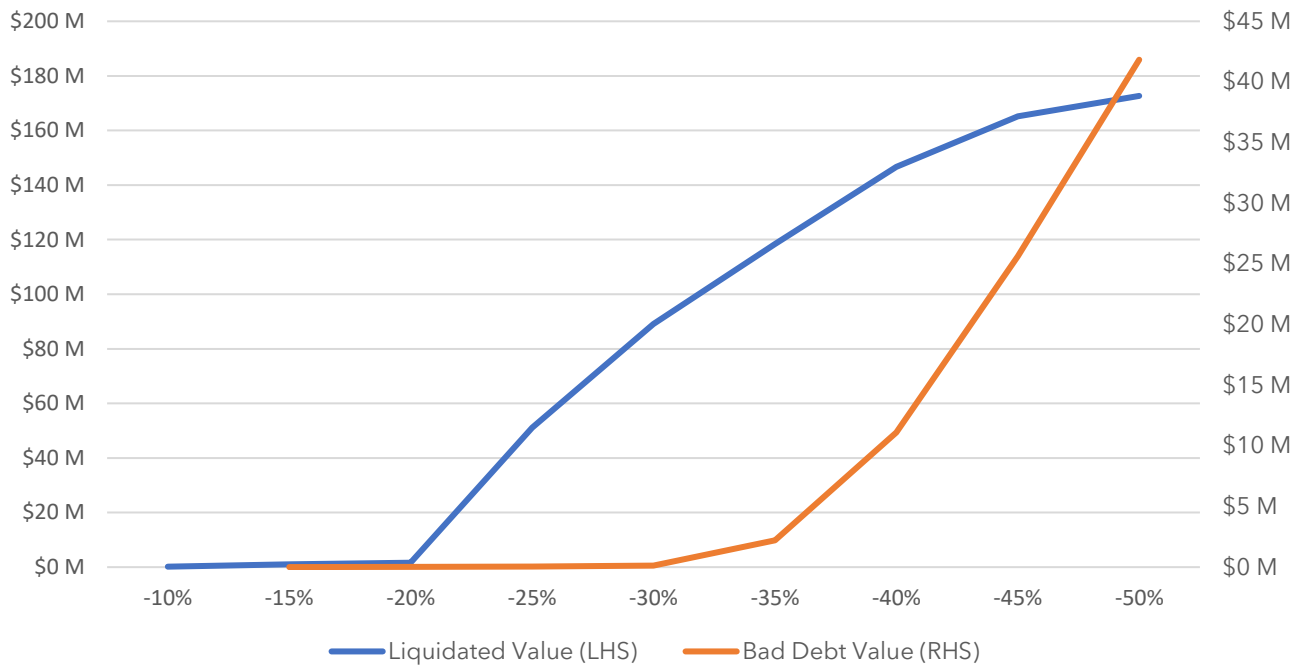
1- Historical: if we want to analyze what would happen if we were to relive the worst day of the crypto market (in terms of returns). We can also imagine a particular adverse scenario with a significant price decrease for an asset where a major technological improvement fails (e.g., The Merge on Ethereum).
2- Mono-Factor simulations: we can use the fact that the crypto asset class exhibits a systematic risk: when Bitcoin is down, a large majority of cryptos is down as well; on the contrary when Bitcoin is up, it is a good day for the entire crypto market. Hence, deriving the returns for the different cryptocurrencies from Bitcoin's returns seems relevant as it is an important driver of the market (it represents approximately 40% of the total crypto market capitalization). What we do in these types of simulations is to define an arbitrary return for Bitcoin and assume that the return of any crypto asset is derived through its BTC beta, computed using past data.
3- Multi-Factor simulations: we can also use the well-known Monte Carlo simulation techniques, where we simulate random price trajectories for the different cryptocurrencies, based on their historical price movements and their interdependences.

- **A recent analysis of the Compound protocol**

As users deposit and borrow crypto assets 24/7, the state of the lending decentralized applications is always evolving and should be monitored continuously. In this section, we present our results concerning the assessment of the state of Compound at Ethereum block number 16426833, validated on January 17th, 2023, at 1.30pm UTC.

We first assume that all the crypto asset prices move accordingly to their Bitcoin exposure (beta) and examine what happens when the price of Bitcoin drops heavily. According to our simulations, if the price drops by 50%, total liquidations will reach nearly $172M in USD equivalent, while around $41M of bad debt will be generated for the protocol. A less extreme scenario could be a 30% Bitcoin price decrease, leading to total liquidated amounts of $89M, and a relatively negligeable bad debt amount of $134k (figure 3), in light of Compound's large Treasury chest, that currently stands at more than $91M.

Figure 2: Liquidated and Bad Debt Values for Bitcoin Returns Scenarios



The figure shows the liquidated and bad debt values for different Bitcoin return scenarios, with the x-axis representing the percentage change in Bitcoin return, and the y-axis representing the corresponding liquidated and bad debt values, with the blue line indicating the liquidated value and the orange line indicating the bad debt value.

We also analyze the distribution of the Health Factor of Compound's users in figure 4 (blue bars).

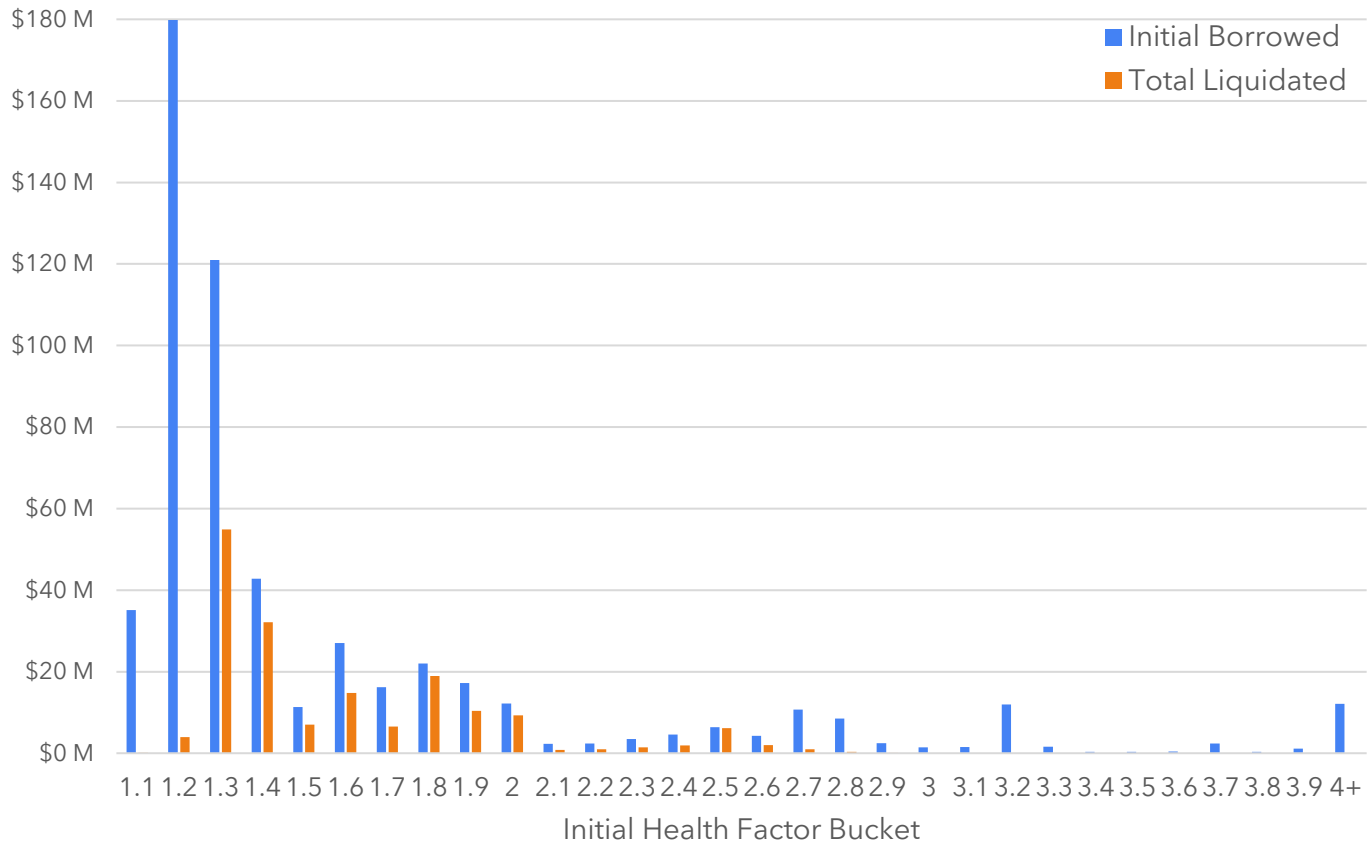
We observe that many users have a relatively low heath factor, concentrated around the 1.2 level. As we will see, these are likely to be users that borrow and deposit against their initial deposit to receive Compound's token and benefit from this protocol's incentive program. This makes sense in the current risk-off environment where lending and borrowing rates are low, making liquidity mining (of Compound's incentive) an interesting option.

This is confirmed by the distribution of user's health factor after a 30% BTC drop (orange bar). We indeed observe that the majority of wallets that are liquidated correspond to initial health factors that are greater than 1.2 (blue bar). In a nutshell, a majority of the low health factors users (<1.2) seem to correspond to wallets that deposit and borrow the exact same tokens.

It is particularly interesting to analyze this range of bitcoin returns as it corresponds to the historical worst bitcoin returns:

Period	Worst performance since 2015
1 day	-35%
2 days	-36%
3 days	-36%
4 days	-37%
5 days	-42%

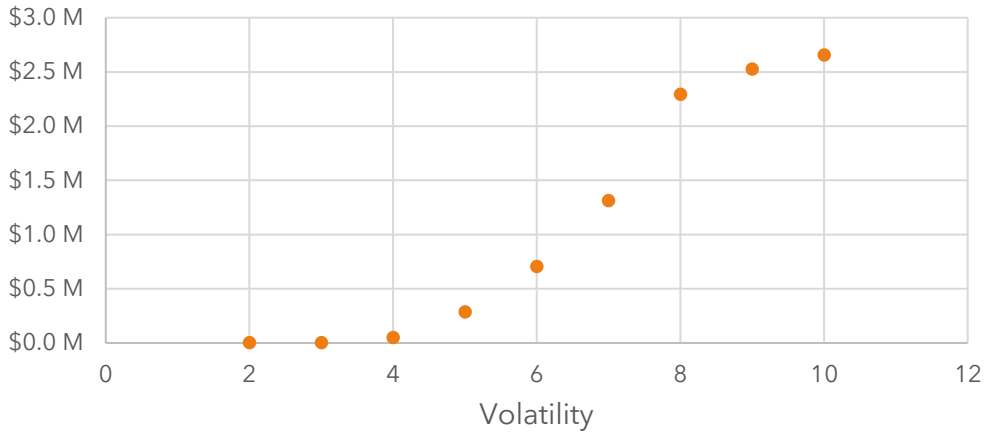
Figure 3: Health Factor distribution



The figure represents the Health Factor distribution, with the x-axis showing the Health Factor range and the y-axis showing the total value, where the accounts with higher Health Factors are considered less risky borrowers, and the accounts with lower Health Factors are considered more risky borrowers.

We now proceed to stress test Compound's protocol for an increase of the crypto market volatility. To do so, we run various simulations based on past historical correlation and increased the volatility to different levels.
We noticed in figure 4. that the state of Compound as of the extraction date was rather safe as the $1M bad debt threshold is only reached, on average, if the volatility is multiplied by 7. Again, things can change rapidly and even if the current situation is not alarming, a continuous monitoring of these 24/7 operating platforms must be performed.

Figure 4: Compound's average Bad Debt for different volatility levels



The figure displays Compound's average Bad Debt for different volatility levels, with the x-axis representing the level of volatility and the y-axis representing the corresponding average Bad Debt, with each data point on the graph representing the average Bad Debt for a particular level of volatility.

- **Protocol safety nets**

Protocols may have in some cases a reserve that can be used to reimburse lenders if bad debt is generated on the protocol. The reserve is built up by putting aside a percentage of the fees generated by the platform. In some cases, governance token holders can also deposit their governance tokens in the reserve and receive a fraction of the fees. Their tokens may be sold and used to compensate for lenders' losses if an adverse bad debt scenario occurs.

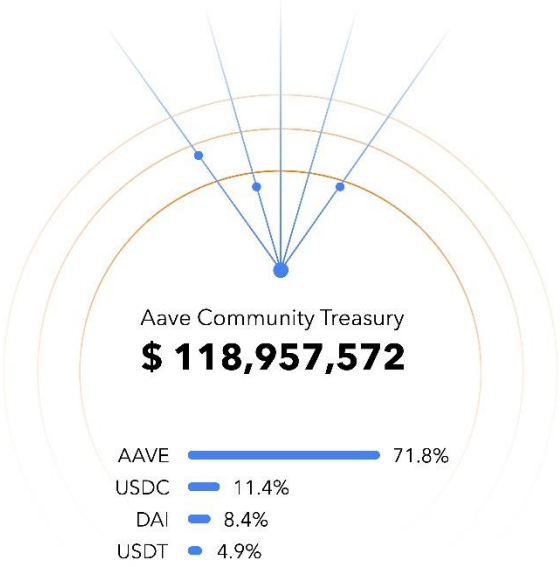
We do consider protocol reserves in our assessment. However, we always keep in mind that reserve composition must be examined closely: if the reserves are mainly denominated in the protocol's governance token, then we can expect death spiral scenarios where the token highly depreciates and leaves the lenders with no guarantee. The current breakdown of AAVE Treasury chest is provided below and shows that a significant proportion is held in the AAVE token.

It is also the case for Compound where nearly 90% of the Treasury is kept in the platform COMP token:

Crypto	Reserve percentage
Compound token (COMP)	88.86%
Bitcoin, Ether	10.25%
Stablecoins	0.87%
Others	0.01%

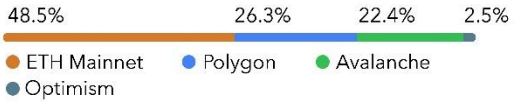
In the light of Compound's treasury composition, Another adverse scenario would be for btc to drop 25% and compound to zero, which would likely wipe out the full treasury and lead to the insolvency of the protocol.

Finally, another important consideration is to analyze protocol's rules that define the conditions upon which lenders must be reimbursed in any scenario.



The Aave treasury is composed of the ecosystem reserve (AAVE tokens) and Treasury collectors which earn fees from:

- Reserve factor: percentage of protocol interest paid by borrowers
- Instant liquidity fees: percentage of fees from instant liquidity transactions (V3 only)
- Liquidation fees: percentage of collateral liquidation bonus (V3 only, not yet active)
- Portal fees: paid by bridging protocols to reback assets (V3 only, not yes active)



Ecosystem Reserve
$ 85,462,357

Treasury Collectors
$ 33,495,216

III. Conclusion

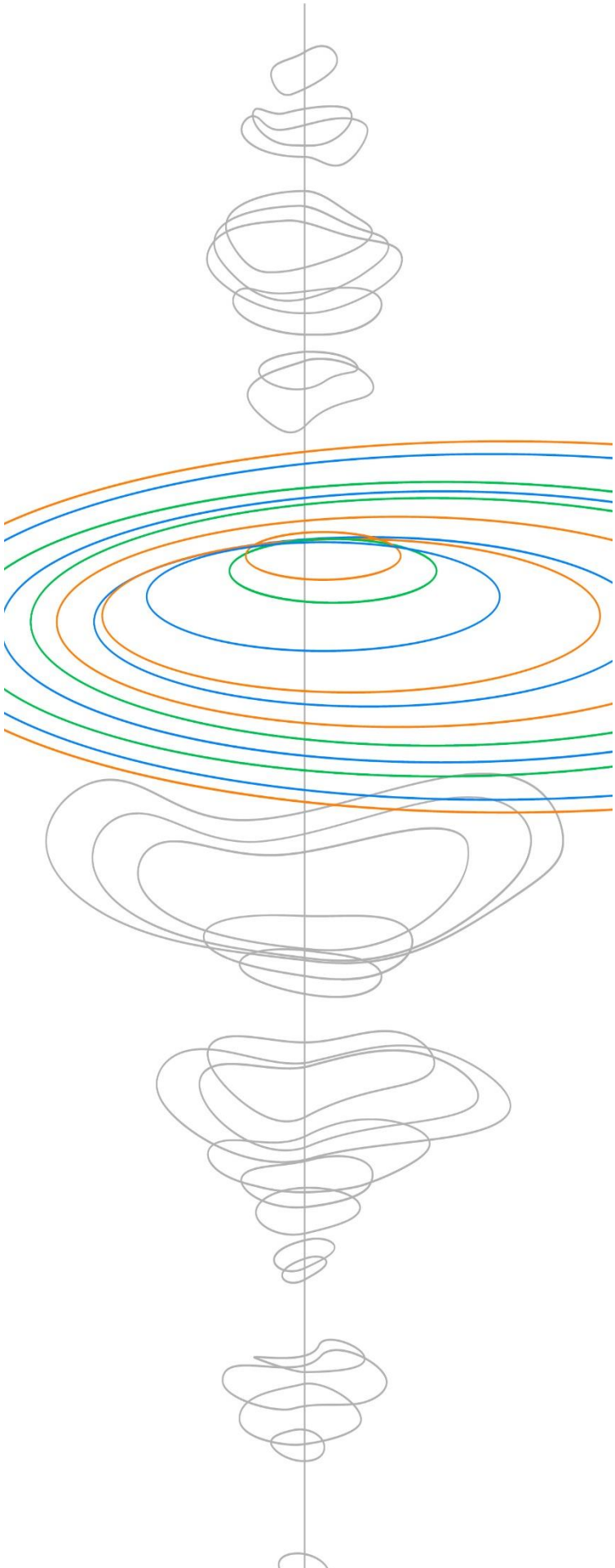
DeFi is a novel and interesting technology offering numerous advantages but also risks. Decentralized lending can be particularly interesting for those who have assets to lend in the crypto ecosystem. However, this activity is not risk-free. A key risk for a lender is the possibility of the loan becoming under-collateralized which should be assessed before considering any investment.

Our study showed however that this risk is currently somewhat limited on a protocol such as Compound, with actors unwilling to build highly leveraged positions. As a result, Compound's bad debt risk is currently not significant. Nevertheless, things can change very quickly in crypto, and 24/7 monitoring is necessary for long-term depositors. For protocols like Compound or AAVE, the price of its token is a key indicator of health as its safety net is highly dependent on it.

Another application of our approach would be to analyze the Celsius crisis and the risks incurred by the Lido protocol during this period. This would be possible by replaying the Ethereum blockchain and Lido's smart contracts in their point in time state, a key feature of the blockchain technology.

References

[1] Mathis Gontier Delaunay, Quentin Garchery, Paul Frambot, Merlin Egalité, Julien Thomas, Katia Babbar. Morpho V1 Yellow Paper.



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The Maximum Diversification® approach, TOBAM's flagship investment process founded in 2006, is supported by original, patented research and a mathematical definition of diversification and provides clients with diversified core exposures, across equity and fixed income markets.

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