From Collateral to Liquidation:
Understanding Trustless Loan Systems

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Abstract

This paper examines collateralized borrowing in cryptocurrency markets. Collateralized borrowing is a practice that has emerged from the DeFi ("Decentralized Finance") movement which facilitates loan provision. The leading decentralized lending platform, Maker is a credit system that allows users to originate their own stablecoin-based loans based on prescribed types of collateral deposited into smart-contract based vaults. We provide a comprehensive understanding of the loan process from debt origination to loan liquidation. Using four years of data (2019-2023), we find that loan protocol parameters (stability fee, liquidation ratio), stablecoin integrity, and collateral concentration affect the demand for loans. Users with greater familiarity with the protocol exhibit lower levels of collateralization, consistent with better overall risk-management practices.

Keywords: Cryptocurrency, trustless lending, DeFi, Collateral, Debt

JEL Codes: G10, G14, D47

1 Introduction

Cryptocurrencies have attracted significant attention over the past decade owing to their potential to disrupt financial systems. Arguably, the most important part of this nascent digital economy is decentralized finance (DeFi) which refers to the use of decentralized networks, smart contracts, and other blockchain-based technologies to deliver financial services that are typically provided by traditional financial institutions. These services include lending, borrowing, trading, and other such financial functions.[1] Currently, over $100 billion USD is locked in DeFi platforms, reflecting the rising rate of adoption and growing confidence in trustless systems.

This paper examines the role of a financial innovation that allows crypto assets to be used as collateral to back autonomous, non-contingent financial loans. Borrowing and lending protocols are amongst the most capitalized cryptocurrency use cases and are designed to facilitate intermediary-free loans through staking (depositing) digital assets. Pledging collateral for loans provides a significant source of short-term funding in cryptocurrency markets.[2] It provides users with the ability to leverage financial positions, engage in intertemporal consumption smoothing, and create non-taxable liquidity events. The focus of this investigation is the pioneering lending protocol Maker, established in 2014.[3] Maker offers trustless borrowing underpinned by smart contracts on the blockchain. In this model, tokens are deposited as collateral for loans in the form the protocol's native stablecoin, Dai. Dai is a stable unit of account that is soft pegged to the U.S dollar and can be used across the cryptocurrency ecosystem as a medium of exchange. Collateralized vaults are non-custodial and key loan parameters (e.g., interest rate, haircuts) are pre-defined in smart

[1]Borrowing and lending protocols make up approximately 30% of TVL (The Block, 2023 – Retrieved from https://www.theblock.co/data/decentralized-finance/total-value-locked-tvl on 18 November 2023). Other use cases include decentralized exchanges derivatives, payments, and asset management protocols. Challenges that face decentralized finance are associated with regulation, smart contract security, scalability, interoperability, custodial risk, liquidity, and volatility risks.

[2]Total value locked (TVL) represents the sum of all assets deposited in decentralized finance (DeFi) protocols. It is thus a measure of supply secured by DeFi applications. Yardeni et al., (2022) for comparison report $820bn of stock pledged for individual stock-based loans, with Chen (2019) and Pang and Wang (2020) suggest that up to 10% of total share capital is pledged for loans.

[3]The Maker Protocol, a pioneering decentralized finance (DeFi) platform, was founded in 2014 by Danish entrepreneur Rune Christensen. In 2018, the Maker Foundation, a non-profit organization, was established to oversee the initial development and funding of the Maker project. This foundation was dissolved in 2021, transitioning the governance responsibilities to MakerDAO, a decentralized autonomous organization (DAO). Consequently, holders of the MKR token assumed the role of governing the Maker Protocol, making decisions on key parameters and ensuring the stability and growth of the ecosystem.

contracts. Unlike traditional loan contracts, DeFi loans are contingent on a small set of quantifiable real-time information and overcollateralization functions as the primary source of risk control (Chiu et al., 2022).[4]

Our paper is among the first to analyze the system of trustless loan generation and user actions in this environment. Specifically, we provide a comprehensive understanding of the Maker protocol, the leading decentralized lending protocol over the last five years, covering critical aspects of loan functionality and liquidation. We conduct an empirical examination of how DeFi users employ their collateral on the protocol to generate loans. We assess the fee structures associated with these loans and the effectiveness of risk management practices employed by users. Furthermore, we evaluate the protocol's effectiveness in dealing with situations that result in vaults becoming undercollateralized. Our analysis also delves into the factors that affect loan demand in this trustless environment. We find that higher stability fees, liquidation ratios, and levels of collateral concentration contribute to lower levels of loan demand. Additionally, greater variance in returns around the Maker native stablecoin is also consistent with a lower demand for loans.

Our paper is most closely related to the recent work of Saengchote (2023), which provides specific insights into the Compound protocol. Both MakerDAO and Compound offer decentralized lending and borrowing services, but they differ significantly in at least three key ways. First, regarding collateral and liquidity, Compound operates with joint liquidity pools. This pooled liquidity is available for borrowers, and lenders earn interest based on the overall demand for borrowing from the pool. In contrast, MakerDAO uses individual debt collateral positions, where user collateral is locked into a vault and not pooled with other vaults. This system allows users to generate debt, minted in their native stablecoin, Dai, with key lending parameters (interest rate on debt, liquidation ratio) managed by a decentralized governance system. Second, Compound uses algorithmic models to determine interest rates for borrowing and lending, whereas MakerDAO's rates are governed by decentralized governance. Finally, a significant driver of loan demand for Compound was the aggressive yield farming incentives through COMP token distribution in the second half of 2020. While this practice also influences MakerDAO's growth, the demand for loans through MakerDAO

[4] Soft information which relates to borrower attributes, and which is utilized extensively in traditional loan contracts does not feature in the process due to the pseudo-anonymity of the blockchain.

is likely to reflect more traditional loan demand properties.

Using four years of data (2019-2023), we find that loan protocol parameters (stability fee, liquidation ratio), stablecoin integrity, and collateral concentration affect the demand for loans. Users with greater familiarity with the protocol exhibit lower levels of collateralization, consistent with better overall risk-management practices. The paper is organized as follows. In Section 2 we provide a comprehensive overview of the Crypto-asset lending market. In this overview, we give specific consideration to the Maker protocol, focusing on loan origination, the role of stablecoin, and the impact of liquidations. We address related literature in Section 3. We detail the data used and variable construction in Section 4. In Section 5, we conduct a protocol and vault level analysis of the Maker protocol. Section 6 concludes.

2 An overview of the Crypto-Asset Lending Market

DeFi lending platforms are part of a decentralized movement that aims to transform traditional financial systems using blockchain technology. DeFi employs smart-contract technology which enable decentralized applications (dApps) to automate financial transactions such as lending and borrowing without the need for financial intermediaries. Within this ecosystem, key lending platforms include MakerDAO, Compound, and Aave. These protocols operate a collateralized loan model, requiring borrowers to provide collateral to secure a loan.[5] The protocols mandate a loan-to-value (LTV) ratio, which determines the amount that can be borrowed relative to the value of the collateral, with interest rate terms ranging from variable to fixed. Where these interest terms are variable, they are algorithmically determined based on supply and demand dynamics within the platform. These loans are generally utilized for leveraging exposure, margin trading, and meeting liquidity needs.[6] Numerous in-depth overviews of the general architecture of DeFi and its suite of protocols are provided by Schär (2021), Harvey et al. (2022) and Aspris et al. (2022). This section

[5]Aave offers uncollateralized loans in the form of flash loans. Flash loans are consummated within a single transaction block, meaning that if the loan is not repaid within the same transaction, the entire transaction is reversed, effectively canceling the loan. These loans are typically used for arbitrage opportunities. There are additionally centralized lending services such as those provided by Binance and Nexo.

[6]Crypto loans provide liquidity without the need to sell existing holdings. For instance, a trader could use their ETH holdings to collateralize a loan for DAI on the Maker protocol, allowing them to retain exposure to movements in ETH while fulfilling their liquidity needs.

discusses the main institutional features of the Maker protocol system: the Maker market (2.1), the Dai Stablecoin (2.2), and the collateral and loans system (2.3).

2.1 The Maker Market

MakerDao launched in 2014 and is a decentralized autonomous organization (DAO) responsible for governing the Maker ecosystem.[7] At its core, Maker is a collateralized loan facility that allows users to issue a debt position against collateral in a permissionless manner. The issued debt takes the form of its native stablecoin, Dai, which is pegged to the US Dollar. Collateralized borrowing is an integral component of the financial plumbing of the cryptocurrency market and Maker loans are a primary source of short-term funding for users. The value of loans outstanding is currently worth $USD 8.3bn with an average collateralization ratio of 157%.[8] Other core features of the Maker protocol include savings, loans on real-world assets (RWA), and the facilitation of liquidity through its stablecoin. These features are described in detail in Figure 1.

[Insert Figure 1 here]

Figure 1 illustrates the collateral and debt positions for Maker vaults over time. Panel A presents the total value of collateral locked (TVL) in the Maker protocol and the amount of debt (Dai) borrowed from the vaults, covering the period from July 2019 to January 2024. This panel captures the growth and subsequent decline in borrowing, which closely mirrors broader trends in the cryptocurrency market, as indicated by the price of ETH shown in Panel B. Panel B depicts the price of ETH relative to the number of new vaults created on the platform over time. The significant rise during the 2020-2022 period underscores the increased adoption of cryptocurrencies and DeFi applications. Conversely, the post-2022 decline in borrowing reflects broader movements in both traditional and crypto markets.

Maker loans are collateralized and held over short durations, and this helps to reduce the cost of

[7] Maker holders stake their MKR tokens to vote on proposed changes to the Maker Protocol, thereby ensuring the efficiency, transparency, and stability of the protocol.

[8] As at 13 June 2024 (source: makerburn.com). ETH vaults have a current TVL of 5.0bn with an average collateralization ratio of 551%.

borrowing for financially constrained investors (relative to default-adjusted uncollateralized borrowing). Increases in the value of the collateral provides users with the ability to increase the size of their loans. Falls in value through safe risk ratios, however, leads to forced liquidations.[9] In financial markets, where banks default on their promise to repurchase the collateral, investors have the right to terminate the agreement and keep (or sell) the collateral. In the Maker protocol, forced liquidations trigger a market-based auction to recover the outstanding debt that will be used to recapitalize the protocol, thereby preserving the stability of the system.

[Insert Figure 2 here]

2.2 Dai Stablecoin

The creation of Maker loans on the distributed blockchain network relies on the Dai stablecoin. The Dai stablecoin was released in 2017, becoming the first stablecoin on the Ethereum protocol. Stablecoin is a catch-all term used to describe a spectrum of coins that peg a token to an exogenous value (Grobys et al., 2021; Lyons and Viswanath-Natraj, 2023). Typically, the external value is the US Dollar. Dai is specifically, a non-pool based, on-chain and collateral-backed stablecoin. It allows for the value of loans to be price-stable making it useful in critical apparatuses in the DeFi ecosystem. Dai is also highly composable meaning that DeFi developers can easily integrate Dai into their applications fostering an environment with widespread positive network and liquidity effects.

[Insert Figure 3 here]

Figure 3 shows how Dai is being utilized by its users in the cryptocurrency ecosystem. Using blockchain data, we categorize Dai daily balances into five groups: centralized protocols (CeFi),

[9] Although the arrangements appear on the surface like a mortgage, that is individuals can get loans against property by borrowing against it, mortgages are not subject to margin calls. Banks have a lien on the collateral which is costly to enforce and MakerDAO loans are overcollateralized with crypto assets that can be automatically liquidated if the collateral ratio falls below a certain threshold, making them more akin to margin loans than traditional mortgages.

decentralized protocols (DeFi), lending protocols (Lending), blockchain bridges (Bridge), and externally owned accounts (EOA). As of December 2021, approximately one-third of Dai balances are held in EOAs, which are Ethereum accounts with traditional key pairs, distinct from smart contract accounts that have unique public addresses. Over 40% of daily balances are held in decentralized lending protocols and exchanges, such as Compound, Yearn Finance, Uniswap, and Aave. Users leverage these protocols for token swaps, position leveraging, arbitrage trading, and high-yield earning opportunities. Additionally, a significant portion of Dai balances are distributed across alternative blockchains, connected via blockchain bridges. Notable examples of these networks include Fantom and Polygon.

2.3 Collateral and Loans

2.3.1 Loan Functionality

Collateral is a central feature in many credit contracts (Stulz and Johnson, 1985; Benmelech and Bergman, 2009). It disciplines the borrower by allowing the lender to seize the collateral in case of default. In the case of the Maker protocol, collateral preserves the integrity and solvency of the Maker ecosystem. Debt issuance is analogous to the creation of a risky debt obligation, requiring users to lock their risky assets (from a preselected list of accepted cryptoassets) into personalized Maker vaults. These vaults are self-custodial and held by users through Ethereum-based addresses. To repay this debt, borrowers must repay the Dai-denominated loan, including interest charges, to reclaim their collateral which is burnt and removed from circulation. The amount of collateral required for each vault to maintain the loan obligation depends on the value of the collateral relative to the allowed threshold (liquidation ratio). These limits are influenced by risk factors such as the expected volatility of the crypto-asset being used as collateral. The Dai loan can be repaid at any time to retrieve the collateral.

[Insert Figure 4 here]

The protocol charges a Stability Fee ("Fee") to borrowers which is the interest charge on the Dai-denominated debt as is typical in most traditional loan arrangements. This Fee is is continuously compounded rate of interest that accrues to the outstanding debt balance.[10] Importantly, this Fee can influence the number of Dai in circulation since raising (lowering) interest rates makes borrowing Dai more (less) expensive. The fees are variable over time and subject to the discretion of MKR Governance token holders, with consideration given to the price stability of the Dai stablecoin, the risk-adjusted return to the Maker Protocol, and the competitive nature of the yield within the global landscape. The evolution of key parameters within the Maker protocol since its inception is illustrated in Figure 5. Over the sample period, the stability fee has predominantly fluctuated within a narrow range of 2-5%. The initial high level of collateralization reflects a substantial margin of safety on the principal locked collateral, Ether (ETH). Subsequent decreases in the collateralization ratio can be attributed to the incorporation of stablecoins with significantly lower liquidation ratios. The substantial uptick in the liquidation ratio is a consequence of the market instability associated with the collapse of TerraUSD (UST) in May 2022, which precipitated a approximately 65% decline in the price of Bitcoin, the leading cryptocurrency, over the ensuing three-month period.

[Insert Figure 5 here]

A final and important risk element within the Maker lending platform is the debt ceiling. The debt ceiling resolves the maximum number of Dai that can be lent out given a particular collateral type. The level of collateral in turn is linked to the Maximum Exposure Level (MEL) and is related to the exposure of a specific type of collateral relative to the available supply. The Dai debt ceiling can be adjusted to allow for more or less supply to meet demand changes, with the ceiling preventing new Dai from being minted.

2.3.2 Collateral Types

Up until November 2019, Ether was the only collateral accepted by Maker for loan creation. Following the transition to a multi-collateral Dai model, the MakerDao community initiated the accep-

[10] Appendix A provides a comprehensive review of the stability fee and DSR accumulation in Maker.

tance of new collateral types, including various utility tokens, payment tokens, security tokens, and, most recently, stablecoins. Appendix B provides a list of the approved tokens permitted for use as collateral to generate Dai-denominated loans, including details of the onboarding and offboarding processes.

2.4 Motivations for Issuing Dai

Collateralized loans are used by a diverse group of users to finance margin trades, create non-taxable liquidity events, execute arbitrage trades, and engage with a vast number of other applications and services. The primary purpose for collateralized loans is investment leverage. To illustrate this, consider an investor with a holding of 1ETH and a cost base of $1,500. Further, assume the investor is capital constrained with an expectation that the price of their holding will double (positive state) in value over the short-to-medium term. Using the Maker protocol, an investor can obtain their desired leverage by first locking up her 1ETH as collateral in a vault. Assuming the investor can borrow at the liquidation ratio of 1.5x, 1,000 Dai can be issued against the collateral, resulting in a 1,000 Dai debt balance. This debt balance can then be exchanged via the secondary market for 0.67ETH meaning that through the vault the investor has exposure to 1.67ETH. This process can be recursively exercised, giving the investor up to 3x leverage. In practice, any drop in collateral value will result in a position being automatically liquidated with a penalty cost which deters users from overextending their use of leverage in the system. Users will typically hold buffers which are linked to the perceived riskiness of the underlying collateral. To provide attestation to such a scenario, Figure 6 describes the transaction cycle of single user vault over a trading day.

[Insert Figure 6 here]

A secondary use-case involves short-term liquidity needs. Users with an optimistic outlook on the price of their collateral may not want to liquidate their collateral holdings and therefore sacrifice potential future upside. By allowing users to lock their collateral, and generating a Dai debt position, the Maker protocol provides users with optionality. Where users are conscious of liquidity concerns over their collateral, the Maker protocol may additionally assist investors with avoiding the high cost of price impact. Whereas the deposit of risky assets as collateral is associated with speculators looking to leverage their position or alternatively gain utility from the Dai in DeFi applications, the use of stablecoins as collateral on the protocol harbours different intentions. The primary purpose of stablecoins as collateral in the protocol is to engage in arbitrage activity. Where the demand for Dai, for example, drives the Dai trade at a premium to its dollar peg, arbitrageur gains could be earned by exploiting differences with centralized stablecoin equivalents. To close a peg-price premium, arbitrageurs deposit collateral, borrow Dai and sell this in the secondary market. This action of leaning on centralized stablecoins has to date seen Dai hold its peg with the USD over periods of market volatility and instability.

2.5 Liquidations and Auctions

Collateralization is the primary mechanism for achieving economic security in trustless lending protocols. If the collateralization level in a user vault falls below a system-defined threshold, automatic redemptions of collateral can be triggered. System arbitrageurs, known as "Keepers," are tasked with reducing user borrowing exposure and are economically incentivized to maintain system stability by claiming sequestered collateral at a discounted valuation.

The state of collateralization for a user vault is monitored by price oracles, which notify the system once the collateralization ratio crosses the threshold. When liquidation is triggered by a Keeper (or liquidator), an internal market-based auction (Dutch auction) is held for the seized collateral to recover the outstanding debt.[11] Collateral auctions are designed to recover debt from insufficiently collateralized vaults, thereby recapitalizing the system. Keepers, typically represented as automated bots, use proprietary bidding models to win auctions based on the value of the collateral. Previous literature on the determinants of liquidation values of assets suggests that the redeployability of assets (Williamson, 1988) and asset illiquidity (Shleifer and Vishny, 1992) help explain cross-sectional and time-series patterns. However, the distinctive features of blockchain, such as settlement design and legal enforceability, limit further comparisons.

[11] Liquidated vaults also incur a penalty fee, which is applied to the Dai debt and subtracted from collateral holdings. As of the time of writing, this penalty fee is 13%. This fee serves as a dual incentive for users to maintain sufficient collateral and for Keepers to trigger the auction when a position becomes undercollateralized.

The auction process runs in multiple phases. In the first phase, Keepers bid for the amount of debt (Dai) they want to cover, with the payment increasing until target proceeds are met. In the second phase, with the debt amount set, liquidators bid for the debt collateral. The reward received decreases until no bidders are willing to tender lower bids, or the auction reaches its maximum duration. The conclusion of the auction unlocks the auction reward, which is settled based on the auction price of the collateral relative to its market value. If the auction reward is less than the collateral originally offered (due to decreasing bids in the second phase), the difference, less penalty fees, is returned to the owner of the liquidated vault.[12]

In the event that the value of collateral falls below the value of the outstanding debt, a buffer pool within the MakerDao protocol is used to cover the debt deficiency. The accumulation of these bad debts reduces liquidity in the lending protocol, potentially leading to the intervention of MKR Governance token holders. MKR token holders assume ultimate responsibility for the recapitalization of the protocol if liquidations fail to cover the outstanding Dai. They may adjust the Stability Fee for borrowers or issue additional MKR tokens, which are auctioned off in exchange for Dai to cover protocol losses. Although this practice is dilutive to MKR token holders, they are incentivized by cash flows from interest revenue and liquidation fees to ensure the system's solvency.[13]

3 Related Literature

This work is part of a diverse and extensive literature on the use of collateral in debt contracts. Theoretical literature has shown that both ex-ante and ex-post asymmetric information problems can restrict borrowing capabilities in traditional financial markets. The use of collateral can help to alleviate such frictions and promote better access to credit and higher borrower debt capacity (Besanko and Thakor (1987); Boot and Thakor (1994)). The work in this paper is additionally part

[12] On March 13, 2020, following a 43% drop in the price of ETH, a fault in the liquidation bots caused the liquidation transactions not to be included in the blockchain, allowing other liquidators to win the MakerDao auctions at negligible cost. Since then, Maker has implemented several updates to its liquidations module, including instant settlement, flash lending of collateral, and price-versus-time curves.

[13] The system aims to maintain a buffer of 60 million Dai, with any surplus used to buy back and burn MKR, mitigating the dilutive effect.

of an emerging literature on decentralized finance. A first strand of literature examines the role and impact of protocols that help to bypass financial intermediation, with the primary focus being on the role and impact of decentralized exchanges (Aspris et al. (2021); Aoyagi and Ito (2021); Capponi and Jia (2021); Lehar and Parlour (2021); Park (2023)). Another strand of literature studies the structure of decentralized lending Chiu et al. (2022) and stablecoins (d'Avernas et al. (2022), Li and Mayer (2022); Kozhan and Viswanath-Natraj (2021)).

4 Data selection

The data utilized in this paper are obtained from several sources. First, we acquire data directly from the Maker protocol via its Application Programming Interface (API), covering the period from November 13, 2019, to October 1, 2023. The MakerDAO API retrieves data directly from the Ethereum blockchain, where all transactions and states of the Maker Protocol are recorded.[14] The Maker API provides access to vault-level data, which includes a detailed transaction history of individual user activities such as deposits, withdrawals, debt creation, and debt payback. Each transaction is time-stamped to the nearest second and is associated with specific digital wallet addresses. The dataset includes 31,061 unique vaults, featuring 188,292 deposits and 139,999 withdrawals, and 198,254 debt-generating events and 128,020 debt payback events. The value of loans generated across these vaults amounts to over USD 33.3 billion, with fees (interest) generated on these loans totaling over USD 200 million. Over the sample period, 2,245 liquidation events are triggered on 2,061 vaults to maintain the stability and integrity of the Maker protocol. This dataset also includes protocol-level parameters, detailing the collateral types that have been onboarded and the specific risk parameters such as the stability fee, minimum collateralization ratio, and debt ceiling that apply to each collateral type. Additionally, we capture governance-level data at the protocol level, specifically voting statistics related to the onboarding of new collateral types.

We supplement our token series with a selection of on-chain metrics which are used to illuminate

[14]Data from the Maker API is retrieved from the endpoint: https://data-api.makerdao.network. A web-based UI is available at https://maker.blockanalitica.com/. The MakerDAO API provides a streamlined way to access and interact with data on the Ethereum blockchain, which can be verified and further explored using Etherscan, a blockchain explorer.

user behaviour from the blockchain ledger. This data is sourced from Coinmetrics.io which is a leading provider of crypto asset market and network data (Tsang and Yang, 2021). Among metrics obtained, include the number of unique and active addresses in the network, the number of on-chain transactions, measures of supply dispersion such as the network distribution factor (NDF), and valuation metrics including network value transfer (NVT).[15]. We additionally obtain trading data for all tokens used as collateral on Maker. The data is obtained from CoinMarketCap.com, which is a commonly used source of data in cryptocurrency-related research (Momtaz, 2021) and includes fields such as daily prices, trading volume, circulating supply, and market capitalization. We obtain an additional secondary price series from Brave New Coin (BNC) to limit the possibility of erroneous inferences drawn from data discrepancies.

4.1 Loan Demand Model

To formally examine the factors affecting loan demand (LD) based on a multi-collateral framework we specify the following equation as follows:

$$\begin{aligned} LD_{it} = &\beta_0 + \sum_{p=1}^{3} \beta_{1p} \text{ProtocolParams}_{p,i,t-1} + \sum_{c=1}^{3} \beta_{2c} \text{CollateralFactors}_{c,i,t-1} + \sum_{o=1}^{3} \beta_{3o} \text{OtherFactors}_{o,i,t-1} \\ &+ \text{FEs} + \epsilon_{it} \end{aligned} \tag{1}$$

In this model, LD_{it} represents the loan demand for collateral i at time t. LD_{it} is expressed and examined in three ways: 1) it is the value of all outstanding collateralized debt positions; 2) It is the value of new loan positions added on the protocol for collateral i at time t ; 3) It is the net-value (minus loans paid back) of new loan positions. The term β_0 is the intercept. The sum $\sum_{p=1}^{3} \beta_{1p} \text{ProtocolParams}_{p,i,t-1}$ represents the protocol parameters, which include the stability fee,

[15]The BNC Digital Currency Indexed EOD data feed contains historical price indexes for 1,500+ cryptocurrencies and 6,000+ currency pairs, as captured and calculated by Brave New Coin (BNC). The data includes OHLC prices, volume, VWAP and TWAP, volume-weighted across exchanges and consolidated according to BNC's methodology. Historical coverage varies by currency, with the longest history dating back to April 2014. See https://data.nasdaq.com/databases/BNC2/documentation

the liquiditation ratio, and the Dai savings rate (DSR). The $\sum_{c=1}^{3} \beta_{2c}\text{CollateralFactors}_{c,i,t-1}$ include market volatility, 7-day moving average collateral returns, and the volatility of the Dai stablecoin. The $\sum_{o=1}^{3} \beta_{3o}\text{OtherFactors}_{o,i,t-1}$ encompass average gas fees for transacting on the Maker protocol, vault age, and a distance from peg, associated with the variance of returns on Dai. The term FEs are the fixed effects, and we include collateral type and time-specific effects. These are used to control for changes in loan effects across collateral and time. Finally, ϵ_{it} is the error term. Standard errors are clustered at the collateral and date level.

5 Summary Statistics

5.1 Protocol Level Analysis

Summary statistics in Table 2 show user activity and protocol parameters for the Maker collateral over the full sample period.[16] The statistics are organized based on the form of collateral locked in the user vault. The most popular collateral form among vault users is Ethereum (ETH), a leading base protocol coin for DeFi applications. Users can choose between three different types of Ethereum-collateralized debt positions, each with distinct parameters. For example, ETH-A has a liquidation ratio of 150% and an average stability fee of 2.2% over the period, while ETH-B has a higher stability fee (5.5%) but a lower liquidation ratio (130%), allowing users to generate more Dai but with increased risk and cost. The figures reveal a positive correlation between the variance in returns of the underlying collateral and the protocol parameters. A structured governance process is used to evaluate changes in liquidity, volatility, and other relevant factors, and to implement changes based on these evaluations. The demand for loans on Maker is not uniform, with KNC (Kyber Network Crystal) token drawing only $52.1 million in locked collateral and generating only 0.1 vaults per day for a total of $21.54 million in Dai loans.[17] Vault positions and protocol parameters for stablecoin collateral are documented in Panel B. The stability fees and liquidation ratios of these stablecoin vaults are considerably lower than those of crypto-asset-collateralized vaults, which is

[16] We exclude liquidity pool loans, lending protocol loans, and real-world asset (RWA) loans from consideration.

[17] The Maker governance team evaluated the risk and performance of this collateral type and determined it did not meet the adequate standards, resulting in a proposal to offboard the token after only 15 months of its initial onboarding.

expected given their risk profile. However, there is some variation in terms of preference, with USDC and USDP (PAXUSD-A) providing the most favorable terms and generating the highest level of demand.

6 Vault Analysis

6.1 Collateral Provision and Loan Demand

Figure 1 describes the total value of collateral locked (TVL) into the Maker protocol between November 2019 and March 2022. The total value locked into the protocol rose to USD5 billion in February 2021, approximately 18 months after the launch of the Dai stablecoin. Growing interest in the ecosystem of decentralized applications (exchanges, lending, bridges) combined with greater exposure to alternative collateral types, significantly escalated the rate of growth of the protocol, with the value of collateral locked in the protocol quadrupling by December 2021, reaching approximately USD20billion.

Table 4 provides summary statistics for variables of interest related to collateralized vaults over the sample period. Panels A-C present variables that describe the daily position of vaults, the daily transactions associated with vaults, and the corresponding fees, respectively. Over the sample period, 16,652 active crypto collateral-backed unique vaults transacted on the Maker protocol.[18] The average vault in our sample is approximately 0.72 years old and has a collateral balance of $880,850 and a debt balance of $286,610. The average vault is overcollateralized at 4.87 times compared to a liquidation ratio of 1.73 times. Vaults maintain an active collateral and debt balance for over 85% of the sample period. Notably, collateral and debt balances exhibit considerable right skew. Focusing on vault transactions, Panel B of Table 4 shows that, on average, each vault has 9.22 collateral-increasing actions and 7.18 collateral-decreasing actions. The average transaction size for these events is $2,746,950 and $2,796,590, respectively. Additionally, each vault has, on average, 9.88 debt-increasing actions and 6.62 debt-decreasing actions, with the size of each debt-

[18]There are a further 522 stablecoin-backed vaults. Stablecoin backed vaults are not principally driven by a desire for leverage and are thus considered separately. Results for stablecoin-backed vaults are included in the Appendix.

generating and payback event being $1,287,490 and $1,294,470 respectively. Our analysis of vault costs in Panel C shows that fees corresponding to each vault, on average, make up 1.46% of the total outstanding debt. Similar to vault positional balances, transaction activity is positively skewed, with nine times as many debt-generating actions in the third quartile as in the first quartile of vaults. Loan size is approximately twenty-five times larger. This suggests user-level heterogeneity and disparate loan activities.

Table describes the provision of capital on the Maker protocol. Over the sample period, 15 altcoins and 5 stablecoins were onboarded on the Maker protocol allowing users to deposit their collateral and engage with the permissionless lending platform. Within specific collateral types, multiple tranches may exist which employ different combinations of protocol parameters. ETH-A, ETH-B, and ETH-C, for example, relate to the use of Ethereum as collateral, which provide users with different combinations of liquidation ratios and stability fees. The main collateral types used in the Maker protocol are ETH and BTC (or 'wrapped Bitcoin') with an average 24.8 and 4.37 vaults added daily since inception. On average, with each of the collateral types, there are 197.64 and 27.59 collateral actions, which is the act of depositing or withdrawing collateral from user vaults. Users with ETH wallets furthermore deposit on average, USD42.89m per day on the protocol. The size of collateral balances for the altcoin class dwarf stablecoin alternatives which is naturally a reflection of the number of use cases for altcoins versus stablecoins. Two further interesting insights are gleaned from Table 1. First, the rapid growth in the overall value of collateral locked into the protocol is disproportionately spread across the different collateral types. For example, despite the BAT token being part of original launch of the multi-collateral Dai, its value to the overall protocol has been negligible, with collateral balance attributable to this token averaging 0.42A second noteworthy result that is gleaned from Table 1 is the relationship between the supply of collateral for loan provision and parameter protocols. Tokens with higher levels of price dispersion are correlated with higher liquidation ratios for users. The flexibility to set these individual risk parameters controls the risk to the protocol that comes from a drop in the price of a collateral asset. As such, liquidation ratios assigned to risky collateral exceed that assigned to stablecoins by a significant margin. It is important to consider that higher liquidation ratios render vaults less capital efficient, being unable to issue as much debt, therefore making such vault less attractive to users.

7 Conclusion

This paper examines the role of a financial innovation that allows crypto assets to be used as collateral to back autonomous, non-contingent financial loans. We provide a comprehensive overview of trustless loans within the crypto-asset market, specifically focusing on the mechanism identified as Maker. We highlight key aspects of the process, from loan origination to loan liquidation for undercollateralized loans. Additionally, we empirically assess the factors affecting loan demand (LD) within this multi-collateral framework, focusing on protocol parameters, collateral performance, and market-based factors. Our findings suggest that both protocol-based factors and collateral performance significantly impact the demand for Maker loans. Our analysis also examines individual vault actions, particularly the role of learning in user debt actions. We find that as users become more familiar with the protocol, their risk management practices become more efficient, resulting in lower levels of overcollateralization.

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Table 1: Table 1

Collateral Summary Statistics This table summarizes the activity and protocol parameters for the Maker facility by individual collateral assets. *Vaults Added* represents the daily number of vaults added to Maker. *Collateral EOD* and *Debt EOD* are the average collateral and debt at the end of the day for the different forms of collateral, respectively. These values are expressed in thousands (ten) of US dollars (USD). *Deposit* and *Debt Generated* are the values of deposits and debt originated from the respective collateral forms over the sample period, expressed in millions of USD. *Stability Fee, Liquidation Ratio, Debt Ceiling, and Min Debt* are the median values of the stability fee (annualized), liquidation ratio, debt ceiling, and minimum vault debt. *Daily Return* is the average daily return, and *Volatility* is the average daily volatility, measured using the Parkinson daily volatility measure. Both return and volatility estimates are measured from the period of collateral onboarding until the last generated vault in the sample period. These variables are expressed in percentage terms. Panel A reports estimates for crypto-assets onboarded to the Maker protocol over the period utilized for debt origination. Panel B reports estimates for stablecoins onboarded to the Maker protocol over the sample period.

	Vaults Added	Collateral EOD	Principal EOD	Deposit	Debt Generated	Stability Fee	Liquidation Ratio	Debt Ceiling	Min Debt ($)	Daily Return	Volatility
Panel A. Crypto-Assets											
AAVE-A	0.12	175.83	44.49	368.38	168.19	1.00%	2.10	102.79	10.00	0.20%	13.09%
BAL-A	0.06	154.56	45.29	107.61	57.11	1.00%	1.75	40.51	10.00	0.16%	12.61%
BAT-A	0.52	41.15	12.49	473.98	189.54	4.00%	1.50	100.00	5.00	0.18%	9.90%
COMP-A	0.05	414.44	97.39	248.23	140.93	1.00%	1.75	100.00	10.00	0.16%	8.13%
ETH-A	12.62	845.46	249.67	260,339.52	128,118.45	2.20%	1.50	33,955.56	5.00	0.29%	7.20%
ETH-B	0.98	1,146.01	483.89	34,406.83	18,230.35	5.00%	1.30	2,617.05	30.00	0.27%	8.06%
ETH-C	2.01	2,872.14	713.16	68,570.60	25,550.16	0.50%	1.70	8,262.08	5.00	0.11%	7.34%
GNO-A	0.01	23,281.13	1,490.16	380.72	30.96	2.50%	3.50	50.00	100.00	0.15%	2.85%
KNC-A	0.10	12.05	3.25	52.10	21.54	5.00%	1.75	50.00	10.00	0.16%	13.88%
LINK-A	0.48	935.95	284.49	11,113.13	4,153.37	2.50%	1.65	1,400.00	10.00	0.13%	9.77%
LRC-A	0.08	159.10	27.27	337.57	118.91	4.00%	1.76	42.89	10.00	0.32%	14.57%
MANA-A	0.07	3,415.63	472.79	884.33	216.54	6.00%	1.75	161.67	10.00	0.68%	13.81%
MATIC-A	0.04	10,964.59	1,604.19	1,837.06	277.28	3.00%	1.75	297.38	15.00	0.08%	10.59%
RENBTC-A	0.15	213.15	67.91	595.71	244.86	2.50%	1.65	73.24	15.00	0.04%	7.76%
RETH-A	0.31	570.15	312.88	750.23	458.60	1.50%	1.70	35.13	15.00	0.26%	3.23%
UNI-A	0.28	322.26	105.21	1,629.64	936.64	3.00%	1.65	246.11	15.00	0.26%	12.40%
WBTC-A	2.00	1,623.80	607.14	92,719.02	37,145.52	2.50%	1.45	14,018.64	10.00	0.16%	7.12%
WBTC-B	0.23	663.56	279.35	1,704.09	942.70	4.00%	1.30	444.28	30.00	-0.08%	5.46%
WBTC-C	0.57	1,122.41	353.89	11,234.43	4,089.02	0.70%	1.75	2,038.70	7.50	-0.09%	4.90%
WSTETH-A	0.71	3,215.97	1,010.73	21,255.73	10,502.58	2.20%	1.60	1,860.09	15.00	-0.03%	3.32%
WSTETH-B	0.85	3,326.99	1,144.58	20,645.41	9,260.47	0.00%	1.85	1,534.17	5.00	0.08%	3.32%
YFI-A	0.30	1,941.58	330.49	7,259.64	3,819.89	1.00%	1.65	798.84	10.00	0.11%	12.74%
ZRX-A	0.08	155.73	45.57	271.47	96.74	4.00%	1.75	67.78	10.00	0.18%	12.54%
Panel B. Stablecoins											
GUSD-A	0.02	223.27	207.64	112.07	103.42	1.00%	1.01	50.00	15.00	0.01%	1.27%
PAXUSD-A	0.03	3,047.65	3,006.80	1,347.08	1,289.56	1.00%	1.01	1,000.00	10.00	0.00%	1.03%
TUSD-A	0.09	957.39	947.28	722.31	710.91	0.00%	1.01	1,350.00	10.00	0.00%	0.45%
USDC-A	0.96	810.28	798.75	18,889.74	16,565.73	0.00%	1.01	5,550.00	10.00	0.00%	0.81%
USDC-B	0.03	2.84	2.09	445.86	323.85	50.00%	1.20	300.00	10.00	0.00%	1.01%
USDT-A	0.08	1.09	0.53	49.15	26.63	8.00%	3.00	100.00	10.00	0.00%	0.33%

Table 2:

Liquidation Descriptives This table reports descriptive statistics for vault liquidations on the Maker protocol against different forms of collateral. *Liquidations* and *Unique Vault Liquidations* describe the total number of liquidations and the unique number of liquidations to user vaults, respectively. *Debt Liquidated* is the dollar value of debt liquidated when a vault becomes undercollateralized. *Liquidate Fees* are the penalty fees associated with risky borrowing practices and the incentive fees given to Keepers for actively monitoring the system and participate in auctions. *Liquidate Fees (%)* are the fees expressed as a percentage of debt liquidated. *Liquidations ($)/ Debt Generated ($)* are the proportion of loans that have defaulted over the sample period relative to the debt generated. *Collateral Discount (%)* is the discount that is associated with the collateral that is auctioned off to recover the debt. *Collateral Sold (%)* is the percentage of collateral sold to recover the debt and fees. Any remaining collateral after covering the debt and fees is returned to the vault owner.

ILK	Liquidations	Unique Vault Liquidations	Debt Liquidated ($)	Liquidate Fees ($)	Liquidate Fees (%)	Liquidations ($) / Debt Generated ($)	Collateral Discount (%)	Collateral Sold (%)
AAVE-A	38	36	2.48	0.02	0.92%	14.55%	(1.39%)	54.43%
BAL-A	13	11	0.30	0.00	0.61%	5.13%	(1.40%)	49.29%
BAT-A	239	224	3.08	0.06	1.88%	15.80%	(8.55%)	24.84%
COMP-A	16	16	0.91	0.00	0.15%	6.41%	(1.54%)	60.92%
ETH-A	3,017	2,793	201.38	1.98	0.98%	1.51%	(0.86%)	77.51%
ETH-B	90	88	64.76	0.63	0.97%	3.30%	(0.21%)	85.14%
ETH-C	231	220	31.54	0.08	0.25%	1.22%	(0.86%)	66.69%
GUSD-A	5	4	0.34	0.00	0.32%	3.31%	(0.12%)	93.58%
KNC-A	35	32	0.09	0.00	0.34%	4.06%	(1.89%)	24.88%
LINK-A	141	115	13.54	0.13	0.96%	3.20%	(0.90%)	65.26%
LRC-A	30	25	1.40	0.01	0.68%	11.67%	3.17%	54.19%
MANA-A	13	12	0.16	0.00	0.78%	0.67%	(1.89%)	69.00%
MATIC-A	7	5	0.33	0.00	0.34%	1.18%	(0.90%)	55.33%
PAXUSD-A	9	9	6.17	0.12	1.92%	4.75%	(0.05%)	100.00%
RENBTC-A	29	29	1.79	0.04	2.24%	7.07%	(0.29%)	63.20%
RETH-A	1	1	0.17	0.00	0.02%	0.36%	(0.52%)	67.87%
TUSD-A	33	31	26.25	0.42	1.59%	36.87%	(0.05%)	92.68%
UNI-A	70	64	7.35	0.04	0.52%	7.77%	(2.87%)	66.77%
USDC-A	248	248	223.68	3.54	1.58%	13.18%	(0.01%)	83.08%
USDT-A	9	9	0.00	0.00	5.36%	0.04%	(1.12%)	57.82%
WBTC-A	300	276	77.40	0.92	1.19%	2.00%	(0.90%)	76.05%
WBTC-B	12	12	1.30	0.01	1.13%	1.33%	(0.86%)	89.66%
WBTC-C	17	16	1.51	0.00	0.16%	0.37%	(0.86%)	63.59%
WSTETH-A	47	47	5.38	0.05	0.90%	0.50%	0.14%	72.21%
WSTETH-B	1	1	0.18	0.00	0.04%	0.02%	(8.52%)	68.22%
YFI-A	44	39	2.54	0.02	0.67%	0.65%	(1.89%)	66.27%
ZRX-A	35	31	5.34	0.03	0.56%	53.99%	(5.95%)	44.95%
Average	4,730	4,394	679.38	8.10	1.19%	2.48%	(0.86%)	72.99%

Table 3:
Loan Demand This table reports the results of the panel regression for loan demand and loans added on the Maker protocol. The dependant variable *Loan Demand* is the value of all outstanding collateralized debt positions on Maker. *Loans Added* are the value of new loan positions created on day t. *Net Loans Added* are the net-value of loans (less payback) added on Maker. The first specification considers all vaults, including crypto- and stablecoin-backed assets. The remaining specifications only consider crypto-backed assets. The explanatory variables are related to protocol parameters, the underlying collateral, and stablecoin integrity. *Stability Fee* is the stability fee of collateral i at time t. *Liquidation Ratio* is the minimum required collateralization level for each collateral i at time t. *DSR* is the Dai Savings Rate on the Maker Protocol, a variable interest rate that allows DAI holders to earn a return on their holdings. *Vault Age* is the average age of active vaults. *Return (7-day)* is the lagged 7-day moving cumulative return associated with the locked collateral. *Volatility* is the daily volatility of ETH, and *Concentration* measures collateral concentration, specifically the percent of value collateral held by the top 1000 holders. *Gas Fee* is an estimate of gas fees associated with blocks that contain Maker vault transactions. *Peg* is the average daily distance from parity for the Dai stablecoin. All explanatory variables, with the exception of lagged cumulative returns are lagged by one period (day). The model includes collateral and date fixed effects (FE), and standard errors are clustered at the collateral and daily levels, reported in parentheses. *p<.1; **p<.05; ***p<.01.

	Loan Demand	**Loan Demand**	**Loans Added**	**Net Loans Added**
	All	*Crypto*	*Crypto*	*Crypto*
Intercept	9.929 ***	21.154 ***	14.203 ***	12.818 ***
	(0.800)	(0.616)	(1.184)	(1.079)
Stability Fee	-1.180 ***	-0.525 ***	0.146 ***	0.326 ***
	(0.033)	(0.026)	(0.044)	(0.044)
Liquidation Ratio	-0.824 ***	-0.876 ***	-0.592 ***	-0.677 ***
	(0.045)	(0.043)	(0.045)	(0.073)
DSR	0.528 ***	-0.014	-0.324 ***	-0.435 ***
	(0.026)	(0.021)	(0.035)	(0.032)
Vault Age	2.330 ***	1.338 ***	1.395 ***	1.772 ***
	(0.093)	(0.083)	(0.080)	(0.074)
Return (7day)	-0.000 ***	-0.000 ***	0.000	-0.000 ***
	(0.000)	(0.000)	(0.000)	(0.000)
Volatility	0.001 *	0.001	0.003 ***	0.005 ***
	(0.001)	(0.000)	(0.001)	(0.001)
Concentration	-2.536 ***	-10.150 ***	-7.775 ***	-5.808 ***
	(0.280)	(0.200)	(0.204)	(0.205)
Gas Fee	0.005 ***	0.004 ***	0.006 ***	0.005 ***
	(0.001)	(0.001)	(0.001)	(0.001)
Peg	-0.016 ***	-0.022 ***	-0.017 ***	-0.009
	(0.004)	(0.006)	(0.006)	(0.007)
Fixed Effects	Yes	Yes	Yes	Yes
Observations	8,338	7,768	4,832	3,813
R-Square (%)	62.41	81.94	19.99	49.61

Table 4:
Vault Summary Statistics. Panel A presents descriptive statistics. It summarizes the vault balance statistics for vaults created in Maker during the sample period. *Collateral (Debt) Balance* refers to the balance of the vault expressed in USD. The *Collateralization Ratio* is the ratio of the value of the locked collateral to the generated debt. The *Liquidation Ratio* represents the minimum collateralization level required for a Maker Vault to avoid liquidation. *Zero Collateral (Debt) Balance Days* indicate the percentage of days over the sample period when vaults have a zero collateral (debt) balance. Panel B summarizes the transactions for these respective vaults during the sample period. Vaults created with stablecoins are excluded from this analysis. Additionally, only vaults older than 30 days are retained. An account is considered inactive when the collateral balance of a vault is zero for a period of 90 days. *Collateral (Withdrawn)* represents the USD values deposited into and withdrawn from user vaults. *Debt Generated (Payback)* refers to the value of debt generated and paid back in a transaction. *Collateral Actions (Add/Withdraw)* are the number of collateral changes for each Maker vault. *Debt Actions (Add/Payback)* are the number of debt actions associated with each vault. Panel C reports the average stability fee incurred per vault, as well as the average liquidation fee incurred during a liquidation event.

	n	Mean	StdDev	5th Percentile	1st Quartile	Median	3rd Quartile	95th Percentile
Panel A. Vault Summary								
Collateral Balance ($000)	16,652	880.85	13,953.86	0.20	5.13	34.51	154.99	1,781.41
Debt Balance ($000)	16,652	286.61	4,730.21	0.03	1.31	9.93	48.15	541.86
Collateralization Ratio	16,524	4.87	15.71	1.98	2.52	3.16	4.34	10.42
Liquidation Ratio	16,652	1.73	4.24	1.45	1.49	1.50	1.50	1.75
Vault Age	16,652	262.65	246.62	37.00	80.00	170.00	371.00	817.00
Zero Collateral Balance Days (%)	16,652	9.89	21.04	0.00	0.38	1.10	3.23	65.18
Zero Debt Balance Days (%)	16,652	15.58	27.00	0.00	0.52	1.69	16.57	84.68
Panel B. Vault Transactions								
Collateral Added ($000)	16,651	2,746.95	56,216.47	0.26	7.23	51.83	286.30	4,338.33
Collateral Withdrawn ($000)	15,926	2,796.59	55,897.64	0.39	9.57	57.52	315.73	4,725.71
Debt Generated ($000)	16,649	1,287.49	22,329.53	0.10	3.47	24.50	142.68	2,305.00
Debt Payback ($000)	15,787	1,294.47	22,784.36	0.10	2.89	21.06	134.54	2,300.00
Collateral Liquidated ($000)	4,054	165.62	1,794.49	0.03	0.28	7.78	35.31	409.15
Principal Liquidated ($000)	4,054	103.40	1,087.08	0.02	0.18	5.00	21.73	252.60
Collateral Actions (Add)	16,652	9.22	22.72	1.00	2.00	3.00	8.00	35.00
Collateral Actions (Withdraw)	15,927	7.18	28.71	1.00	1.00	2.00	5.00	27.00
Debt Actions (Add)	16,649	9.88	24.10	1.00	2.00	4.00	9.00	38.00
Debt Actions (Payback)	15,787	6.62	18.01	1.00	1.00	2.00	6.00	24.00
Panel C. Vault Transaction Fees								
Stability Fee (%)	16,652	0.03	0.02	0.00	0.02	0.03	0.04	0.06
Stability Fee / Debt (%)	16,274	1.46	1.64	0.00	0.27	0.86	2.03	5.08
Liquidation Fees ($)	4,054	992.92	6,772.29	0.00	0.37	16.10	227.97	3,160.78

Table 5:
Vault Analysis - Duration and Activity This table presents descriptive statistics for key variables related to vaults created on the Maker lending protocol. The vaults are categorized by duration (days since vault opening) and activity (number of debt-generating events). Panels A-D display descriptive statistics for vaults with durations of 30-90 days, 90-180 days, 180-365 days, and over 365 days, respectively. The key variables include *Collateral Balance*, *Debt Balance*, *Debt No. Actions*, *Debt Added*, and *Collateralization Ratio*. All dollar balances and changes are expressed in USD. The sample period spans November 2019 to October 2023.

	Collateral Balance ($)		Debt Balance ($)		Debt No. Actions		Debt Added ($)		Collateralization Ratio	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Panel A. 30-90 days (n=4151)										
1 (least active)	178,546	7,948	46,191	2,263	0.03	0.03	46,615	2,940	3.57	2.93
2	369,951	19,494	121,474	6,161	0.07	0.07	113,321	5,000	3.47	2.88
3 (most active)	955,291	36,176	376,301	13,886	0.32	0.20	231,442	7,320	2.97	2.49
Average	500,782	18,228	181,138	5,946	0.14	0.07	130,295	5,000	3.34	2.76
Panel B. 90 - 180 days (n=4,151)										
1 (least active)	254,633	13,881	76,764	3,812	0.02	0.02	72,902	4,145	3.92	3.31
2	377,174	29,191	104,169	9,095	0.04	0.04	74,959	6,441	4.25	3.16
3 (most active)	1,356,169	57,272	489,070	21,280	0.22	0.13	238,212	9,325	3.34	2.56
Average	662,787	27,528	223,376	8,898	0.09	0.04	128,705	6,150	3.83	3.00
Panel C. 180 - 365 days (n=3,954)										
1 (least active)	444,526	20,533	109,516	4,851	0.01	0.01	120,749	5,000	5.61	4.10
2	876,959	47,818	258,607	12,453	0.03	0.03	175,635	8,532	4.44	3.49
3 (most active)	1,518,805	76,124	612,724	28,005	0.16	0.09	151,727	10,660	3.52	2.73
Average	946,982	40,945	327,025	11,233	0.07	0.03	149,405	7,700	4.52	3.36
Panel D. >365 Days (n=5,103)										
1 (least active)	88,643	2,163	12,448.72	127.38	0.00	0.00	14,221	244	17.58	9.50
2	605,294	56,094	104,863.49	13,786.69	0.01	0.01	77,996	8,472	6.65	4.26
3 (most active)	2,911,093	140,939	915,900.50	48,437.83	0.10	0.06	198,689	15,833	5.51	3.12
Average	1,201,778	42,260	344,422.35	10,202.61	0.04	0.01	96,981	6,000	9.80	4.12

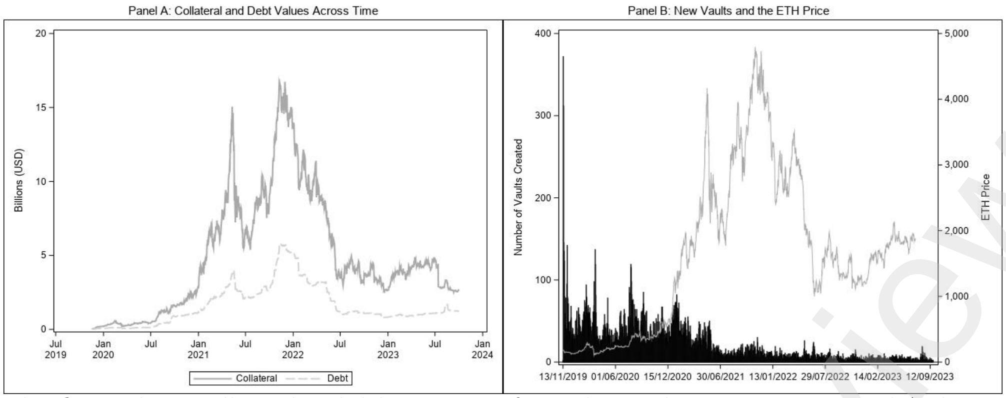

Figure 1: This figure shows collateral and debt positions for Maker vaults across time. Panel A shows the value of collateral locked and debt originations related to Maker protocol across time. Panel B shows the number of new vaults added to the Maker protocol relative to the value of ETH across time. The data is from November 2019 to October 2023. Liquidity Pools loans (e.g. CRVV1ETHSTETH-A), lending protocol loans (e.g. DIRECT-AAVEV2-DAI), and Real-world asset (RWA) loans are excluded from consideration.

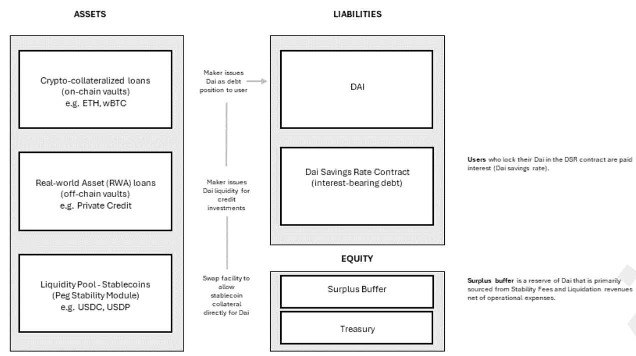

Figure 2: This figure provides a balance sheet representation of Maker core practices. Lending activities are automated through smart contracts, and the issuance of debt is initiated by users by locking collateral assets in Maker vaults. Borrowers reapy the debt (Dai) and reclaim their collateral assets and the stability fees generated on the loan forms part of the surplus buffer that accumulates over time. MakerDao has diversified collateral types over time to include off-chain real-world assets (RWA). These RWA fall into private and public categories and provide financing for real estate, trade finance, and SMBs. Maker also holds stablecoins in a Peg Stability Module (PSM) which allows users to swap between Dai and other stablecoins at a fixed rate. This practice helps to maintain the peg of Dai. The DSR is a feature that allows Dai holders to lock their tokens into a DSR smart contract to earn interest on their holdings.The interest is earned on every block and is funded from stability fees paid by users with collateralized debt positions. Dynamic adjustments to the DSR and Stability Fee are made based on the deviation of the market price of DAI from its target price.

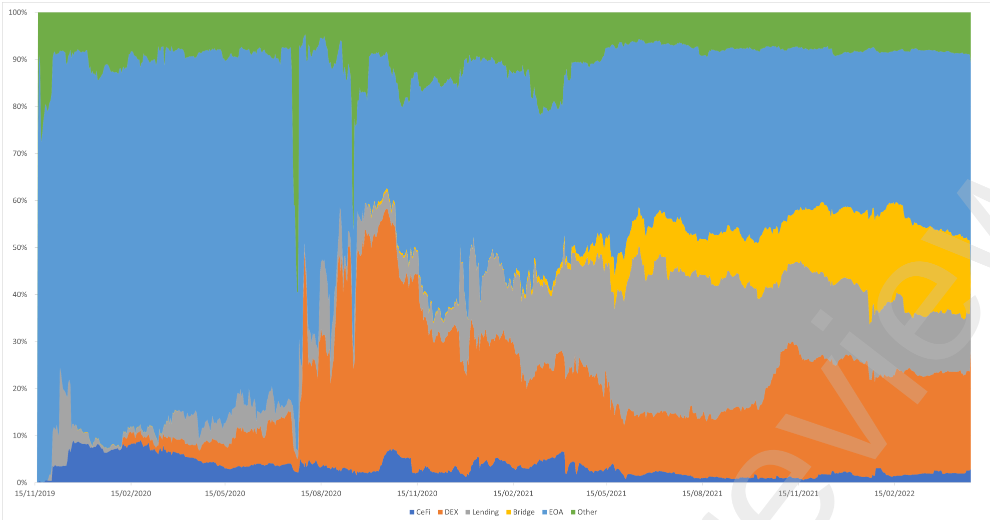

Figure 3: Where is Dai held? This figure illustrates the evolution of Dai in the cryptocurrency ecosystem across time. Using blockchain data, daily balances are marked to one of five categories including centralized protocols (CeFi), Decentralized protocols (DeFi), lending protocols (Lending), blockchain bridges (Bridge) or in externally owned accounts (EOA).

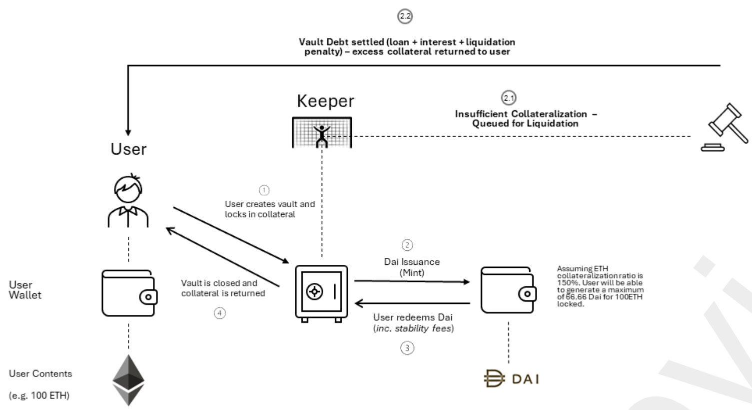

Figure 4: This figure explains the core functionality of Maker's lending activities. Borrowers issue (mint) debt by locking collateral assets in vaults, creating a collateralized debt position. To repay this debt, borrowers repay the Dai-denominated loan, including stability fees, and reclaim their collateral. The repaid Dai is burnt and removed from circulation. If the collateral value falls below a predefined liquidation ratio, the Maker protocol triggers a liquidation process. The debt is repaid through a collateral auction, where the Dai received is used to cover outstanding debt obligations, with any residual returned to the user.

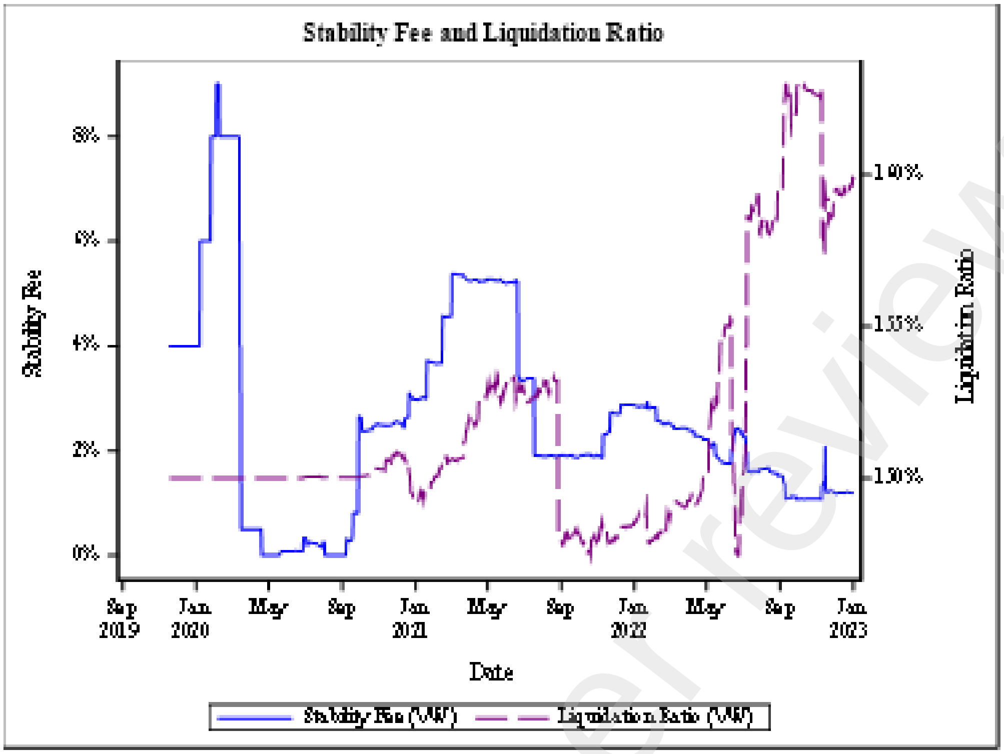

Figure 5: This figure illustrates the change in stability fee and liquidation ratio since the inception of the Maker protocol. The stability fee reflects the charge to borrowers and is a continuously compounded rate of interest that accrues to the outstanding debt balance. The liquidation ratio is the minimum collateralization ratio required for each collateral (ilk) form permitted on the Maker protocol. The stability fee and liquidation ratio are weighted by debt outstanding by ilk on a daily basis.

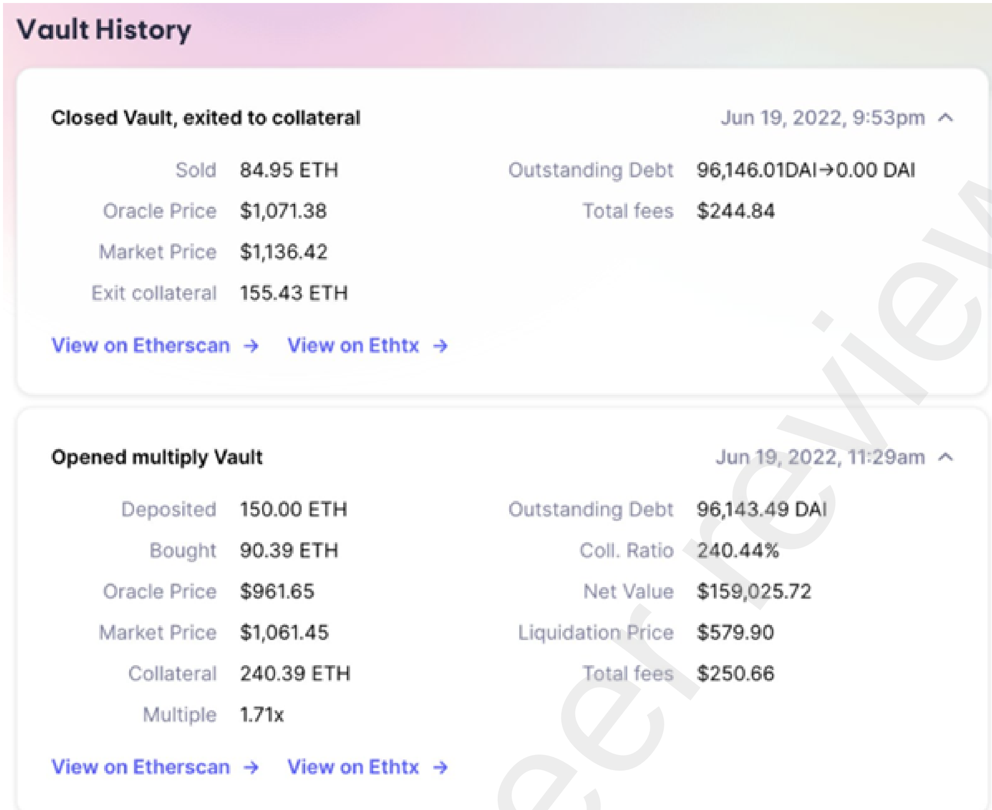

Figure 6: This figure shows a transaction cycle for vault 28,733 established on 19th June 2022. The figure depicts the actions of a user depositing 150ETH on the Maker protocol. This collateral is leveraged, gaining exposure to 240.39ETH with a resultant outstanding debt position of 96,143.49DAI at a collateralization ratio of 240.44%. The market price for ETH at the time the position was established was $1,061.45USD. The user position is closed at 9:53pm on June 19, 2022 (approximately 10 hours later) with a net gain of 5.43ETH or 11%.

Appendix A: Stability Fees, Total Debt, and DSR

To provide a comprehensive understanding of the stability fee and Dai Savings Rate (DSR) accumulation in the MakerDAO system, the following detail is provided.

Stability Fees and Total Debt

Vaults with outstanding debt are charged a stability fee by the Maker protocol. All vaults in the system are charged the base rate (r_f) equally. For each vault, depending on the type of collateral locked, an additional duty rate (r_p) is charged, which is called the risk premium. Both the base and duty rates are accumulated together in a single rate accumulator. Given that each vault (v) is associated with a single collateral type, the cumulative rate $R(v,t)$ can be expressed as:

$$R(v,t) = R(v,0) \times \prod_{i=t_0+1}^{t} (1 + F_i) \tag{1}$$

where F_i is the per-second stability fee at time i, and accumulation occurs in discrete 1-second time intervals, starting from t_0. To relate this to continuous compounding, we note that for very small time intervals, the per-second stability fee F_i can be approximated by the continuous rate $r_f + r_p$ as follows:

$$1 + F_i \approx e^{(r_f + r_p)} \tag{2}$$

Thus, the product of the per-second rates over time approximates the continuous exponential function:

$$\prod_{i=t_0+1}^{t} (1 + F_i) \approx e^{(r_f + r_p)\times(t-t_0)} \tag{3}$$

Therefore, the cumulative rate can also be expressed as:

$$R(v,t) = R(v,0) \times e^{(r_f + r_p)\times(t-t_0)} \tag{4}$$

Let a vault be created at time t_0 with debt D_0 drawn immediately. The normalized debt A_0 is expressed as $A(v,0)$ where:

$$A(v,0) = \frac{D(v,0)}{R(v,0)} \tag{5}$$

Substituting the expressions for $A(v,0)$ and $R(v,t)$, we get:

$$D(v,t) = \left(\frac{D(v,0)}{R(v,0)}\right) \times \left(R(v,0) \times e^{(r_f + r_p)\times(t-t_0)}\right) \tag{6}$$

Simplifying this, we obtain an expression for the total debt ($D(v,t)$):

$$D(v,t) = D(v,0) \times e^{(r_f + r_p)\times(t-t_0)} \tag{7}$$

DSR Accumulation

The Dai Savings Rate (DSR) accumulation is handled in a similar manner to the stability fee accumulation but applies to Dai deposits.

Let $\chi(0)$ be the initial cumulative interest rate at the last update time t_0. r_{dsr} is the per-second DSR rate (which is analogous to the accumulator rate in the stability fee case) and t is the current time. The cumulative interest rate parameter for DSR at time t is denoted as $\chi(t)$:

$$\chi(t) = \chi(0) \times \prod_{i=t_0+1}^{t} (1 + r_{dsr}) \tag{8}$$

To relate this to continuous compounding, we note that for very small time intervals, the per-second DSR rate r_{dsr} can be approximated by the continuous rate r_{dsr} as follows:

$$1 + r_{dsr} \approx e^{r_{dsr}} \tag{9}$$

Thus, the product of the per-second rates over time approximates the continuous exponential function:

$$\prod_{i=t_0+1}^{t} (1 + r_{dsr}) \approx e^{r_{dsr}\times(t-t_0)} \tag{10}$$

Therefore, the cumulative interest rate can also be expressed as:

$$\chi(t) = \chi(0) \times e^{r_{dsr} \times (t - t_0)} \tag{11}$$

When a user deposits N Dai into a central pot at time t_0, the user's internal Dai balance $B(u)$ is set to:

$$B(u) = \frac{N}{\chi(0)} \tag{12}$$

The total Dai that a user can withdraw from the central pot at time t is:

$$W(u, t) = B(u) \times \chi(t) = N \times e^{r_{dsr} \times (t - t_0)} \tag{13}$$

This formulation ensures that the user's balance grows according to the DSR over time, reflecting the continuous compounding nature of the interest rate.

Appendix B: Maker Collateral Tokens

This table lists tokens used as collateral in the Maker system since its inception. Onboarding a token follows a defined process starting with an application to the MakerDAO community, detailing tradability, legal, and technical information. After a Community Greenlight Poll, MKR holders vote on the token's potential as collateral. Poll results guide domain teams in prioritizing collateral types. Core Units (CU), elected by MKR holders, use a spreadsheet to prioritize assessments and perform various protocol duties, including risk evaluations. A prioritization score is calculated to facilitate discussions among CU teams. Following community and CU assessments, a Governance Poll is held for MKR holders to support or oppose the collateral type. If approved, CU teams prepare the token for inclusion, involving smart contract development and testing. If the executive vote passes, the collateral is added to the Maker Protocol and announced on social channels. Tokens are offboarded through a similarly structured governance process. To execute this change strategic adjustments are made to liquidity parameters (liquidation penalty is set to zero and a high liquidation ratio is applied) and the debt ceiling is set to zero. This ensures that the offboarding process is smooth and does not destabilize the Dai stablecoin.

Token	Name	Category	Current Status	Description
AAVE	Aave	Utility	Inactive	The governance token for Aave, a decentralized liquidity protocol. Added in December 2020.
BAL	Balancer	Utility	Inactive	The governance token for Balancer, a decentralized liquidity protocol. Added in October 2020.
BAT	Basic Attention Token	Utility	Inactive	The reward token for Brave browser project. Supported since launch of Multi-Collateral Dai in November 2019.
COMP	Compound	Utility	Inactive	The governance token for lending protocol Compound.Finance. Added in September 2020.
ETH	Ethereum	Utility	Active	Ethereum's native coin and most popular form of collateral to generate Dai.
GUSD	Gemini	Stablecoin	Active	Gemini dollar, a regulated stablecoin backed by US Dollars and issued by Gemini Trust Company. Added in November 2020.
KNC	Kyber Network Crystal	Utility	Inactive	A token used to pay fees on Kyber Network, a DEX protocol. Added in June 2020.
LINK	Chainlink	Utility	Active	The payment token for decentralized oracle network Chainlink. Added in September 2020.
LRC	Loopring	Utility	Inactive	The native token for Loopring, a protocol for high-scale exchange and payment applications. Added in September 2020.
MANA	Decentraland	Utility	Active	Native currency for Decentraland, a blockchain-based virtual world. Added in July 2020.
MATIC	Polygon	Utility	Active	A token underpinning (payment and settlement) the Polygon network. Added in August 2021.
UDSP	Pax Dollar	Stablecoin	Active	Paxos Standard is a regulated stablecoin backed by US Dollars held by Paxos Trust Company. Added in September 2020.
RENBTC	renBTC	Utility	Active	An Ethereum token that is 1:1 backed by BTC, locked bia RenVM, a permissionless interoperability network. Added in December 2020.
TUSD	TrueUSD	Stablecoin	Active	A regulated dollar-backed stablecoin issued by Trust-Token. Added in June 2020.
UNI	Uniswap	Utility	Active	The governance token for DEX Uniswap. Added in December 2020.
USDC	USD Coin	Stablecoin	Active	A stablecoin backed by US Dollars held in reserves with regulated financial institutions. Added in March 2020.
USDT	Tether	Stablecoin	Active	Tether USD is a stablecoin backed by US Dollars and other asset held by Tether. Added in September 2020.
WBTC	Wrapped Bitcoin	Utility	Active	Wrapped Bitcoin, a token backed 1:1 by BTC held by custodian BitGo. Added in May 2020.
YFI	Yearn.Finance	Utility	Active	The governance token for DeFi aggregator system Yearn.Finance. Added in October 2020.
ZRX	0x	Utility	Inactive	The governance token 0x, a DEX protocol. Added in June 2020.

From Collateral to Liquidation: Understanding Trustless Loan Systems

Angelo Aspris*

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Draft. Not to be quoted.

Abstract

This paper examines collateralized borrowing in cryptocurrency markets. Collateralized borrowing is a practice that has emerged from the DeFi ("Decentralized Finance") movement which facilitates loan provision. The leading decentralized lending platform, Maker is a credit system that allows users to originate their own stablecoin-based loans based on prescribed types of collateral deposited into smart-contract based vaults. We provide a comprehensive understanding of the loan process from debt origination to loan liquidation. Using four years of data (2019-2023), we find that loan protocol parameters (stability fee, liquidation ratio), stablecoin integrity, and collateral concentration affect the demand for loans. Users with greater familiarity with the protocol exhibit lower levels of collateralization, consistent with better overall risk-management practices.

Keywords: Cryptocurrency, trustless lending, DeFi, Collateral, Debt

JEL Codes: G10, G14, D47

*Angelo Aspris (Email: angelo.aspris@sydney.edu.au) is at the University of Sydney.