HONG KONG MONETARY AUTHORITY

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THE ROLE OF MONETARY CONDITIONS IN DEFI

Key points:

- *Decentralised Finance (DeFi) has witnessed significant growth and is becoming increasingly interconnected with traditional finance, as exemplified by the recent failures of two crypto-friendly banks, Silvergate Bank and Signature Bank. Motivated by the observation that the DeFi boom and bust in 2020-2022 coincided with a loosening and subsequent tightening of US monetary policy, this study examines the transmission of monetary policy conditions into DeFi as a novel source of financial stability risk.*

- *This study focuses on the largest DeFi lending platform, MakerDAO. We estimate the impact of a shift in US monetary conditions on DeFi lending activity at both the aggregate and vault (i.e. account) levels. We find that monetary policy drives DeFi credit cycles in a similar fashion as in traditional finance, where leverage plays a key role in amplifying the shock.*

- *Furthermore, the study finds that tightening US monetary conditions have a larger impact on the value of collateral than that of debt, thus heightening the system-wide leverage and increasing the likelihood of abrupt deleveraging, which can be particularly disruptive given the nature of automatic liquidation in DeFi.*

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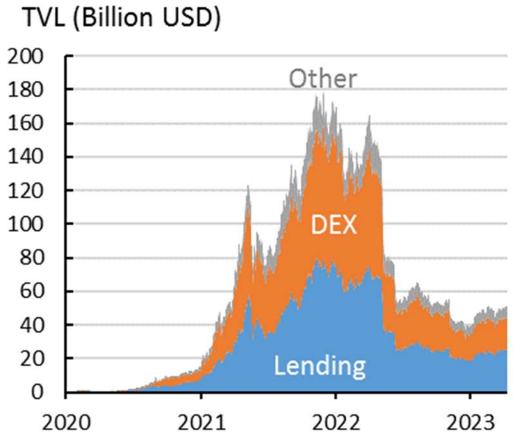
I. INTRODUCTION

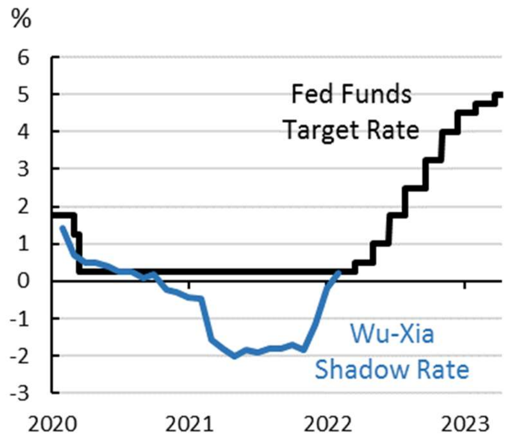
Decentralised Finance (DeFi) is an emerging architecture of financial services that utilises smart contracts and blockchain technology to connect market participants directly, bypassing traditional financial intermediaries such as brokers / dealers. DeFi has grown substantially since early 2020 with the total value locked (TVL, the value of assets deposited in transactions and hence locked on the chain) rising from about US$600 million in December 2019 to about US$160 billion in March 2022, before tumbling thereafter (Chart 1a). The boom and bust of DeFi coincided with a loosening and subsequent tightening of US monetary policy (Chart 1b), suggesting a considerable effect of US monetary conditions on DeFi activity.

Chart 1a: DeFi protocols by TVL



Note: DEX refers to decentralised exchange, which utilises liquidity pools of crypto assets to enable users to trade among themselves.
Source: DeFiLlama.

Chart 1b: Measures of US monetary policy stance



Note: The Wu-Xia shadow rate is a summary measure of the macroeconomic impact of unconventional monetary policy when the Fed Funds target is constrained by the zero lower bound.
Sources: Federal Reserve and Atlanta Fed.

The transmission channels of monetary policy to traditional finance (TradFi) and DeFi are arguably similar. For instance, monetary policy may affect market sentiment and confidence in both TradFi and DeFi. It can also generate swings in market liquidity and hence fund flows into or out of the crypto sector. A few studies note that DeFi faces traditional problems originating from economic forces that are inherent in financial markets, such as liquidity and maturity mismatches, leverage and interconnectedness, asymmetric information, adverse selection, and moral hazard.[1] That being said, as will be discussed later,

[1] See Makarov and Schoar (2022); FSB (2023); Niepelt (2022).

DeFi-specific features and the lack of regulations may result in vulnerabilities playing out in unforeseen ways.[2]

In this study, we focus on lending activities on MakerDAO, the largest DeFi lending platform by TVL[3] to date. We consider borrowers' behaviours in response to changes in monetary conditions and the implication of their use of leverage.[4] Our result shows that DeFi lending exhibits similar credit cycles as in TradFi. Specifically, a tightening of monetary conditions can significantly slow DeFi lending activity by inducing borrowers to deleverage, more so if they already have a high leverage (loan-to-value) ratio before the shock. Worse still, the leverage ratio can rise further as tighter monetary conditions reduce collateral prices, which could trigger a wave of disruptive liquidation that undermines the stability of the DeFi lending platform. The risk is amplified by volatile market conditions and the ability of investors to take highly leveraged and interconnected positions in the DeFi ecosystem.

Heightened market volatility and/or the loss of confidence could be contagious to other parts of the DeFi ecosystem and trigger runs on other DeFi platforms and stablecoins (digital assets pegged to fiat-currencies, which play the role of safe assets in DeFi). The run risk is demonstrated by the Terra crash in May-June 2022 and the collapse of FTX in November 2022. In view of these events, global policymakers and regulators (see FSB 2023) have raised concerns about the financial stability implications of DeFi and their spillovers to TradFi and the real economy.

While the overall size of DeFi is still small compared to TradFi and has been remaining largely self-referential (i.e. DeFi products and services interact with other DeFi products and services, rather than with the traditional financial system and the real economy), the interconnection between the two has become increasingly evident in recent years. As a case in point, the crypto winter since 2022 had a ripple effect on deposit withdrawals from crypto-friendly banks like Silvergate Bank and Signature Bank, which partially contributed to the failure of

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[2] There are a few other studies of the financial stability implication of DeFi features, including Darlin et al. (2022) on debt-financed collateral, Qin et al. (2021) and Lehar and Parlour (2022) on the liquidation mechanism, Chiu et al. (2022) on a price-liquidity feedback loop. Most of these papers focus on the Aave platform and the Compound platform, while MakerDAO is less studied.

[3] Other major DeFi applications include decentralised crypto exchanges, yield farming, and insurance.

[4] Kyriazis et al. (2023) also consider the transmission of US monetary policy to the DeFi ecosystem. However, their event study is severely constrained by the lack of observations given only a handful of FOMC meetings since the boom of DeFi. We overcome the data limitations by focusing on monetary conditions instead of monetary shocks, which allows us to estimate formal econometric models on a larger sample. Furthermore, we provide novel evidence based on vault (account) level data, while Kyriazis et al. (2023) focus only on aggregate data.

both banks in March 2023. New real-world use cases are emerging, such as the tokenisation of traditional assets and the adoption of stablecoins as a medium of exchange. Looking forward, meeting the challenge brought by DeFi and exploiting its potential require a better understanding of its nature, an aspect this paper hopefully sheds light on.

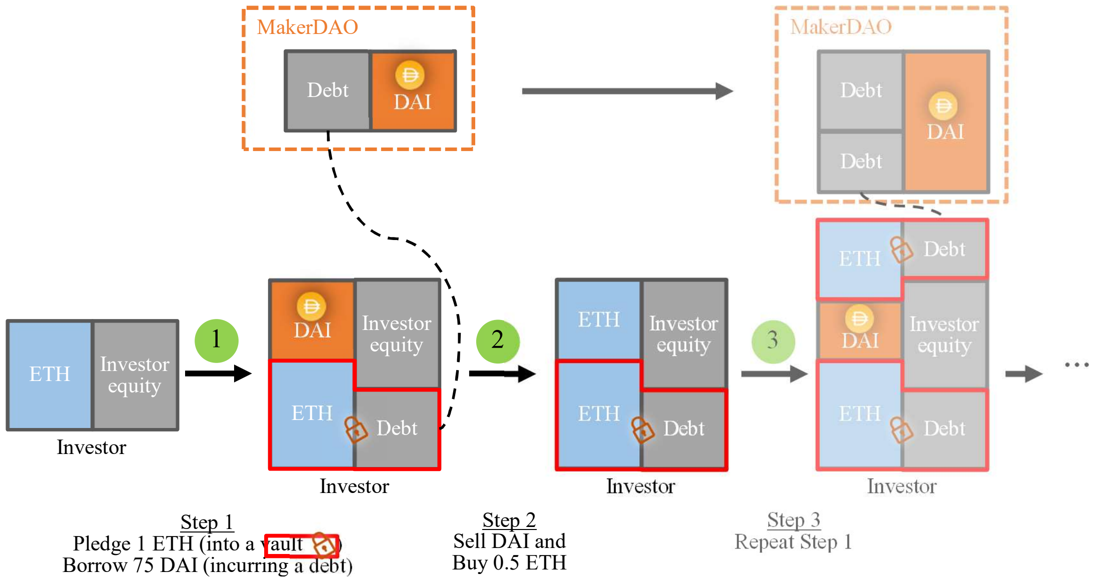
The rest of this paper is structured as follows. Section II provides an overview of the DeFi ecosystem, with a focus on the lending sector and its stability risk. In Section III, we present data sources used in our analysis. The econometric framework and key findings are presented in Section IV. Finally, Section V concludes.

II. DEFI LENDING AND STABILITY RISK

In this section, we illustrate how financial stability risks may unfold in DeFi lending using a stylised example, which applies to all major platforms (e.g. MakerDAO, Compound and Aave). We note platform-specific features wherever relevant.

Suppose a borrower plans to borrow 75 units of DAI – the native currency of MakerDAO and a major stablecoin – from a DeFi lending platform. DeFi loans must be secured by collaterals because anonymity in DeFi prevents credit checks or any form of borrower-specific evaluations. The loan-to-value ratio (LTV) is typically below 100% (i.e. overcollateralisation is required) and subject to a maximum cap, given mark-to-market collateral valuation and the extreme volatility of crypto assets prices. Suppose the borrower puts 1 ETH as collateral, which is worth 100 DAI when the loan is made, subject to the maximum LTV of 75%. In this case, the borrower has maxed out the leverage. Despite the maximum LTV on one loan, the borrower can build higher leverage by using proceeds of this loan as collateral for another loan. Chart 2 demonstrates this process in MakerDAO.

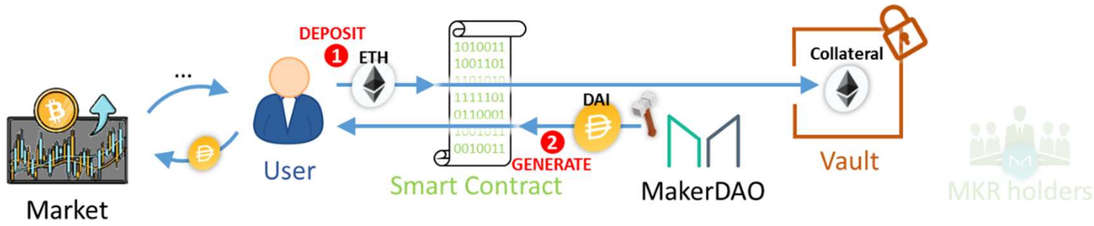
Chart 2: Borrowing in MakerDAO



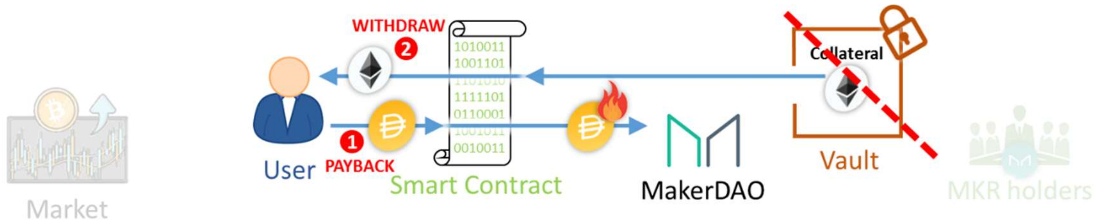
On major risk in DeFi is that the lending terms (e.g. maximum LTV ratio, the list of acceptable collaterals, interest rate) are pre-programmed in smart contracts and contingent on a small set of variables. These terms are reviewed periodically by a decentralised governing body of the platform at low frequencies (e.g. monthly), meaning that they are not responsive to macroeconomic shocks. For example, the interest rate is not determined by the market but a fixed parameter in MakerDAO, referred to as the stability fee. In other major platforms, interest rates are functions of, for instance, the platform-wide borrowing-to-lending ratio (the so-called utilisation ratio). As capital is withdrawn from the platform, the utilisation ratio and interest rates rise. This motivates borrowers to close out their loan or triggers liquidation (more on this below), reducing the platform's run risk. Chart 3 illustrates some of the main user interactions with MakerDAO through smart contracts.

Chart 3: Examples of Users' Interaction with MakerDAO through Smart Contract

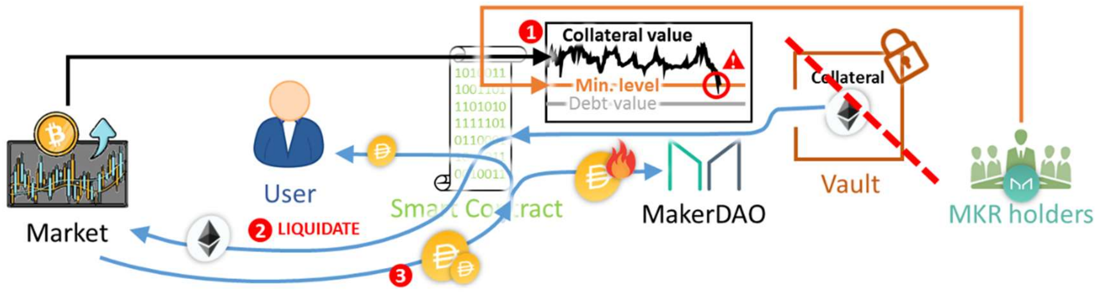
A: Creation of DAI loan



B: Principal Repayment



C: Liquidation



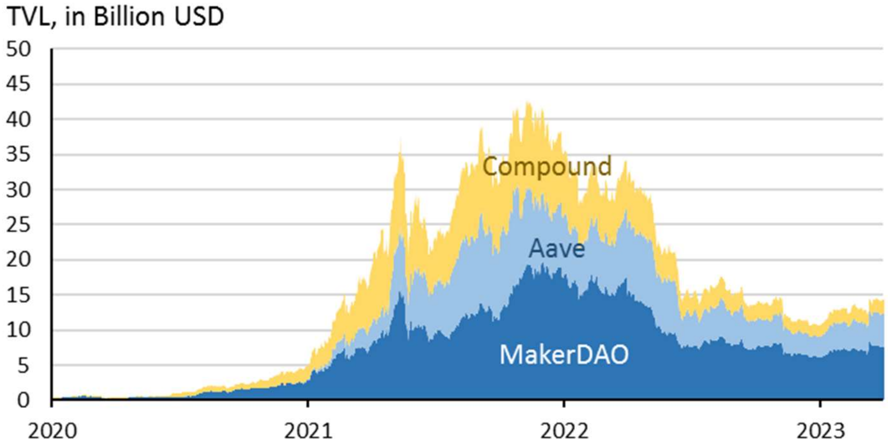
Note: The above illustration attempts to capture the most salient features of user-MakerDAO interactions but inevitably involves some simplification. For example, when a user repays the debt along with the interest, the resulting interest profit will be used to purchase and burn MKR tokens[5], which can be deemed as a share buyback, ultimately driving up the price of MKR. Besides, the platform may not liquidate the entire collateral but only a portion sufficient to repay the debt.

Another major feature of DeFi is that smart contracts automate the execution of various aspects of an agreement (e.g. holding collateral in escrow, approving loans, collecting interests, etc.) whenever pre-determined conditions are met. While the absence of human interventions may enhance the credibility and predictability of the platform, automatic liquidation could risk exacerbating financial market stress in times of volatility. The liquidation process in DeFi lending, as well as its financial stability implications, will be discussed in Section 4.3.

[5] MKR is the governance token of the MakerDAO. Its holders are responsible for governing the Maker Protocol, which includes adjusting policy for the DAI stablecoin, choosing new collateral types and improving governance.

III. DATA

Chart 4: Total Value Locked (TVL) of Top 3 DeFi Lending Project on Ethereum Chain



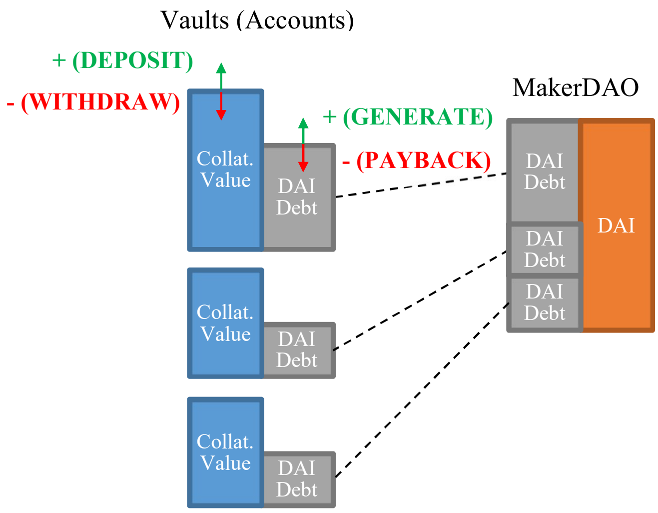
Source: DeFiLlama.

This study focuses on MakerDAO because of its significant market share (Chart 4) and the fact that its full transaction data is more readily accessible than other lending platforms. Daily data from November 2019 to mid-February 2023 are collected from various sources (See Annex A for more details). Specifically, transaction data recorded on blockchains, such as vault ID, operation type, and amount. Other data includes crypto price data, Crypto Fear & Greed Index, 2-year US Treasury yield and VIX.

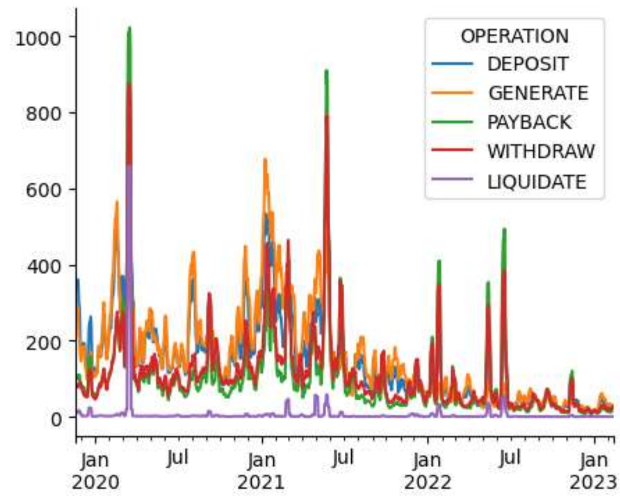
Throughout this paper, we focus on four types of basic vault operations, as illustrated in Chart 5A, namely DEPOSIT (putting collateral into the vault), WITHDRAW (taking collateral from the vault), GENERATE (borrowing DAI against the collateral in the vault) and PAYBACK (repaying the debts with DAI). The daily number of these operations as well as the daily incurrence of liquidation are presented in Chart 5B.

Chart 5: Daily Number of Non-stablecoin Vault Operations

A. Vault operations and vault balance sheet



B. Daily number of operations on non-stablecoin vaults



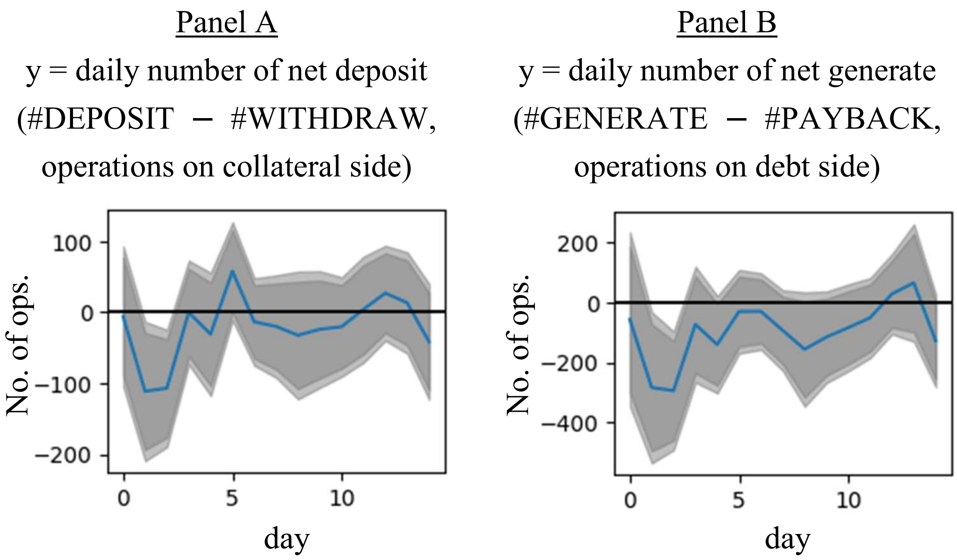
Note: data are shown as 7-day moving averages.
Sources: MakerDAO and HKMA staff estimation.

IV. Empirical Analysis

4.1 Aggregate-level analysis

While a policy tightening by the Fed can generate swings in market liquidity, induce stress on investors having duration mismatches in their balance sheet, and fund flows out of the crypto sector, it can also erode investor confidence and hurt market sentiment in DeFi. In this regard, DeFi platform users may take actions to reduce their exposure to the crypto sector, manifested in a reduction of the vault's balance sheet. Chart 6 shows the contractionary effect of a 1 percentage point (%pt) increase in the 2-year US Treasury yield on vault operations in the following 15 days (See Annex B1 for technical details). Such a shift in monetary outlook is estimated to trigger over 100 net WITHDRAW operations per day and around 300 net PAYBACK operations per day within the next two days.

Chart 6: Impact on Vault Operations of a 1%pt Change in $\Delta UST2Y_t$

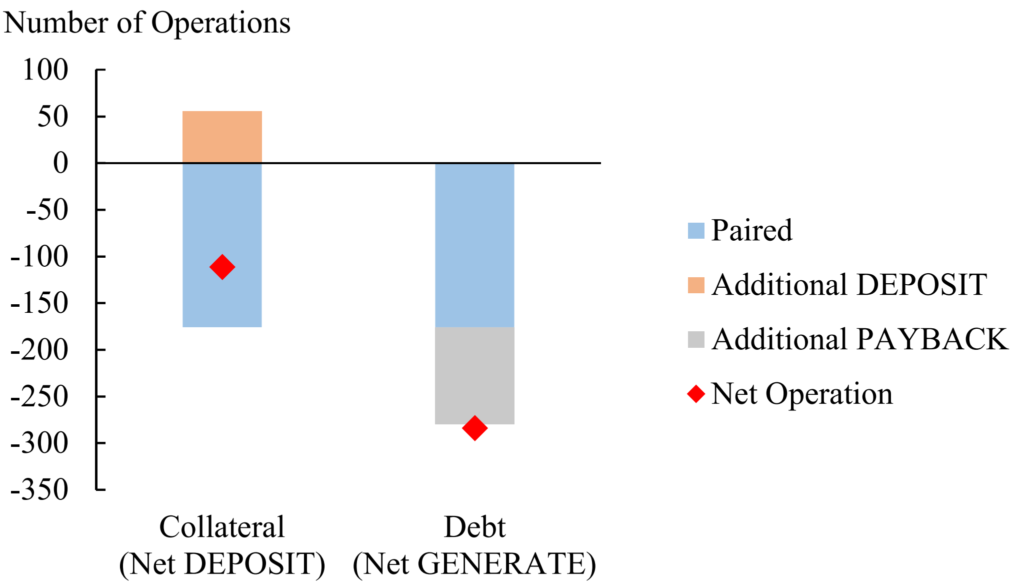


Source: HKMA Staff Estimation.

Noting a larger impact on net generate (Chart 6B) than that on net deposit (Chart 6A), we recategorise user operations to take a closer look at the impact of tightened monetary conditions. Specifically, we consider operations to be "paired operations"[6] when they change the vault's asset and liability (i.e. collateral and debt) in the same direction, i.e. DEPOSIT-GENERATE pair and WITHDRAW-PAYBACK pair. Otherwise, the operations are regarded as "additional operations" when they lead to additional changes in either collateral or debt, i.e. leftover operations that cannot pair up with others (See Annex C for technical details). Under this framework, the estimation in Chart 7 shows that a large share of operations are paired to reduce collateral and debt at the same time (the blue bars). On top of that, vault owners built up further the collateral stock (the orange bar) while paying back more debt (the grey bar). In this sense, tighter monetary conditions lead to deleveraging operations and a significant slowdown of lending activity.

[6] Technically, this is the minimum of DEPOSIT and GENERATE, subtracted by the minimum of WITHDRAW and PAYBACK.

Chart 7: Breakdowns of Vault Operations on k = 1 (immediately upon tighter monetary conditions)

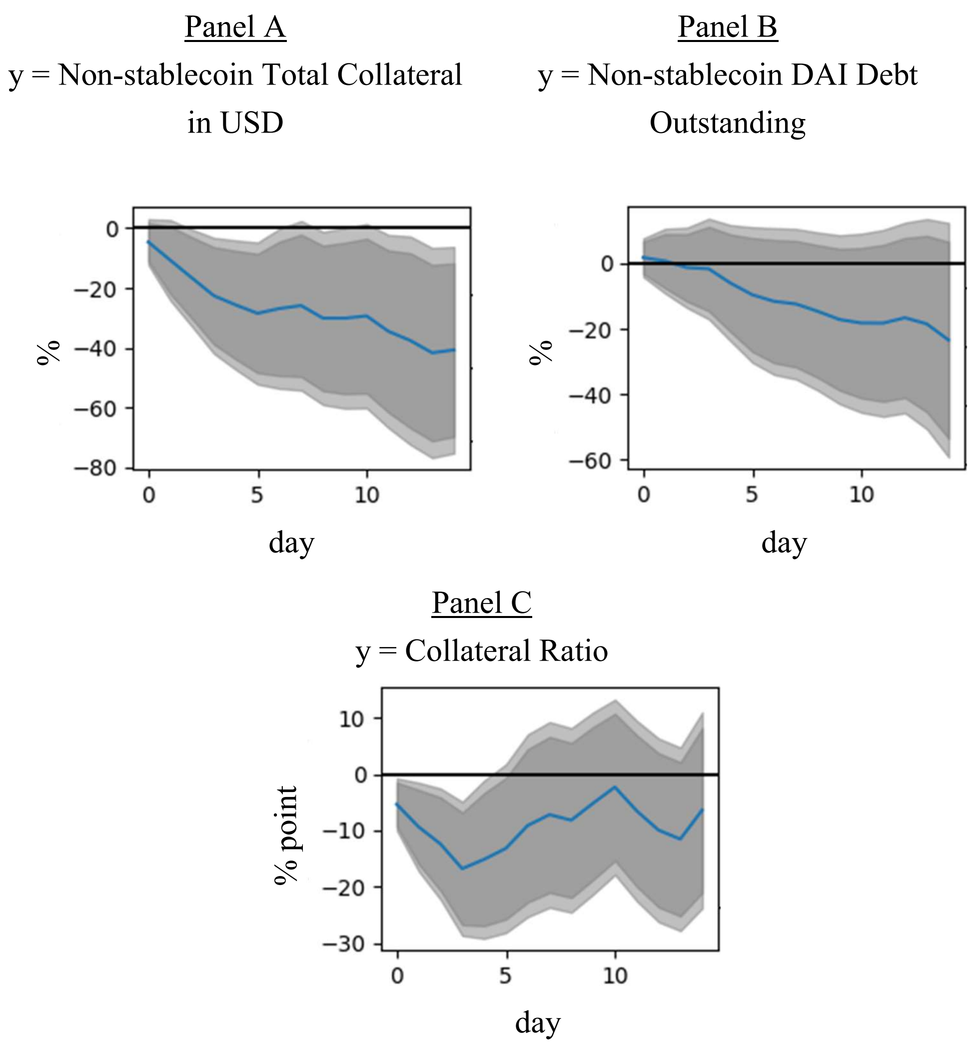


Source: HKMA staff estimation.

In value terms, when factoring in the effect of monetary policy on crypto collateral prices, the impact on the collateral value is, unlike in user operations, larger than that of debt, leading to an adverse change in collateral ratio in the system. Chart 8 shows that the total collateral value and the total outstanding debt fall more than 30% and 20% respectively following a 1%pt increase in 2-year US Treasury yield. As a result, the collateral ratio declines by around 10 %pts (Chart 8C)[7]. With a lower collateral ratio, lending platforms can face higher stability risk and heightened likelihood of voluntary deleveraging which aims to avoid forced liquidation, as exemplified in Chart 7.

[7] DAI is evaluated at the target price of 1 USD.

Chart 8: Impact on Vault Balance Sheet of a 1%pt Change in $\Delta UST2_{t}$



Source: HKMA staff estimation.

4.2 Vault-level analysis

At the vault level, the effects of monetary conditions on lending behaviours become more apparent. A tightening monetary condition can dampen new borrowing and incurring repayment in the lending platform. As shown in Table 2 (See Annex B2 for technical details), a 25 bps increase in 2-year US treasury yield would reduce the median GENERATE probability by 1.53%pt and increase the median PAYBACK probability by 0.83%pt in the subsequent 7 days. This effect is beyond the effect of monetary policy on collateral price since the latter enters the model separately.

Table 2: Impact on vault operation decision

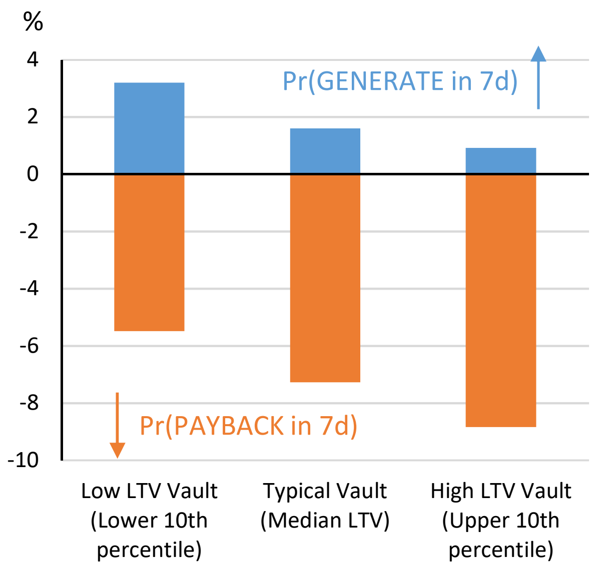
	Prob. (GENERATE in 7 days)	Prob. (PAYBACK in 7 days)
Baseline Probability [Note]	11.86%	11.35%
Scenarios:		
Collateral price rises by 10%	+3.79%pt***	-5.09%pt***
2Y UST yield rises by 25bps	-1.53%pt***	+0.82%pt***
LTV is higher by 50%	-3.52%pt***	-0.67%pt***
Additional effect of 2Y UST yield +25bps when LTV is 50% above mean	-0.11%pt***	+3.18%pt***

* $P \leq 0.1$, ** $P \leq 0.05$, *** $P \leq 0.01$.

Note: The baseline probability assumes vault to be ETH and all other variables to be at their median level. See Annex B2 for more details about the Probit model.

Furthermore, we find that higher vault leverage can amplify the effect of monetary conditions on user operations, particularly on PAYBACK operations (-0.11%pt and +3.18%pt on GENERATE and PAYBACK baseline probability respectively in Table 2). Put it in the context of 2022, we infer the probability of GENERATE and PAYBACK in 7 days under different LTV ratios upon a 25 bps increase in 2-year US Treasury yield. A vault owner with LTV at the upper 10th percentile is 3.36%pt more likely to PAYBACK and 2.28%pt less likely to GENERATE than a vault with LTV at lower 10th percentile in 7 days (Chart 9).

Chart 9: Model-inferred Probability of Vault Operations under Different LTV Ratios in the Context of 2022



Source: HKMA staff estimation.

Note: change in 2-year US Treasury yield is assumed to be 25 bps, other variables take the median values in 2022 and collateral type is assumed to be ETH.

4.3 The financial stability implications of DeFi deleveraging cycles

As monetary tightening raises the average LTV ratio, the rigid nature of smart contracts in the face of constantly-changing macroeconomic conditions can pose risks to the stability of DeFi ecosystem by triggering large waves of automatic liquidation. Whenever the LTV ratio of an individual loan rises above the threshold, the borrowing position can immediately be liquidated partially or wholly by any market participants. Decentralised liquidators buy the collateral at a discount price, pay back the loan with the proceeds, and can sell the collateral at exchange markets for a profit.[8]

While swift liquidation minimises the credit risk of individual positions, liquidators selling collateral are likely to have a negative impact on the prices of the underlying assets.[9] Borrowers may also need to liquidate other crypto assets to cover any shortfalls in their positions arising from the involuntary liquidation. These actions could put more borrowing positions under water, triggering liquidation waves across several crypto markets. Moreover, liquidators have an incentive to trade in predatory fashion by shorting collateral assets, thus triggering liquidation of an otherwise healthy loan and profiting from purchasing the collateral at a discount.

To put the speed of deleveraging in DeFi lending platforms during the 2020 – 2022 boom-bust cycle into perspective, we compare it against past episodes of deleveraging[10] in two avenues of TradFi, namely, stock market and banks. As shown in Chart 10, the deleveraging cycle in DeFi is generally comparable to those in TradFi sectors. Abrupt DeFi deleveraging is often triggered by large waves of liquidation, which could lead to a sharp depreciation of cryptocurrencies. Chart 11 shows that a liquidation episode puts significant

[8] Liquidation is facilitated by two DeFi features. First, the whole liquidation process is executed in a "all-or-nothing" basis, implying no credit risk in liquidation. As a result, liquidators can borrow so-called flash loans (loans without collateral) to remove capital constraints. Second, loan positions are publicly observable thanks to the permissionless nature of the underlying blockchains. Because of these features, professional liquidators are usually automated trading bots who monitor loan positions constantly.

[9] If collateral is sold at a decentralised exchange market, the exchange rate is determined by some deterministic rule called the bonding curve and depends typically on the pools of both tokens being exchanged.

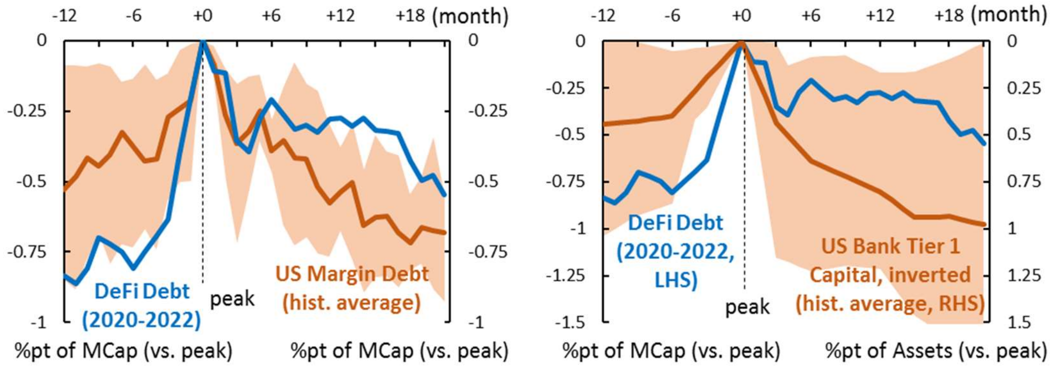
[10] The stock market deleveraging episodes in Chart 10a include the dot-com bubble, 2008 Global Financial Crisis, 2018 stock market downturn (US-China trade war) and COVID-19 pandemic. And the US banking sector deleveraging episodes in Chart 10b include the 1989 Savings and Loan Crisis, 2008 Global Financial Crisis and COVID-19 pandemic.

pressure on crypto asset prices and DeFi lending, both of which fall by more than 10% in the following week.[11]

Chart 10: Comparison of deleveraging cycles in DeFi and TradFi

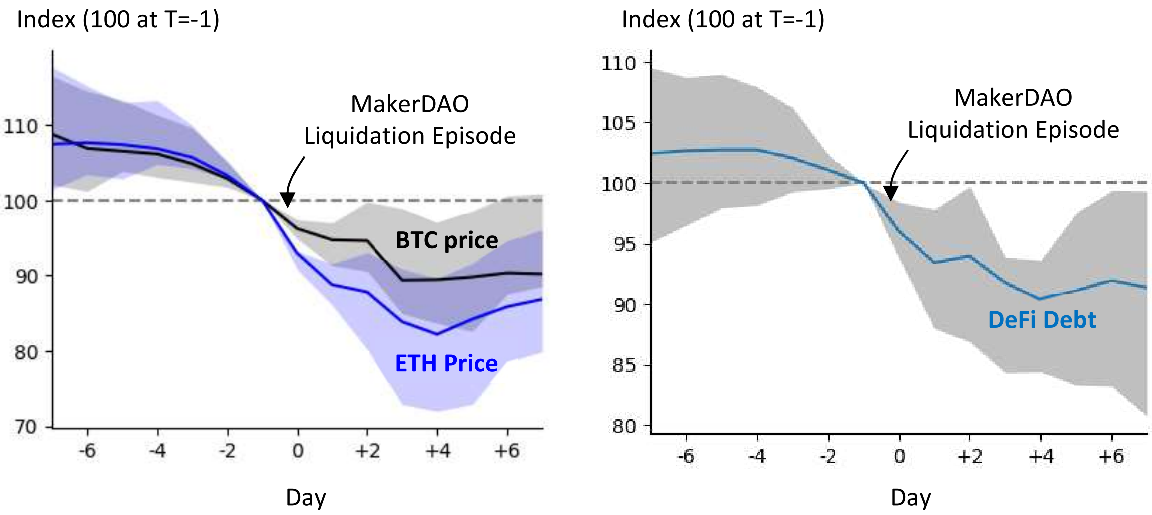
(a) Changes in DeFi debt and margin loans

(b) Changes in DeFi debt and US banks' Tier 1 capital ratio



Source: HKMA staff calculations.
Note: The shaded area represents the range, i.e. minimum and maximum, in historic episodes of deleveraging. MCap is the total crypto market capitalisation for DeFi and S&P 500 market capitalisation for TradFi. DeFi debt is the total debt outstanding of the three biggest DeFi lending platforms (MakerDAO, Aave and Compound), margin debt is from FINRA debit balances in margin accounts, and US banks' data is from the FDIC Quarterly Banking Profile (QBP).

Chart 11: MakerDAO Liquidation Episodes



Source: HKMA staff calculations.
Note: The shaded area represents the 25^{th} percentile and 75^{th} percentile in historic episodes of MakerDAO liquidation, where a liquidation episode is defined as more than 50 vaults being liquidated on a day.

[11] The relationship between modest DeFi deleveraging without much liquidation and the prices of cryptocurrencies is less clear. Relatedly, the literature is overall inconclusive about if macroeconomic factors, including monetary policy, affect the prices of digital assets. While the literature often suggests a disconnect between macro fundamentals and digital assets (Benigno and Rosa, 2023), several papers find significant links (Aboura, 2022; Kyriazis et al. 2023), especially after the boom of DeFi in recent years.

V. Conclusion

We study the transmission of US monetary conditions to DeFi lending, using MakerDAO as a laboratory. We find that monetary policy drives credit cycles in DeFi lending in a similar fashion as in TradFi. Tighter monetary conditions induce borrowers to deleverage, but the leverage ratio still increases due to a sharp fall in collateral prices. Moreover, we find that leverage plays an important role in the transmission of monetary policy. Higher leverage amplifies the impact of changes in monetary conditions, intensifying the deleverage dynamics which could be especially disruptive due to the automatic liquidation. Given the increasing linkages between DeFi and TradFi (as exemplified by the recent failures of Silvergate Bank and Signature Bank), our findings highlight the need for regulatory surveillance and risk management in DeFi lending, in view of the potential of DeFi boom-bust cycles as a novel source of financial stability risks.

Our study is subject to several limitations. First, our analysis is based on data from a single DeFi lending platform, MakerDAO, and may not generalise to other platforms. Second, our study is limited by the availability of data, particularly with respect to borrower characteristics. Future research could address these limitations by using data from multiple DeFi blockchains and lending platforms, and incorporating insights from borrowers' transaction history and network connection into the analysis.

ANNEX A. DATA SOURCES

Transactional data of MakerDAO on blockchains are made available by MakerDAO through its official API or the snowflake database.[12] Prices data are extracted from Block Analitica and Coingecko[13]. We use the Crypto Fear & Greed Index to measure market sentiments, which are an important driver of DeFi activity as argued by Chiu et al. (2022).[14] Macroeconomic data are obtained from the St. Louis Fed's FRED database, including monetary policy captured by the 2-year US Treasury yield.

Table A: Transactional and auxiliary data used in our analysis

Name	Source	Description
DAI Transactions	MakerDAO[15]	Vault operation, timestamp, collateral, amount, EOD balance, etc.
Crypto OSM Prices	Block Analitica[16]	Prices of most collateral except LRC which is not available, interpolated if necessary
Crypto Market Prices	Coingecko[17]	Prices of LCR collateral
CFGI	Alternative.me	Crypto Fear & Greed Index
UST2Y	FRED	2-Year US Treasury Yield
VIX	FRED	CBOE Volatility Index

[12] We consider all multi-collateral DAI (MCD) system because the previous single-collateral DAI (SAI) system was not significant to the lending sector and was succeeded by more accepted MCD system in 2019, and therefore not considered in our study. Furthermore, since a significant portion of stablecoin vaults are managed by Maker's Peg Stability Module (PSM) which is a special vault maintaining the peg stability of DAI, we exclude all transactions of vaults that pledge stablecoin as collateral.

[13] Oracle Security Module (OSM) prices are used whenever available. If not, Coingecko prices are used. OSM prices are preferred over market prices because many LP token collaterals are not widely traded in the market. Any missing price quotes are imputed with linear interpolation.

[14] Another important factor affecting DeFi activity is fees. First, any transaction processed on the blockchain pays a "gas fee" to validators who verify the transaction. On top of that, users need to pay fees to lending and exchange platforms for their services. In the context of makerDAO, borrowers pay a stability fee as interests on their loans and a liquidation penalty fee when their positions are liquidated. However, related data are hard to obtain.

[15] The web UI is available at https://tracker-vaults.makerdao.network/. The backend dataset and API is available at https://data-api.makerdao.network and on snowflake at https://app.snowflake.com/ (based on an analysis on the source code provided by MakerDAO Data Insights on Github).

[16] The web UI is available at https://maker.blockanalitica.com/oracles/. The backend API is available at https://maker-api.blockanalitica.com (based on the analysis on network traffic of the web UI).

[17] The web UI is available at https://www.coingecko.com/. The backend API is available at https://api.coingecko.com.

ANNEX B. REGRESSION SPECIFICATION

B.1 Aggregate-level analysis

We consider how monetary policy affects activities on MakerDAO, by aggregating end-of-date transactional and balance data across vaults and running the following local projection regressions:

$$y_{t+k} - y_{t-1} = \alpha_k + \beta_k \Delta UST2Y_t + \gamma_k \Delta VIX_t + \sum_{i=1}^{p} B'_{i,k} \begin{bmatrix} \Delta y_{t-i} \\ \Delta UST2Y_{t-i} \\ \Delta CFGI_{t-i} \\ \Delta \log ETH_{t-i} \\ \Delta VIX_{t-i} \end{bmatrix} + \varepsilon_{t,k} \quad (1)$$

where y represents one of the following variables: total US dollar value of non-stablecoin collateral in active vaults[18], total non-stablecoin DAI debts, number of net collateral deposit operation[19] and number of net debt generate operation[20]. We control for $p = 14$ days of lagged variables, including the price of Ether (ETH), Crypto Fear & Greed Index ($CFGI$) and CBOE Volatility Index (VIX). Assuming monetary policy is exogenous to the DeFi ecosystem, the coefficient β_k captures the effect of tightening monetary policy across the horizon k = 0, 1, ….

Our empirical model does not identify the specific structural shocks, such as monetary policy shocks. The interesting question is how monetary policy conditions, regardless of the drivers behind, affect activities in the crypto sector. Nonetheless, we acknowledge that macroeconomic conditions such as inflation can also impact the crypto sector. For example, investors facing higher inflation may invest in cryptocurrencies as hedge against inflation, even if global financial conditions are tight. Our estimate measures the average effect of monetary conditions on DeFi, unconditional on any specific macroeconomic conditions.

B.2 Vault-level analysis

At vault level, we zoom into the decision making process at the vault level. Since vault-level operations are sparse and lumpy, a probit model is employed to examine the probability of vault owners conducting GENERATE

[18] Following MakerDAO's convention, active vaults are vaults with DAI debt outstanding.
[19] The total number of DEPOSIT operations subtracted by the total number of WITHDRAW operations.
[20] The total number of GENERATE operations subtracted by the total number of PAYBACK operations.

and PAYBACK operations in the next 7 days[21]. The model specification is given by

$$\Pr(\text{GENERATE/PAYBACK by vault } i \text{ in 7 days})_{t,i}$$

$$= \Phi\left(\beta_0 + B_1' \begin{bmatrix} \#DaysSinceLastOp_{t,i} \\ \Delta UST2Y_t \\ \Delta \log Collat.Price_{t,i} \\ \log LTV_{t-1,i} - \overline{\log LTV}_i \\ \left(\log LTV_{t-1,i} - \overline{\log LTV}_i\right) \times \Delta UST2Y_t \end{bmatrix} + FE(\text{Collat.}_i)\right) \tag{2}$$

where Φ is the standard cumulative Gaussian distribution function. Since multiple vaults can be owned by the same anonymous investor, we introduce a fixed effect to control for different types of collateral instead of different vaults. In addition to the 2-year Treasury yield, other explanatory variables include the number of days since last operation for the vault ($\#DaysSinceLastOp_{t,i}$ which measures the vault activeness), collateral price returns ($\Delta \log Collat.Price_{t,i}$), the log of end-of-day LTV ratio relative to the vault average ($\log LTV_{t-1,i} - \overline{\log LTV_i}$). We also introduce the interaction term between the log LTV ratio and 2-year US Treasury yield to examine if monetary policy transmission depends on vault-level leverage.

Table B: Vault Level Panel Probit Model Results

	Z-score for	
	$\Pr\left(\begin{matrix}\text{GENERATE} \\ \text{in 7 days}\end{matrix}\right)_{t,i}$	$\Pr\left(\begin{matrix}\text{PAYBACK} \\ \text{in 7 days}\end{matrix}\right)_{t,i}$
Intercept	-0.8180***	-0.8378***
Number of days since last operation $_{t,i}$	-0.0116***	-0.0043***
Collateral Return $_{t,i}$ (1 unit = 100%)	1.8732***	-3.5217***
ΔUST2Y $_t$ (1 unit = 1% point)	-0.3212***	0.1543***
$\log LTV_{t-1,i} - \overline{\log LTV}_i$	-0.5045***	-0.0898***
$(\log LTV_{t-1,i} - \overline{\log LTV}_i) * \Delta UST2Y_t$	-0.3557***	1.5298***
Collateral-type fixed effect	Yes	Yes
Number of observations	3,017,523	3,017,523

* $P \le 0.1$, ** $P \le 0.05$, *** $P \le 0.01$.

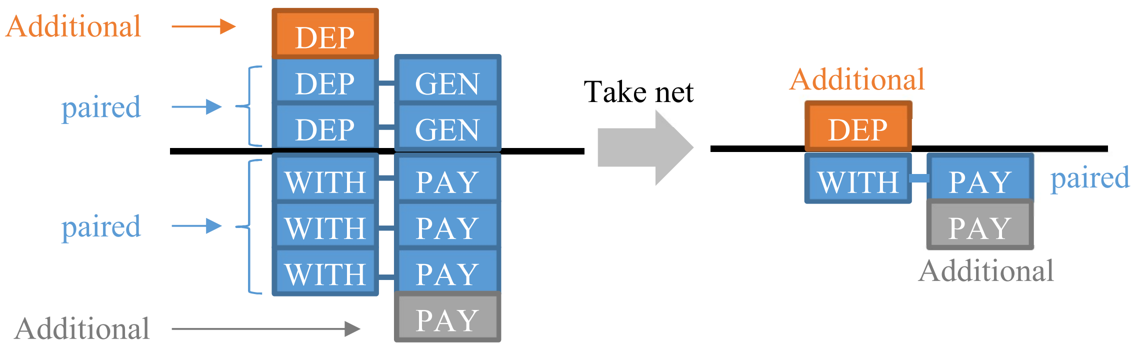
[21] 7 days are chosen to even out potential weekday effects and also allows vault owner to react in a reasonable time frame.

ANNEX C. OPERATION CLASSIFICATION

This section explains in more details how four basic operations are reclassified into paired and additional operations. With the help of this breakdown, we can understand user operations in greater details.

Here we consider an example in which a user performs 3 DEPOSIT, 3 WITHDRAW, 2 GENERATE and 4 PAYBACK operations on a day. Two DEPOSIT operations pair up with two GENERATE operations (expansionary DEPOSIT-GENERATE pair) and three WITHDRAW operations pair up with PAYBACK operations (contractionary WITHDRAW-PAYBACK pair). Hence, there are one DEPOSIT and one PAYBACK operation left unpaired (i.e. additional). On a net basis, there is one contractionary operation in pair and one additional deposit operation and one additional payback operation. This is graphically represented in Chart C1.

Chart C1: Example of operation reclassification



More formally in the algorithm, these metrics are computed as below:

- # net paired operations = min(#DEP, #GEN) – min(#WITH, #PAY)
- # additional collateral operations = (#DEP – #WITH) – # net paired
- # additional debt operations = (#GEN – #PAY) – # net paired

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