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Decentralized lending and its users: Insights from Compound

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Kanis Saengchote

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Kanis Saengchote*

Chulalongkorn Business School

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ABSTRACT

Decentralized finance (DeFi) has recently gained much attention and scrutiny because of its rapid growth. DeFi services replicate traditional financial services such as lending, exchange, and asset management, but they are currently unregulated, unlike their traditional counterparts. We investigate Compound – one of the earliest and largest DeFi lending protocol – to show how it works, who the users are and the potential motivations behind their uses. We find that the loan durations are short (31 days on average), borrowing rates volatile and borrowers are concerned about liquidation risk. Further analyses reveal that some loan demand may arise from leveraged investment strategies. Taken together with the tacit leverage in DeFi yield farming, further availability of on-chain lending could potentially transpire into DeFi systemic risk.

Key words: DeFi, lending, incentives

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* Corresponding author. Chulalongkorn Business School, Chulalongkorn University, Phayathai Road, Pathumwan, Bangkok 10330, Thailand. (email: kanis@cbs.chula.ac.th). I would like to thank Unnawut Leepaisalsuwanna for helping me understand how smart contracts and blockchain work and Supakorn Phattanawasin for excellent research assistance.

1. Introduction

The term decentralized finance (DeFi) carries a very a specific meaning in 2021: it generally refers to an alternative financial system built on a blockchain-based infrastructure (often public) that promises openness, efficiency, transparency, interoperability, and decentralization (for example, Harvey et al., 2021; Schär, 2021). It is a system of computer algorithms, often called a "protocol" of "smart contracts", that replicates traditional financial services such as lending, exchange, and asset management, and are structured via a series of smart contracts that may be represented by transferable (hence tradeable) numerical values also known as "tokens". Smart contracts can be connected to form a network that comprises tokens across any number of protocols without the need to ask for permission for inclusion. This interoperability is often referred to as "composability", and DeFi money is referred to as "Lego money" for this reason. Because of its openness, DeFi is currently unregulated, but policymakers around the world are discussing whether it should be.

In its simplest abstraction, traditional lenders raise fundings in various forms: deposits, bills of exchanges, or even shareholder equity, and lend them out to those who need capital in exchange for interest income. In doing so, they take on several risks, such as interest rate risk (discrepancies in interest income and expense co-movements arising from fixed and variable interest rates), maturity mismatch risk (borrowed funds tend to have shorter maturity than lent funds) and credit risk (borrowers may not be capable of repayment). In other words, lenders not only connect but transform the needs of suppliers and borrowers of capital in a way that an agreement can be reached.

In DeFi, where there is no such centralized institution to take on these risks and identities of participants are unknown, mechanisms need to be redesigned so that suppliers and borrowers of capital can still reach an agreement, and this is the role of the smart contracts in a protocol. In this article, we show that Compound – one of the earliest and largest DeFi lending protocol – does not take on interest rate risk, maturity mismatch risk, faces very small credit risk and does not require any external funding. In fact, Compound could be considered a mutual lender, where depositors mutually "own" the economic benefits to the protocol, like how a mutual insurance company operates. The contingent claims by the depositors make a deposit economically very similar to owning common equity, but without any legal rights attached to it.

In this paper, we illustrate how Compound – one of the earliest and largest DeFi lending protocol that has supplied more than $61.1 billion in token loans between May 2019 and June 2020 – works, who its users are, and how they interact with the protocol. Like its traditional counterparts, the distribution of users in DeFi seems to also be characterizable by skewness, with the top 100 depositor addresses accounting for 75% of all deposits and the top 100 borrower addresses 78% of all loans. We document the factors that influence aggregate depositing and borrowing activities, how incentives via token distribution may influence the decision of users, and potential reasons behind the on-chain loan demand. With the short duration of the loans, volatile borrowing rates and risk of liquidation (89% of loans are in stablecoins), the uses for such loans are currently limited. Some of our findings shed light on potential risks associated with composability, specifically with reference to DeFi "yield farming" amplified by leverage, which might be of interest from a regulatory perspective.

As DeFi is an emergent field, there is extant research on the issue, particularly on lending. Several papers explain how DeFi lending protocols work (Bartoletti et al., 2020; Gudgeon et al., 2020; Perez et al., 2020; Kozhan and Viswanath-Natraj; 2021), with Perez et al. (2020) specifically investigating Compound. However, most of the papers approach the issue at a conceptual level or rely on aggregate flow data. In contrast, our paper uses transaction level blockchain data to shine light and provide a more microscopic view on the issue. The rest of this paper is organized as follows. Section 2 provides an overview of Compound and how its lending algorithm works. Section 3 outlines data source and empirical methodology. We present the results in section 4 and attempt to delve deeper into the reasons behind borrowings in section 5. Section 6 concludes.

2. How Compound Works

2.1 An Overview of Compound

Founded in 2017, Compound launched its "money market" protocol in September 2018. The protocol's mission is to generate an efficient system for earning interest, which is achieved by a dynamic interest rate algorithm that automatically adjusts borrowing and saving rate as a function of available liquidity. Because it needs to generate token income to pay depositors, Compound can also be viewed as a lending protocol and, in many ways, it seems to prioritize depositors over borrowers. Users must deposit accepted tokens into Compound's cToken smart contracts, which return the wrapped cToken (i.e. DAI for cDAI) as depository receipts. The cToken smart contracts set the exchange rates between the tokens according to accrued saving rates, giving users more of the deposited tokens when redeemed, effectively paying interest upon redemption. For example, when a user first deposited DAI to the cDAI contract, the exchange rate may be 46.2896 cDAI to 1 DAI. One day later, the exchange rate may move to 46.2859, so 1 DAI deposited will now be redeemed back for 46.2896 / 46.2859 = 1.0000081 DAI after one day, equivalent to 3% annually. The fully flexible interest rate is set automatically via computer code, to be described later.

Compound initially accepted 4 tokens: wrapped Ether (WETH), 0x Protocol (ZRX), Basic Attention Token (BAT), and Augur (REP). As of July 2021, the list stood at 12 tokens, including stablecoins such as DAI, USD Coin (USDC) and Tether (USDT), and its governance token, COMP. As of July 26, 2021, the most popular deposited tokens in Compound were USDC ($5 billion), followed by DAI ($4.3 billion) and ETH ($3.3 billion).[1] Figure 1 Panel A shows the cumulative dollar value of cToken outstanding against Ether (ETH) price. While most of the dollar value is in from stablecoins, net value outstanding tracks movements in ETH price well.

The deposited tokens become part of the liquidity pool that can be lent out to users. In other words, it is a peer-to-contract (or peer-to-pool) interaction. Users who want to borrow must first deposit accepted tokens as collateral and maintain sufficient overcollateralization, or face being liquidated. Effectively, a DeFi loan is a repurchase agreement rather than a credit agreement. With the anonymity of participants in the ecosystem, the only way to ensure repayment is to have the borrower pledge something valuable as collateral. As collateral must be on-chain for smart contracts to have any authority over them (hence, they must be tokens) and be continuously transactable (that is, they must have liquid markets), this restricts the space of permissible collaterals. As such, the tokens that Compound accepts tend to be popular tokens per examples above. Figure 1 Panel B shows the dollar value of token loans originated in each month. Stablecoins form the majority of loans in the protocol, with DAI the most popular, followed by USDC.

Compound is backed by several high-profile venture capital funds, such as Andreessen Horowitz, Polychain Capital and Bain Capital Ventures, who are majority holders of their governance tokens, COMP. As of July 26, 2021, the three VC firms own a combined voting power of 32.85%.[2] A governance token is a special case of a native token (token issued by the protocol's

[1] Source: https://compound.finance/markets, accessed on July 26, 2021.
[2] Source: https://compound.finance/governance, accessed on July 26, 2021.

smart contract) that contains voting rights; a native token may or may not contain any rights at all. Compound is the pioneer of rewarding protocol participants with its governance/native token. Within one week of its launch on June 15, 2020, the price of COMP doubled. The event is said to have kickstarted the yield farming phenomenon and the brief DeFi Summer of 2020 that ended in September 2020.[3] As of July 26, 2021, COMP had circulating supply of 5,373,538.37 and had already distributed 973,535 with current emission rate of 2,312 per day.[4]

2.2 Compound's Interest Rate Model

While there are potentially many mathematical equations that could be used as interest rate model (see Gudgeon et al., 2020 for examples), the key objective is to ensure that the protocol earns enough interest on borrowers to pay depositors, and perhaps keep some as reserves or profits. Because interest rate is essentially the price of money, changes in market supply and demand of tokens can affect the price. Sponsors then need to decide whether they want to have fixed or variable prices in their protocol. Compound chooses to have variable rate for both supply and borrow, thus bearing no mismatch risk, but other protocols that offer fixed rates exist (e.g. Aave on the Ethereum blockchain fixes borrow rate, while Anchor on the Terra blockchain fixes the supply rate). This makes borrowing a highly uncertain experience, reflecting its inclination toward depositors as a money market protocol.

Let i_b denote the borrow rate, i_s denote the supply (deposit) rate, U denote the utilization rate, computed as outstanding loans divided by outstand deposits, λ denote the reserve factor, we can write Compound's interest rate model as follows:

$$i_b = \begin{cases} a + bU & if\ U \leq U^* \\ a + bU^* + c(U - U^*) & if\ U > U^* \end{cases}$$

$$i_s = i_b(1 - \lambda)U$$

The borrow rate is a kinked linear function in U with a as the base rate. As U exceeds some threshold U^* representing the "optimal" utilization rate, the slope of i_b with respect to U changes from b to c, a higher rate. This increased sensitivity both discourages borrowers from taking on new loan and encourages depositors to supply capital, ensuring that the lending operations will not

[3] Source: https://www.coindesk.com/comp-below-100-defi-summer-over, accessed on July 26, 2021.
[4] Source: https://coinmarketcap.com/currencies/compound/, https://compound.finance/governance/comp, accessed on July 26, 2021.

halt.[5] The supply rate is moderated by U as there needs to be sufficient income to pay depositors, and the reserve factor λ sets aside interest income as buffer for potential credit risk, incentives participants (more on this soon) or retained as profits. As supply and demand of tokens change in each block, interest rates are adjusted accordingly.

Figure 2 plots the daily supply rates for selected tokens computed from the changes in cToken exchange rates from deposits and redemptions (withdrawals). Note that the relationship is not linear because it is the borrow rate that is linear in U, not the supply rate. However, we cannot infer the borrow rate from the observed blockchain data, so we illustrate the trends using the non-linear supply rates instead. Interest rates track utilization rates, but there appears to be different regimes, particularly for stablecoins. This is because Compound made several changes to the interest rate model. For example, DAI underwent 3 changes: the first time on April 7, 2020; the second time on May 2, 2020; and the third time on July 28, 2020. USDC underwent a single change on September 21, 2020, and USDT on August 21, 2020. The changes would be proposed to the community and voted by on holders of COMP, reflecting the governance role that the token holders have. Figure 3 plots the supply rates for DAI and USDC under several regimes marked using different colors and symbols. The distribution of data points suggests that they do indeed belong to different interest rate regimes.

Let us now discuss how Compound manages credit risk. Compound calculates the borrow limit (credit line) of each borrower as follows. Let $(1-\gamma_j)$ be collateral factor for token j, Q_j be the number of deposited token collateral and P_j be the price of token j.[6] The dollar value of outstanding loan in token i must be within borrow limit $\sum_j (1-\gamma_j)P_jQ_j$. Because no scheduled payment is necessary, γ_j is set to ensure borrower's ability to repay. If the price of the token j is volatile, γ_j for that token may be set to a higher rate. For example, as of September 13, 2021, $\gamma_{DAI} = 25\%$ (or alternatively, $(1-\gamma_{DAI}) = 75\%$), while $\gamma_{COMP} = 40\%$.

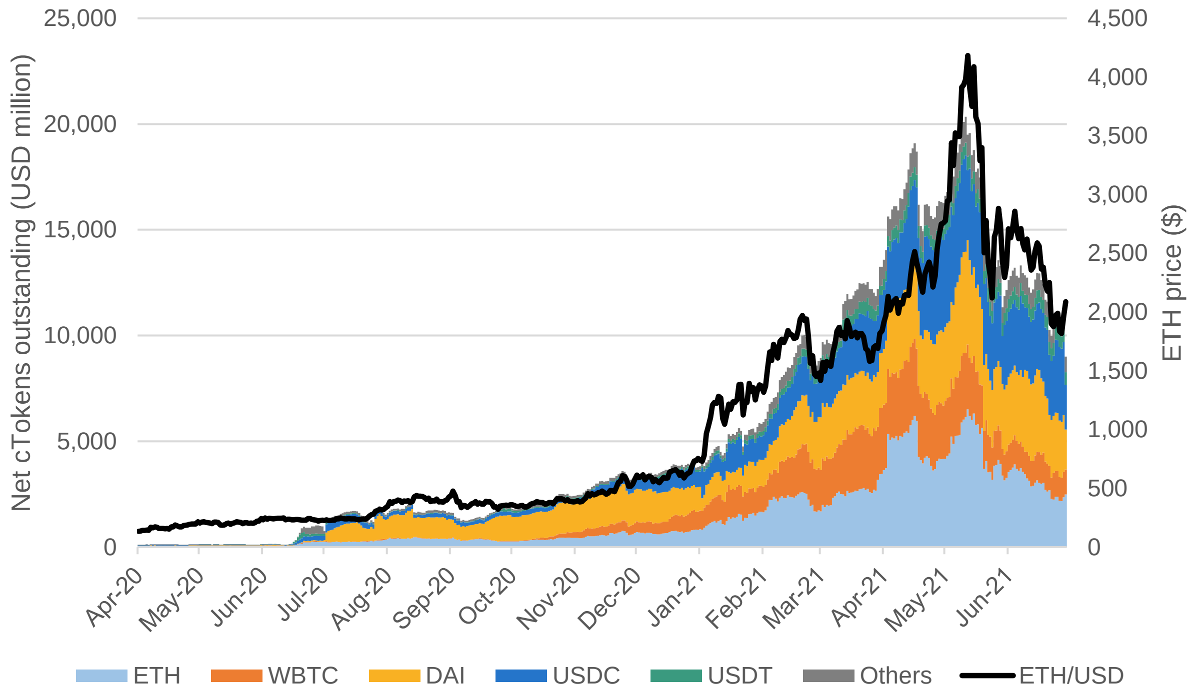
[5] If there are sufficient tokens in the pool for a loan demand, the transaction will fail. Because there is no communication between borrower and lender in the traditional sense, a failed transaction in a permissionless system may cause confusion among participants and induce panic. To ensure continuity, protocols tend design the mechanism to prevent such states from occurring.

[6] Token prices may vary according to trading venues, some of which are not reflected on the blockchain. To import external data, a data oracle (sometimes referred to as price oracle) is required. The oracle code will specify the data source(s) and the price used in the smart contract calculation may involve processing, such as average across sources or time. Data oracles present a potential source of risk (as highlighted in the case of Iron Finance in Saengchote, 2021a), and there are service providers specialized in building trust in the oracle process.

Figure 1: Cumulative cToken deposits and drawn loans

Panel A plots the dollar value of daily net cToken outstanding (cumulative deposits minus redemptions) between May 2019 and June 2021 and daily ETH price (right-hand side scale). The top-five tokens are ETH, WBTC (wrapped Bitcoin), DAI, USDC and USDT. Panel B plots the monthly token loans drawn from cToken smart contracts during the same period.

Panel A: Daily net cToken outstanding in USD million



Panel B: Monthly token loans originated in USD million

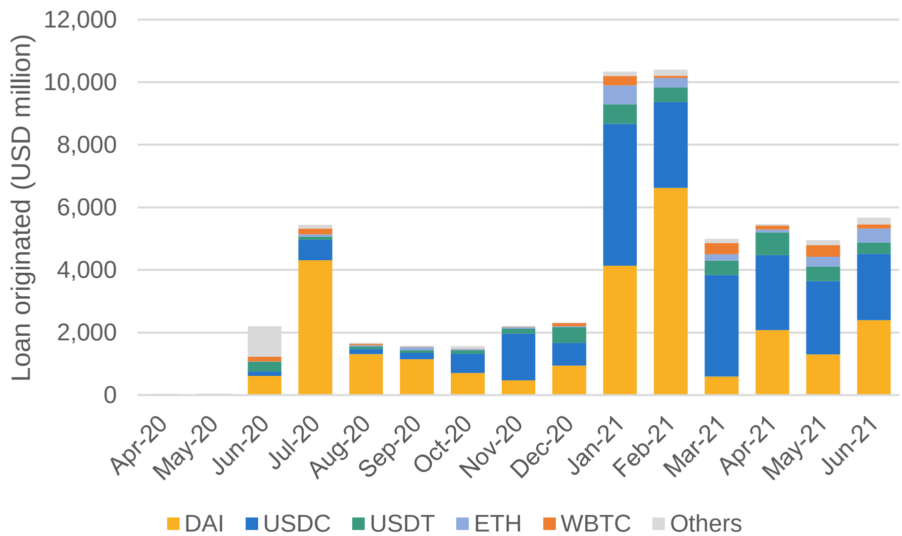
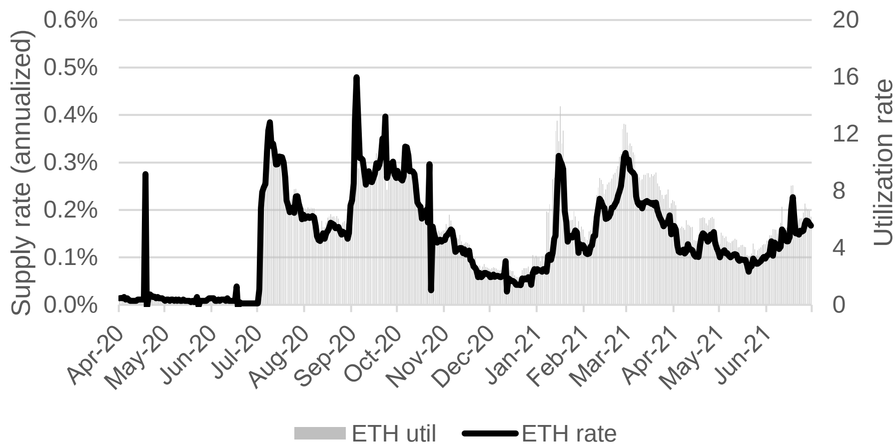


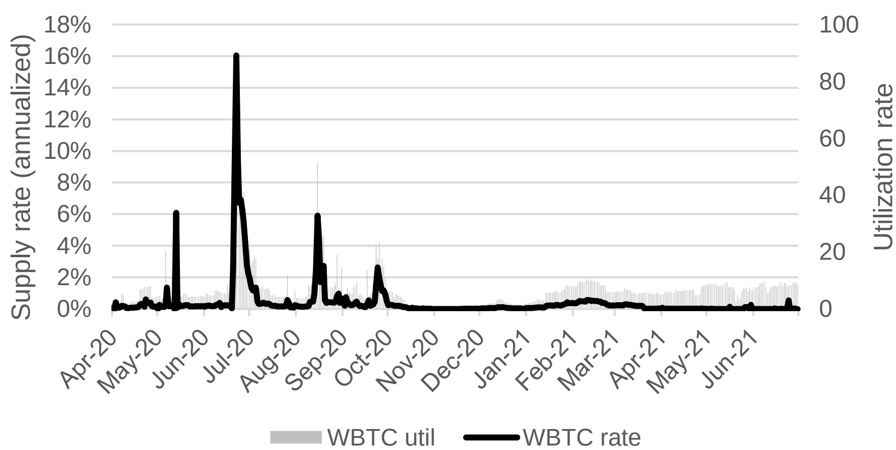
Figure 2: cToken supply rates for selected tokens.

In each panel, the daily supply (deposit) rates for selected tokens are plotted with utilization rate as time series. Utilization rate, computed as outstanding loans divided by outstand deposits, is plotted on right-hand side scale as shaded region. Supply rates are computed from changes in cToken exchange rate and annualized using continuously compounded rate formula. Supply rates are plotted on the left-hand side scale as line.

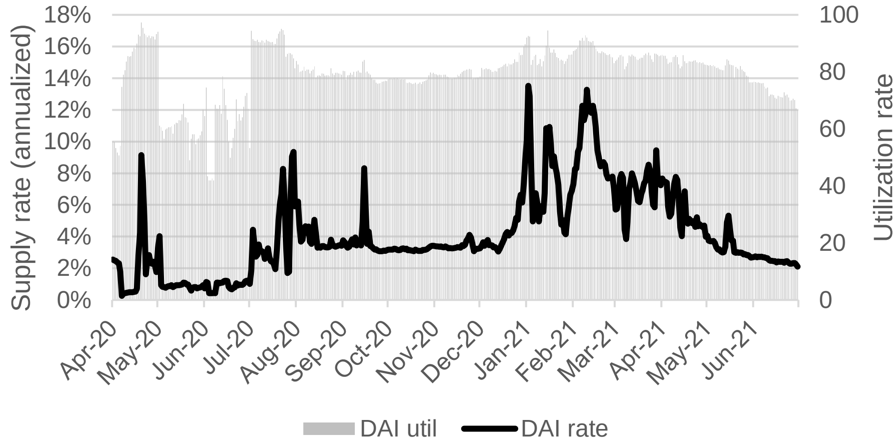
Panel A: ETH supply rate



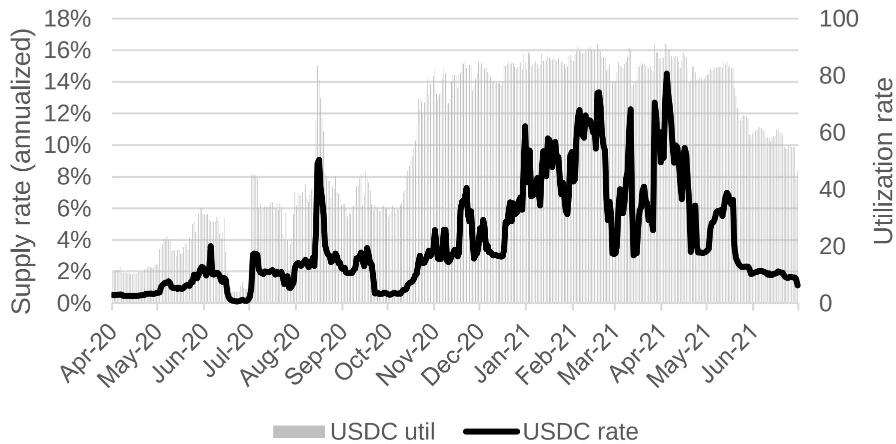
Panel B: WBTC supply rate



Panel C: DAI supply rate



Panel D: USDC supply rate



Panel E: USDT supply rate

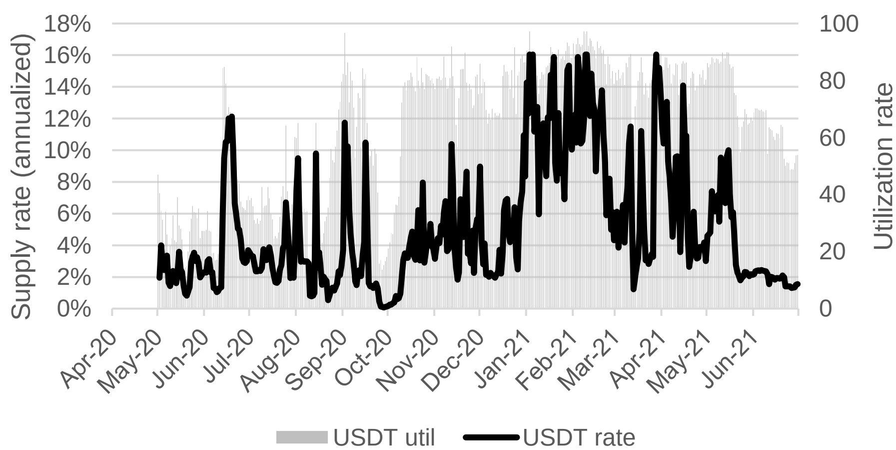
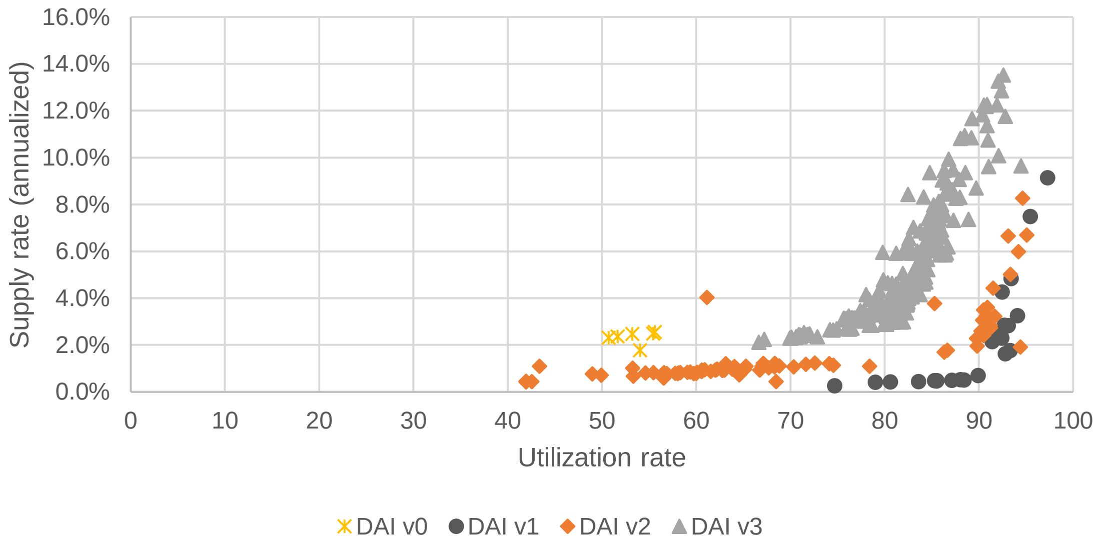
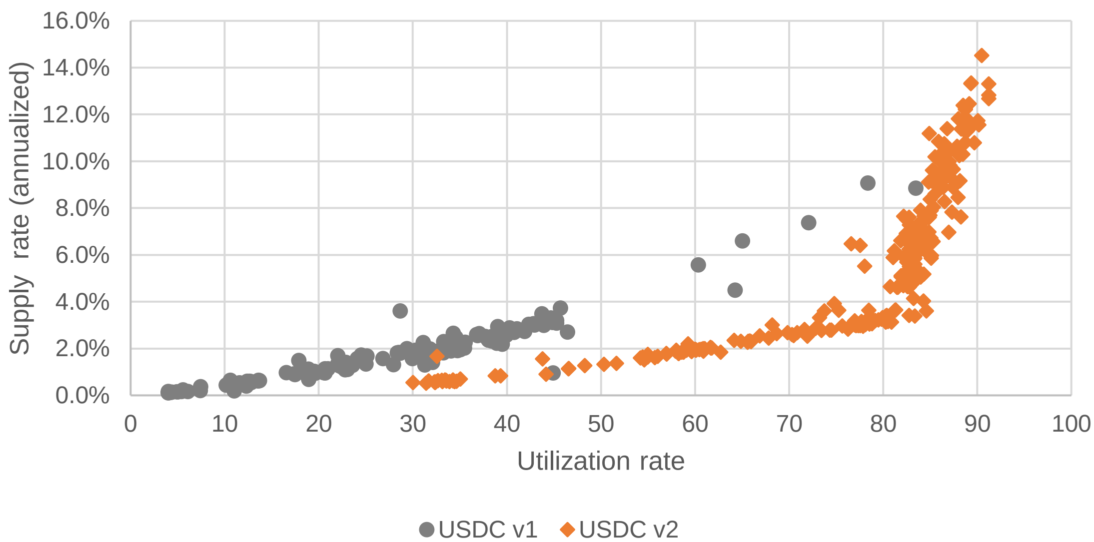


Figure 3: The kinked interest rate model.
In each panel, the daily supply (deposit) rates for selected tokens are plotted against utilization rate as scatter plots. Utilization rate, computed as outstanding loans divided by outstand deposits, is plotted on the horizontal axis. Supply rates, computed from changes in cToken exchange rates and annualized using continuously compounded rate formula, are plotted on the vertical axis. Compound uses a kinked interest rate model, where the interest rate is linear in utilization rate and the slope changes when utilization rate reaches the optimal level. The model is applied to borrow rate and the supply rate is further adjusted based on the utilization rate to ensure the cToken smart contract generates enough interest income to pay depositors. Consequently, the supply rates plotted here are non-linear. Compound adjusts the formula interest calculation several times during its operation. Data points corresponding to different interest rate regimes are marked with different colors. During the sample, DAI operated under 4 different interest rate models, while USDC operated under 2.

Panel A: DAI



Panel B: USDC



2.3 Compound's Loan Liquidation

Let V_i be the outstanding value of loan in token i. At any point in time, borrowers must ensure that $\sum_j (1-\gamma_j) P_j Q_j - V_i > 0$. The expression is referred to by Compound as "account liquidity", which, when negative, permits third party users to partially repay the loan on the borrower's behalf and receive a share of borrower's overcollateralized tokens. In absence of gas cost, this transaction would likely be profitable (unless collateral prices change sharply over a short horizon). But because gas cost does not vary according to transaction value, it is possible that small loans are not liquidated because the arbitrage profits are not sufficient, so Compound adds liquidator incentive paid out of accumulated reserves to make liquidation more profitable. This is because, by design, Compound does not proactively monitor and manage credit risk of lending portfolio but instead outsources the tasks to liquidators. Fearing liquidation, borrowers tend not to borrow up to their full credit limit, making the loans highly overcollateralized. Coupled with active liquidation that is allowed even when the loan is still comfortably overcollateralized, Compound essentially faces little to no credit risk; only a severe drop in collateral tokens' prices (and/or a sharp increase in loan tokens' prices) would potentially threaten Compound with credit loss. The liquidation risk is another aspect which makes Compound more friendly to depositors than borrowers. Technical details on how Coumpound's liquidation mechanism works can be found in Perez et al. (2020).

In short, Compound does not take on interest rate risk, maturity mismatch risk and faces very small credit risk, and does not require any external funding. In fact, in the traditional business sense, Compound's sponsors need not put any equity into its lending business at all, since loans are fully funded by depositors. With variable claims directly tied to the lending income, one could consider Compound a mutual lender, where depositors mutually "own" the economic benefits to the protocol, like how a mutual insurance company (where ownership is shared by policyholders) might operate. The contingent claims by the depositors make deposits economically very similar to common equity, but without any legal rights attached to it.

In this paper, our objective is to provide an overview of Compound's activities, as well as a microscopic view of who its users are and how they interact with protocol. We make the explicit connection between Compound and MakerDAO, another early and influential DeFi protocol that is both a lending protocol and stablecoin protocol, also backed by Andreessen Horowitz. Saengchote (2021b) analyzes MakerDAO and its connectivity to other protocols, where Compound is one of the main destinations minted DAI stablecoins. The paper also documents a drastic change in network diagram of protocol connectivity between June 2020, the period referred to by the crypto community as the beginning of the "DeFi summer" that kickstarted DeFi "yield farming", and 2021, with Compound's smart contracts (cDAI) experiencing the greatest increase in network connectivity among all protocols. More details on yield farming can be found in Saengchote (2021a, 2021b).

3. Data and Empirical Methodology

3.1 Data

The Ethereum blockchain data used in this paper is obtained from Google BigQuery, which is hosted and listed Google Cloud Marketplace. We retrieve Compound's transactions between May 2019 and June 2021, covering over 8 million deposits, 3.56 million redemptions, 0.16 million borrows and 0.13 million repayments of 356,800 unique addresses. The unit of reporting in the Ethereum blockchain is an address, which can hold tokens and thus be used as a wallet. Owner of the address can embed any information in it, including programming codes, which would then make the address a smart contract. While the blockchain is in principle anonymous, owners of smart contracts typically identify themselves and provide their source codes for community audit on websites such as Etherscan.io for credibility. However, this is not mandatory, and many smart contracts are unintelligible to a human reader. While the content of blockchain is transparent for all to see, to an observer, all she sees is binary data that cannot be reverse engineered to any specific programming language or any person.

By manually inspecting the content of each address, one can classify whether it is part of a DeFi protocol, a generic smart contract, or a wallet. For example, the address '0x5d3a536E4D6DbD6114cc1Ead35777bAB948E3643' is Compound DAI (cDAI) contract that accepts DAI for cDAI from depositors and lends out DAI to borrowers. For each transaction, we observe the source and target of token transfer. We manually inspect the top 100 sources and targets of the 12 cToken smart contracts in terms of both token amount and frequency of transactions and classify them by type into 7 categories: (1) large wallet, (2) small wallet, (3) yield aggregator, (4) on-ramp access, (5) decentralized exchange, (6) asset management, and (7) unidentified smart contracts. Large wallets are addresses in the top 100 rankings described earlier, while smart contract protocols are defined according to the criteria described in the Appendix.

3.1 Empirical Methodology

We investigate in the determinants of the net token minting activity – that is, the net amount of minted and redeemed cToken in each day, or net deposits – which represents net inflows into the protocol. For each day beginning at midnight of Coordinated Universal Time (UTC), we aggregate token flows to (minting) and from (redemption) cToken smart contract addresses and analyze the relationship between net token flows and their determinants. Because Compound accepts 12 tokens that include both stablecoins (DAI, SAI, TUSD, USDC and USDT) and cryptocurrencies (all others, which are tokens with volatile prices), we calculate the dollar value of token flows by multiplying the quantity by the daily token prices obtained from the data API of CoinGecko.

$$NetFlow_{k,t} = \alpha_k + \beta_{1,k} Post_t + \beta_{2,k} Post_t \times \ln(COMP_t) + \beta_{3,k} NetDAI_t + \gamma_k X_t + \varepsilon_{k,t}$$

The dependent variable in our regression is net dollar of cToken minted in USD million, which we first aggregate, then separate into flows of stablecoins and cryptocurrencies. As illustrated in Figure 1, most deposited tokens are stablecoins, followed by ETH and WBTC. In an analogue to traditional money market funds, Compound's deposits may be used by token holders who seek safety in deposit-bearing accounts, so market conditions proxied by price levels (log price), trends (past 7-day price change) and volatility (past 30-day volatility) of cryptocurrencies may influence the demand for deposits. While there are multiple cryptocurrencies, the correlation between ETH and other tokens are between 0.73 and 0.92, with correlation between ETH and BTC at 0.80. Since the dominant deposited tokens are stablecoins, ETH and WBTC, we include only variables to ETH in the vector X_t. If this safety demand hypothesis were prevalent, then we should observe a negative relationship between net inflows and the level of ETH and past 7-day return, and positive relationship to past 30-day volatility.

As Saengchote (2021b) documents that much of minted MakerDAO's DAI ended up in Compound, we include the net DAI minted (in USD million) as independent variable to confirm this relationship. Because Compound started distributing its governance token (COMP) on June 15, 2020, as rewards for users, this incentive may attract inflows into the protocol, and the incentive can be stronger as token price increases. We include an indicator variable $Post$ for periods post distribution of COMP and its interaction with log of COMP price in the regressions. If the demand were driven by token incentives, the coefficient on $Post$ and $Post \times \ln(COMP)$ should be positive.

$$\ln(Loan_{k,t}) = \alpha_k + \beta_{1,k} Post_t + \beta_{2,k} Post_t \times \ln(COMP_t) + \gamma_k X_t + \varepsilon_{k,t}$$

We repeat a similar analysis for token loans, omitting net DAI minted and replacing the dependent variable with log of dollar value of token loan (since all values are positive). The demand for loan in Compound could be driven by (1) idiosyncratic demand for liquidity without necessitating a sale that triggers capital gains tax, (2) demand for leverage for long positions in cryptocurrencies, (3) demand for shorting via repurchase agreement, or (4) demand for tokens to be staked in other DeFi protocols to earn yield. (1) is difficult to discern, but its idiosyncratic nature makes it more likely to be noise. (4) can be investigated by looking at the how borrowers use their borrowed tokens, and (2) and (3) can invested in a regression framework with respect to cryptocurrency's price.

In this setting, however, ETH's volatility takes on a different interpretation. While we are unable to observe the token collaterals that back each loan, if one were to surmise that it is more likely that borrowers rely on cryptocurrencies as collateral more than stablecoins, then periods where ETH's price is more volatile would place the borrower at greater risk of liquidation, and thus would be less likely to take out a loan. Consequently, we expect to see a negative coefficient on ETH's past 30-day volatility.

All analyses are conducted at daily frequency and standards errors are estimated using the Newey-West procedure to account for potential serial correlation in the data. Table 1 reports the summary statistics over May 2019 to June 2021 for daily net cToken minting cToken loans in USD million. Most of the activities are in stablecoins, corresponding to the pattern observed in Figure 1. While average daily net cToken minted is small, with median value close to zero, the maximum and minimum values are very high, potentially reaching billions in some tokens. For token loans, stablecoins are also more popular, with as much as $3 billion stablecoin loan taken out in one day.

Table 1: Summary statistics

Panel A reports the summary statistics of daily cToken net minting (deposits minus redemptions) between May 2019 and June 2021. During this period, Compound accepts 12 tokens. The dollar values are calculated using daily prices obtained from CoinGecko. Stablecoins include DAI, SAI, TUSD, USDC and USDT, and other tokens are classified as cryptocurrencies. Panel B reports the summary statistics for daily token loans drawn from cToken smart contracts during the same period.

Panel A: Daily net cToken minting in USD million

	Average	Std Dev	Min	P5	P50	P95	Max
BAT	0.24	55.53	-1,027.30	-3.48	0.00	4.88	437.33
COMP	0.00	0.02	-0.05	-0.01	0.00	0.02	0.23
DAI	5.10	119.12	-803.56	-105.63	1.79	138.19	572.76
ETH	0.00	0.06	-0.64	-0.06	0.00	0.06	0.61
LINK	0.08	0.26	-0.14	-0.11	0.00	0.67	1.24
REP	0.00	0.08	-0.75	0.00	0.00	0.00	1.05
SAI	0.00	0.00	-0.04	0.00	0.00	0.00	0.00
TUSD	3.03	12.79	0.00	0.00	0.00	30.69	59.50
UNI	0.05	0.58	-3.04	-0.61	-0.01	0.93	3.30
USDC	5.09	156.60	-1,323.58	-68.08	2.16	99.44	1,011.93
USDT	1.42	27.01	-158.43	-20.40	0.01	26.08	420.14
WBTC	0.00	0.00	-0.01	0.00	0.00	0.00	0.01
ZRX	0.26	6.16	-39.57	-1.51	0.00	1.60	99.37
All	12.31	207.63	-2,125.02	-222.38	7.57	195.64	954.97
Stablecoin	11.77	205.79	-2,126.06	-210.23	6.82	195.12	956.14
Crypto	0.54	56.35	-990.28	-4.06	0.01	6.44	537.09

Panel B: Daily token loan in USD million

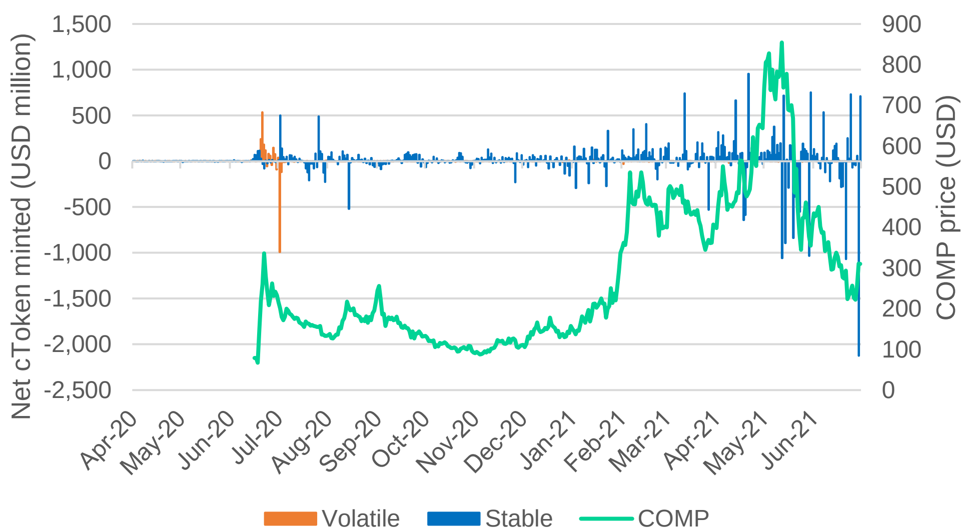
	Average	Std Dev	Min	P5	P50	P95	Max
BAT	2.06	15.03	0.00	0.00	0.00	6.10	278.13
COMP	0.45	3.39	0.00	0.00	0.00	1.12	47.93
DAI	58.44	197.24	0.00	0.02	8.08	246.43	1,792.90
ETH	5.10	18.41	0.00	0.00	0.67	18.10	200.42
LINK	0.19	1.05	0.00	0.00	0.00	0.18	9.63
REP	0.60	6.58	0.00	0.00	0.00	0.01	108.86
SAI	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TUSD	0.21	3.75	0.00	0.00	0.00	0.09	80.00
UNI	1.08	6.11	0.00	0.00	0.00	4.41	105.04
USDC	46.93	156.03	0.00	0.02	7.78	155.94	1,515.29
USDT	9.72	20.51	0.00	0.00	3.21	49.16	185.71
WBTC	4.12	14.66	0.00	0.00	0.16	19.62	156.48
ZRX	0.18	1.72	0.00	0.00	0.00	0.21	29.06
All	129.07	291.82	0.01	0.18	41.62	557.79	3,096.37
Stablecoin	115.29	286.57	0.01	0.08	32.70	520.88	3,066.71
Crypto	13.78	34.25	0.00	0.01	2.91	74.61	341.39

4. Results

4.1 Aggregate Activities

We begin with a graphical illustration of net cToken minting over time. Figure 4 plots the dollar value of net cToken minted categorized by stablecoins and cryptocurrencies along with the price of COMP, Compound's governance token. Most of dollar value minted and redeemed are stablecoins, with cryptocurrencies activity peaking only in June to early July of 2020, shortly after the introduction of COMP. The correlation between COMP price and net stablecoins and cryptocurrencies minted are 0.03 and -0.00 respectively, suggesting that COMP may play little role in attracting users.

Figure 4: Net cToken deposits and Compound's governance token price
This figure plots the dollar value of daily net cToken minted (deposits minus redemptions) between May 2019 and June 2021 and daily COMP price (right-hand side scale). The 12 cTokens are grouped into two categories, where stablecoins include DAI, SAI, TUSD, USDC and USDT, while the other tokens are classified as cryptocurrencies.



Next, we turn to multivariate regressions. Column 1, 4 and 7 of Table 2 report the baseline regression of net cToken minted on ETH-related variables. None of the regressors are statistically significant, with adjusted R-squared values close to zero. On average, net cToken minting activities appear to be unrelated to movements in market conditions. When net DAI minted is included as regressor, explanatory power is improved, but mainly in stablecoins activity. Finally, when Post and its interaction action with log COMP price are included, explanatory power is little changed. This finding is consistent with the lack of correlation in Figure 4; COMP incentive seems to be unrelated to net demand for deposits.

Table 2: Determinants of net daily cToken minting by token type.

This table reports the result from the regressions of net cToken minting (deposits minus redemptions) in USD million between May 2019 and June 2021. In column 1 to 3, the dollar volume is aggregated across all 12 tokens. In column 4 to 6, only stablecoins are included (DAI, SAI, TUSD, USDC and USDT), and in column 7 to 9, only cryptocurrencies (all other tokens) are included. In the baseline regressions (column 1, 4 and 7), log ETH price, 7-day ETH return, and 30-day ETH volatility (measured in percentage point) are included. Next, in column 2, 5 and 7, net DAI minted (minted minus burned) by MakerDAO in USD million is included. In the full specification, indicator variable for periods post COMP distribution (Post) and its interaction with log COMP price are included. Standard errors are computed using the Newey-West procedure with one-day lag and reported in parenthesis. Stars correspond to statistical significance level, with *, ** and *** representing 10%, 5% and 1% respectively.

VARIABLES	(1) All	(2) All	(3) All	(4) Stablecoins	(5) Stablecoins	(6) Stablecoins	(7) Cryptos	(8) Cryptos	(9) Cryptos
Post			-116.3			-73.41			-42.87
			(124.9)			(114.6)			(86.64)
Post * ln(COMP)			29.67			19.68			9.99
			(26.88)			(24.00)			(21.24)
Net DAI minted		1.11***	1.10***		1.12***	1.11***		-0.02	-0.02*
		(0.39)	(0.39)		(0.39)	(0.39)		(0.02)	(0.01)
Ln(ETH)	2.79	-7.80	-30.35	3.35	-7.39	-23.33	-0.56	-0.41	-7.02
	(12.13)	(12.63)	(23.33)	(12.05)	(12.53)	(21.08)	(2.53)	(2.65)	(17.87)
ETH return (7d)	90.14	50.54	59.13	88.38	48.21	54.84	1.76	2.34	4.28
	(94.28)	(72.70)	(73.99)	(93.86)	(71.90)	(73.35)	(15.69)	(16.19)	(11.28)
ETH volatility (30d)	-106.2	-164.5	-3.74	-139.0	-198.2	-66.86	32.83	33.68	63.12
	(358.9)	(358.3)	(418.7)	(357.6)	(356.9)	(418.1)	(110.2)	(111.0)	(41.73)
Constant	-3.49	57.17	157.3	-5.91	55.64	124.0	2.42	1.53	33.32
	(70.49)	(73.35)	(122.2)	(69.38)	(72.12)	(110.5)	(25.26)	(25.98)	(95.43)
Adj R-squared	-0.0034	0.0434	0.0418	-0.0034	0.0458	0.0430	-0.0065	-0.0086	-0.0098

Table 3: Determinants of net daily cToken minting for main stablecoins.
This table reports the result from the regressions of net cToken minting (deposits minus redemptions) in USD million between May 2019 and June 2021 for the three main stablecoins, DAI, USDC and USDT. In column 1, 3 and 5, log ETH price, 7-day ETH return, and 30-day ETH volatility (measured in percentage point), net DAI minted (minted minus burned) by MakerDAO in USD million, indicator variable for periods post COMP distribution (Post) and its interaction with log COMP price are included. In column 2, 4, and 6, one-day lagged annualized supply (deposit) rate for each token is included. Standard errors are computed using the Newey-West procedure with one-day lag and reported in parenthesis. Stars correspond to statistical significance level, with *, ** and *** representing 10%, 5% and 1% respectively.

VARIABLES	(1) DAI	(2) DAI	(3) USDC	(4) USDC	(5) USDT	(6) USDT
Post	-55.40	-54.43	-30.05	-25.03	7.54	8.47
	(73.78)	(73.89)	(91.93)	(92.30)	(17.95)	(18.21)
Post * ln(COMP)	14.91	13.71	7.40	6.14	-1.65	-2.14
	(15.48)	(15.82)	(18.49)	(18.53)	(3.80)	(3.88)
Net DAI minted	1.35***	1.35***	-0.247	-0.235	0.023	0.026
	(0.19)	(0.19)	(0.38)	(0.38)	(0.02)	(0.02)
Lagged rate		2.48		5.23		1.31**
		(2.98)		(3.72)		(0.52)
Ln(ETH)	-24.83**	-26.55**	-1.29	-12.13	1.37	-0.239
	(11.71)	(12.02)	(14.38)	(18.95)	(2.77)	(3.10)
ETH return (7d)	48.97	38.54	-3.45	-38.35	16.65	3.30
	(37.78)	(37.81)	(63.45)	(67.82)	(10.35)	(10.75)
ETH volatility (30d)	-5.16	-8.26	-86.11	13.71	43.54	50.85
	(211.9)	(212.2)	(337.0)	(332.3)	(71.88)	(72.75)
Constant	128.1**	134.2**	12.23	59.54	-9.30	-3.70
	(62.42)	(63.28)	(75.72)	(96.42)	(13.13)	(14.73)
Adj R-squared	0.223	0.224	-0.0085	-0.0042	-0.0043	0.0207

In Table 3, we further investigate the demand for each of the 3 popular stablecoins, DAI, USDC and USDT. We also include lagged supply (deposit) rate illustrated earlier in Figure 2 as regressors in extended model. The average supply rates for DAI, USDC and USDT over the period are 4.13%, 3.91% and 5.10% respectively. This separation gives us a glimpse of how each stablecoin may have a different role in the DeFi ecosystem, as they behave differently. Most notably, only net cDAI minted is related to net DAI minted (as documented in Saengchote, 2021b), and the relationship is very strong: the coefficient suggests that a $1 increase in net DAI minted is associated with a $1.35 increase in net cDAI minted and is statistically significant at 1% level. The relationship is not observed for USDC and USDT. On the other hand, net cUSDC minted is not related to any of the regressors, while net cUSDT minted is correlated with supply rate, while other stablecoins are not. This could be related to level of interest rate, as USDT had the highest average rate of all 3 stablecoins, making it the most attractive.

Table 4: Determinants of daily cToken loans.

This table reports the result from the regressions of log cToken loan between May 2019 and June 2021. In column 1 and 3, the dollar volume is aggregated across all 12 tokens. In column 3 and 4, only stablecoins are included (DAI, SAI, TUSD, USDC and USDT), and in column 5 and 6, only cryptocurrencies (all other tokens) are included. In the baseline regressions (column 1, 3 and 5), log ETH price, 7-day ETH return, and 30-day ETH volatility (measured in percentage point) are included. Next, in column 2, 4 and 6, indicator variable for periods post COMP distribution (Post) and its interaction with log COMP price are included. Standard errors are computed using the Newey-West procedure with one-day lag and reported in parenthesis. Stars correspond to statistical significance level, with *, ** and *** representing 10%, 5% and 1% respectively.

	(1) All	(2) All	(3) Stablecoins	(4) Stablecoins	(5) Cryptos	(6) Cryptos
Post		2.91***		4.13***		-1.19
		(1.00)		(1.01)		(1.58)
Post * ln(COMP)		0.279		0.080		1.11***
		(0.22)		(0.22)		(0.35)
Ln(ETH)	1.63***	0.363**	1.70***	0.467***	1.68***	0.010
	(0.12)	(0.17)	(0.13)	(0.17)	(0.15)	(0.29)
ETH return (7d)	-0.010	0.001	-0.003	0.008	-0.026***	-0.015*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
ETH volatility (30d)	-0.386***	-0.104***	-0.413***	-0.113***	-0.313***	-0.045
	(0.04)	(0.04)	(0.04)	(0.04)	(0.06)	(0.07)
Constant	8.61***	11.64***	7.99***	10.57***	5.20***	10.60***
	(0.78)	(0.85)	(0.84)	(0.86)	(0.92)	(1.44)
Adj R-squared	0.449	0.714	0.433	0.701	0.354	0.539

Unlike the net demand for deposits, the demand for loans is much more correlated to market conditions. Table 4 reports the regression outputs of log dollar value of token loan on ETH-related variables. Interpreting ETH price as proxy for general market conditions, there is greater demand in good markets. During volatile periods, there is less demand for loans, consistent with higher risk of liquidation. Figure 1 Panel B reveals an uptake in loans post COMP distribution, and Column 2, 4 and 6 with additional regressors show similar results. The average volume of loans post COMP distribution is higher for stablecoins, but log COMP price is only related to the demand for cryptocurrencies, not stablecoins. While there are potentially many uses of stablecoins, for cryptocurrencies, the reasons for borrowing them are much more limited. This is also reflected in more generous COMP distribution (when the value of the incentive is calculated as percentage of the loan); often, the net borrow rate (borrow rate minus incentive) can be negative for tokens with low demand, which tend to be cryptocurrencies. This would make it consistent with demand for yield farming.[7] In addition, demand for cryptocurrencies is lower when ETH price has been increasing, suggesting that it could be used to short tokens when their prices are falling. Overall, when compared to the regressions of net demand for deposits, regressions of net demand for loans have much higher adjusted R-squared values.

Last, we turn our attention to individual stablecoins, reported in Table 5. While loan demand for each stablecoin also increase post COMP distribution, they do not appear to be related to COMP price. In fact, they are negatively related, albeit with weak statistical significance. The demand for DAI is negatively related to ETH price (again, weak statistical significance) while the demand for USDC and USDT is positively related. Similar to the results in Table 3, the inclusion of rates does not affect the explanatory power for DAI and USDC, but slightly increases for USDT. However, the direction of the relationship may be different than what one might anticipate: higher USDT rate is positively related to higher demand for USDT loan, rather than negative. In this context, the interpretation is that rate increases cannot deter users from borrowing USDT, and much of the time they continue to do so despite high rate. This is consistent with Figure 2 Panel E which shows that USDT tends to have higher rates and utilization rates, particularly in bull market of early 2021. Since much of cryptocurrency transactions on centralized exchanges tend to be bought using stablecoins such as USDT, the demand for USDT could be fueled by leveraged trading.

[7] Compound allocates a fixed number of tokens per market in each day, to be distributed among suppliers and borrowers. For markets with fewer borrowers than suppliers, the COMP incentive to borrow would very strong. For example, as of May 16, 2021, Compound allocates 141.25 tokens per day to ETH and WBTC markets, but because of differences in market size and utilization rate, ETH borrow would pay 2.82% borrow rate and receive 7.57% COMP incentive (Compound calls this distribution APY), make the net cost to borrow ETH -4.75%, while the same numbers for WBTC are 4.77%, 9.36% and -4.59%. For stablecoins, the net cost to borrow, however, are positive.

Table 5: Determinants of daily cToken loans for main stablecoins

This table reports the result from the regressions of log cToken loan between May 2019 and June 2021 for the three main stablecoins. In column 1, 3 and 5, log ETH price, 7-day ETH return, and 30-day ETH volatility (measured in percentage point), indicator variable for periods post COMP distribution (Post) and its interaction with log COMP price are included. In column 2, 4, and 6, one-day lagged annualized supply (deposit) rate for each token is included. Standard errors are computed using the Newey-West procedure with one-day lag and reported in parenthesis. Stars correspond to statistical significance level, with *, ** and *** representing 10%, 5% and 1% respectively.

	(1) DAI	(2) DAI	(3) USDC	(4) USDC	(5) USDT	(6) USDT
Post	2.91**	2.93**	6.68***	6.72***	11.58***	11.54***
	(1.43)	(1.41)	(1.11)	(1.11)	(1.56)	(1.47)
Post * ln(COMP)	0.517*	0.491	-0.410*	-0.421*	-0.648*	-0.674**
	(0.31)	(0.31)	(0.24)	(0.23)	(0.34)	(0.32)
Lagged rate		5.23		4.97		10.79***
		(5.15)		(3.15)		(3.58)
Ln(ETH)	-0.416*	-0.452*	0.973***	0.870***	1.78***	1.62***
	(0.25)	(0.25)	(0.19)	(0.20)	(0.29)	(0.27)
ETH return (7d)	0.025***	0.023***	-0.001	-0.004	-0.009	-0.019*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
ETH vol (30d)	-0.095	-0.096	-0.121**	-0.112**	-0.402***	-0.386***
	(0.06)	(0.06)	(0.05)	(0.05)	(0.07)	(0.07)
Constant	13.79***	13.92***	5.98***	6.43***	-2.88**	-2.28*
	(1.24)	(1.24)	(0.94)	(0.99)	(1.36)	(1.29)
Adj R-squared	0.538	0.538	0.639	0.640	0.749	0.754

4.2 Address-Level Activities

In this section, we present summary statistics of transactions at address level. While there are 356,800 addresses, there are about 195,200 addresses that made exactly one stablecoin deposit of $3 or less, with 183,000 addresses that made exactly $3 deposit. We classify these addresses as micro addresses and exclude them from summary statistics. Figure 5 plots the new depositors and borrowers between May 2019 and June 2021. Of the remaining 161,569 addresses, we classify them into 7 groups based on embedded smart contracts, and their summary statistics are reported in Table 6, Panel A. Small wallets account for 99.7% of addresses and 16% of dollars deposited, while large wallets (256 addresses) account for 0.2% share but 30.5% of dollars deposited. Smart contract addresses that belong to DeFi protocols tend to make larger deposits, but there are 109 unidentified smart contracts that account for most deposits and have highest average deposits per address. Owners of these smart contracts do not disclose themselves or the intention of the contracts, so it is unclear what they represent. Some of them could be unmarked contracts that belong to some protocol, while others could be privately owned by large investors (e.g. hedge funds). The top 100 addresses account for 75% of all deposits.

For borrowers, the summary statistics are reported in Panel B. There are 22,289 unique borrows, and most of the dollar value is from large wallets (217 addresses) and unidentified smart contracts (51 addresses). 89% of the loans are in stablecoins, and the top 100 addresses account for 78% of all loans. The average loan duration is 31 days, and longer for stablecoins (33.8 days) than cryptocurrencies (23.2 days). Large wallets tend to borrow for shorter duration than small wallets. Asset management protocols have the longest duration because they are used to create leveraged index token (the only two in the sample are ETH and BTC 2x Flexible Leverage Index that borrow USDC). Overall, the short loan duration beckons the question of the purpose behind these loans, which we will attempt to explore in the next section.

5. Where do borrowed tokens go?

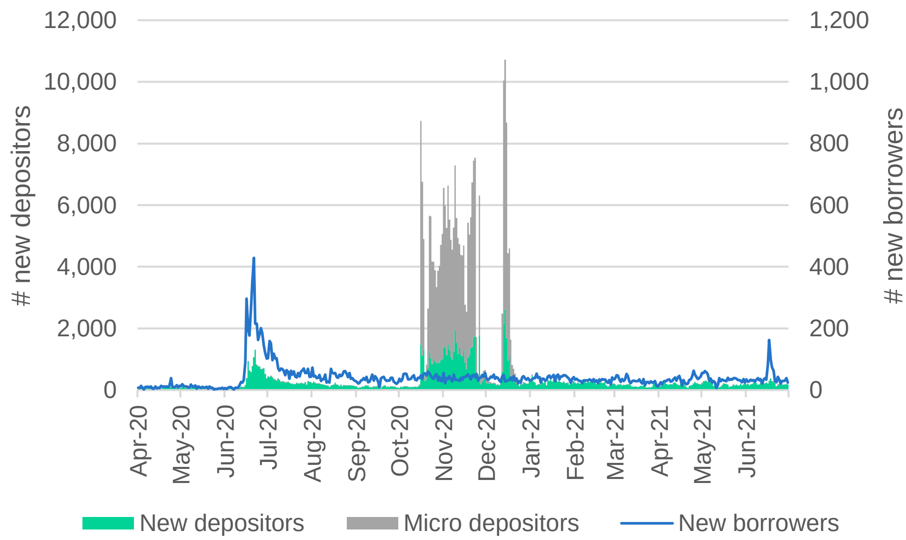
Recall that the demand for loan in Compound could be driven by (1) idiosyncratic demand for liquidity, (2) leverage demand for long positions, (3) demand for shorting, or (4) demand for yield farming. We have shown some evidence that cryptocurrency loans might be used for shorting and yield farming. In this section, we explore the yield farming demand further by investigating redepositing of borrowed tokens. Because a Compound loan must necessarily be preceded by a collateral deposit, redepositing the borrowed tokens again can be interpreted as intention of yield farming with leverage.[8] All such transactions are eligible for COMP distribution.

[8] A description of leveraged yield farming strategy in Compound could be found as early as June 22, 2020 – just one week after distribution of COMP. See, for example, https://defiprime.com/defi-yield-farming.

Figure 5: User acquisition timeline of Compound

Panel A plots the number of new unique addresses that deposit tokens into or take loans out of cToken smart contracts in each day. Of 356,800 addresses, there are about 195,200 addresses that made exactly one stablecoin deposit of $3 or less, with 183,000 addresses that made exactly $3 deposit. The addresses are classified as micro depositors and are excluded from the address-level analysis. There are about 161,500 depositors and 22,300 borrowers in Compound over the sample period. Figure B plots the number of users on a cumulative basis.

Panel A: New depositors and borrowers



Panel B: Cumulative depositors and borrowers

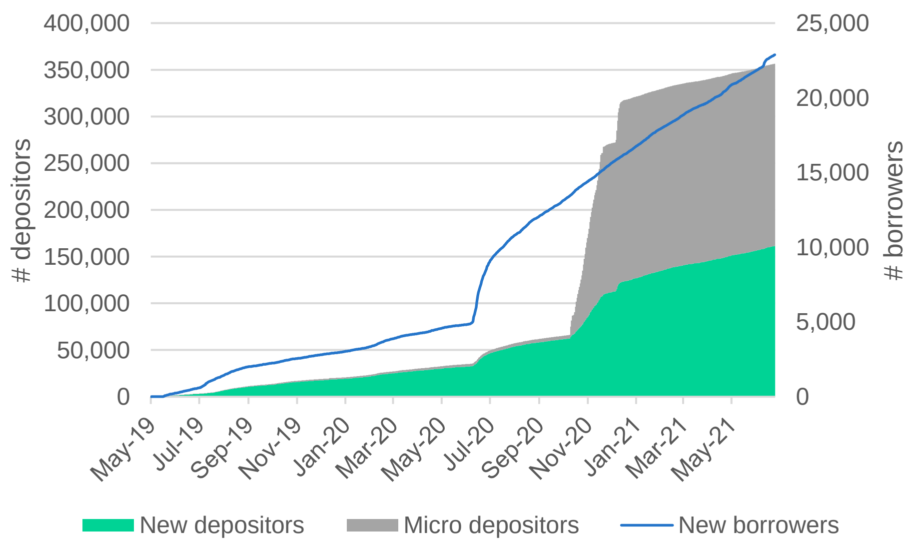


Table 6: Summary statistics of Compound users.

Panel A reports the summary statistics of cToken deposits by type of address. Address type classification methodology is outlined in the Appendix. While there are more than 356,800 unique addresses that made deposits, there are about 195,200 addresses that made exactly one stablecoin deposit of $3 or less, with 183,000 addresses that made exactly $3 deposit. These addresses are excluded from the analysis. Total deposits by address type in USD million, average deposits per address in USD million and median deposits in USD are reported. For each address type, the share of addresses that only made stablecoin deposits and addresses that have at least once deposited ETH or WBTC – the two most popular cryptocurrencies – are reported. Panel B reports the number of unique addresses that borrowed via cToken contracts, the number of loan spells by type (stablecoins, cryptocurrencies and all), and the dollar value of loans in USD million. A loan spell is defined by a complete borrow-repayment cycle for each address; as such, a spell may include more than one drawdown and repayment. The average dollar value of loan in USD million and average duration of loan in days are also reported.

Panel A: Depositors.

	Total deposits (USD mn)	Number of unique addresses	Av. deposits per address (USD mn)	Standard Deviation (USD mn)	Median value of deposits (USD)
Large wallet	50,725.9	256	198.1	467.3	46,700,000
Small wallet	26,712.8	161,103	0.2	2.2	92
Yield aggregator	13,018.8	41	317.5	737.7	30,100,000
On-ramp access	5,852.2	32	182.9	771.5	11,600,000
Decentralized exch.	3,305.3	14	236.1	476.4	36,800,000
Asset management	721.1	14	51.5	139.5	4,618,128
Unidentified contracts	66,226.5	109	607.6	3,922.1	16,400,000
All	166,562.5	161,569			

	Share of deposits (dollar)	Share of addresses (number)	Deposited stablecoins only	Deposited ETH	Deposited WBTC
Large wallet	30.5%	0.2%	11%	75%	49%
Small wallet	16.0%	99.7%	40%	49%	4%
Yield aggregator	7.8%	0.0%	61%	24%	15%
On-ramp access	3.5%	0.0%	31%	66%	25%
Decentralized exch.	2.0%	0.0%	50%	50%	43%
Asset management	0.4%	0.0%	29%	14%	14%
Unidentified contracts	39.8%	0.1%	25%	60%	35%

Panel B: Borrowers.

	Unique addresses	Stablecoin loans (num)	Crypto loans (num)	All token loans (num)	Stablecoin loans (USD mn)	Crypto loans (USD mn)	All tokens (USD mn)
Large wallet	217	1,441	614	2,055	28,659.5	3,762.6	32,422.1
Small wallet	21,986	32,220	12,230	44,450	8,164.3	1,912.9	10,077.2
Yield aggregator	8	55	60	115	4,224.7	145.9	4,370.6
On-ramp access	24	4,062	973	5,035	2,026.6	425.6	2,452.2
Decentralized exch.	1	7		7	3.8		3.8
Asset management	2	2		2	256.6		256.6

Uninden. contracts	51	796	310	1,106	11,345.3	514.8	11,860.0
All	22,289	38,583	14,187	52,770	54,680.7	6,761.9	61,442.6

	Average value of loan (US mn)			Average loan duration (days)		
	Stable	Crypto	All	Stable	Volatile	All
Large wallet	19.89	6.13	15.78	23.6	15.2	21.1
Small wallet	0.25	0.16	0.23	40.6	26.6	36.7
Yield aggregator	76.81	2.43	38.01	2.4	2.9	2.7
On-ramp access	0.50	0.44	0.49	0.6	0.3	0.6
Decentralized exch.	0.54		0.54	0.0		0.0
Asset management	128.32		128.32	81.6		81.6
Uninden. contracts	14.25	1.66	10.72	9.0	6.5	8.3
All	1.42	0.48	1.16	33.8	23.2	31.0

In Table 8, we estimate a logistic model of redeposits for the 5 most popular tokens on Compound, controlling for address type with fixed effects. On average, larger loans are likely to be redeposited (except for ETH), while the rest of the regressors reveal a degree of heterogeneity, particularly between stablecoins and cryptocurrencies. For example, cryptocurrencies are more likely to be redeposited in good market (high ETH price), while stablecoins are less likely. For a user whose objective is to farm COMP tokens, yield farming via stablecoins would shield her from price volatility. The price stability of stablecoin loans makes it more conducive for wide range of uses, including leveraged yield farming.

Moving on the relationship with supply rates, WBTC and USDT rates are both associated with associated with greater likelihood of redeposit, statistically significant at 1% level, while ETH and USDC are negatively related. One way to interpret this divergence is to view each token against its peers in respective groups (cryptocurrencies or stablecoins). The average supply rate for WBTC over the sample period is 0.41%, while ETH is 0.14%. We saw earlier that USDT has the higher supply rate of all stablecoins. It is possible that the higher average supply rates of WBTC and USDT attract users who are more concerned about rates. We do not have information for further delineation, but this finding corroborates the view that each token may serve its own niche in the ecosystem.

To further elaborate on this heterogeneity in the ecosystem, we illustrate the flows of DAI, USDC and USDT to popular smart contract destinations in the DeFi ecosystem in Figure 6. To limit the complexity of the network, we select only smart contracts that accept DAI – the most frequently used stablecoins in Compound both in terms of deposits and borrowings. Line color denotes token type, and node color denotes smart contract type. There are many places that accept these stablecoins; some accept individual tokens (Compound's cDAI contract is one of them), while others may accept multiple (Curve's 3pool contract accepts DAI, USDC and USDT). Moreover, some contracts (not illustrated here) may accept the depository receipt version as well (Curve's crvCOMP accepts cDAI and cUSDC). Those who deposit their tokens may be further rewarded by the native tokens issued by the protocol, hence allowing multiplicative yield farming. In fact, some yield aggregator protocols explicitly employ these strategies (for example, Yearn). While we do not have evidence of how widespread this practice is, our analysis of borrowers in Table 6 Panel B suggests that some protocols do rely on Compound for explicit leverage. Saengchote (2021b) demonstrates that composability in DeFi could lead to implicit leverage via webs of depository receipt creation that is not easy to recognize or monitor, on-chain lenders may provide explicit leverage that further amplify the financial connectivity in the ecosystem.

Table 7: Redeposited loans.

Panel A reports the number of loan day by token and address type. A loan day is counted as whenever an address takes out a token loan on a given day. Because of this, the number of loan days is higher than the number of loan spells, which are defined as complete borrow-repayment cycle. Panel B reports the share of loan days that are immediately followed by a deposit of the same token on the same day. Panel C reports the share of loan days that are followed by a deposit of the same token within one day.

Panel A: Distribution of daily loans by token

	ETH	WBTC	DAI	USDC	USDT	SAI	TUSD	COMP	BAT	LINK	REP	UNI	ZRX	All
Large wallet	151	45	2,884	526	30	64	167	10	72	2,128	1,048	184	46	7,355
Small wallet	3,246	418	31,727	10,312	214	738	3,465	327	765	30,901	14,344	2,599	1,172	100,228
Yield aggregator			8	36			27			26	2	41		140
On-ramp access	29		120	42		11	24		11	127	38	8	20	430
Decentralized exch.			3											3
Asset management										180				180
Unidentified contracts	50	8	1,066	60	8	21	46		25	470	187	119	36	2,096
All	3,476	471	35,808	10,976	252	834	3,729	337	873	33,832	15,619	2,951	1,274	110,432

Panel B: Share of daily loans that are redeposited on the same day

	ETH	WBTC	DAI	USDC	USDT	SAI	TUSD	COMP	BAT	LINK	REP	UNI	ZRX	All
Large wallet	46.4%	33.3%	14.0%	10.1%	40.0%	6.3%	10.2%	10.0%	13.9%	8.9%	1.2%	20.1%	13.0%	11.3%
Small wallet	21.8%	17.0%	12.3%	16.0%	9.8%	2.7%	5.6%	0.3%	15.3%	5.6%	2.5%	9.8%	6.5%	9.1%
Yield aggregator			0.0%	5.6%			14.8%			11.5%	0.0%	87.8%		32.1%
On-ramp access	17.2%		55.0%	11.9%		0.0%	54.2%		0.0%	13.4%	0.0%	0.0%	0.0%	24.7%
Decentralized exch.			100.0%											100.0%
Asset management										0.0%				0.0%
Unidentified contracts	54.0%	0.0%	46.5%	41.7%	62.5%	47.6%	2.2%		16.0%	40.4%	1.6%	20.2%	13.9%	37.7%
All	23.3%	18.3%	13.6%	15.8%	15.1%	4.1%	6.1%	0.6%	15.0%	6.3%	2.4%	12.0%	6.8%	9.9%

Panel C: Share of daily loans that are redeposited within one day

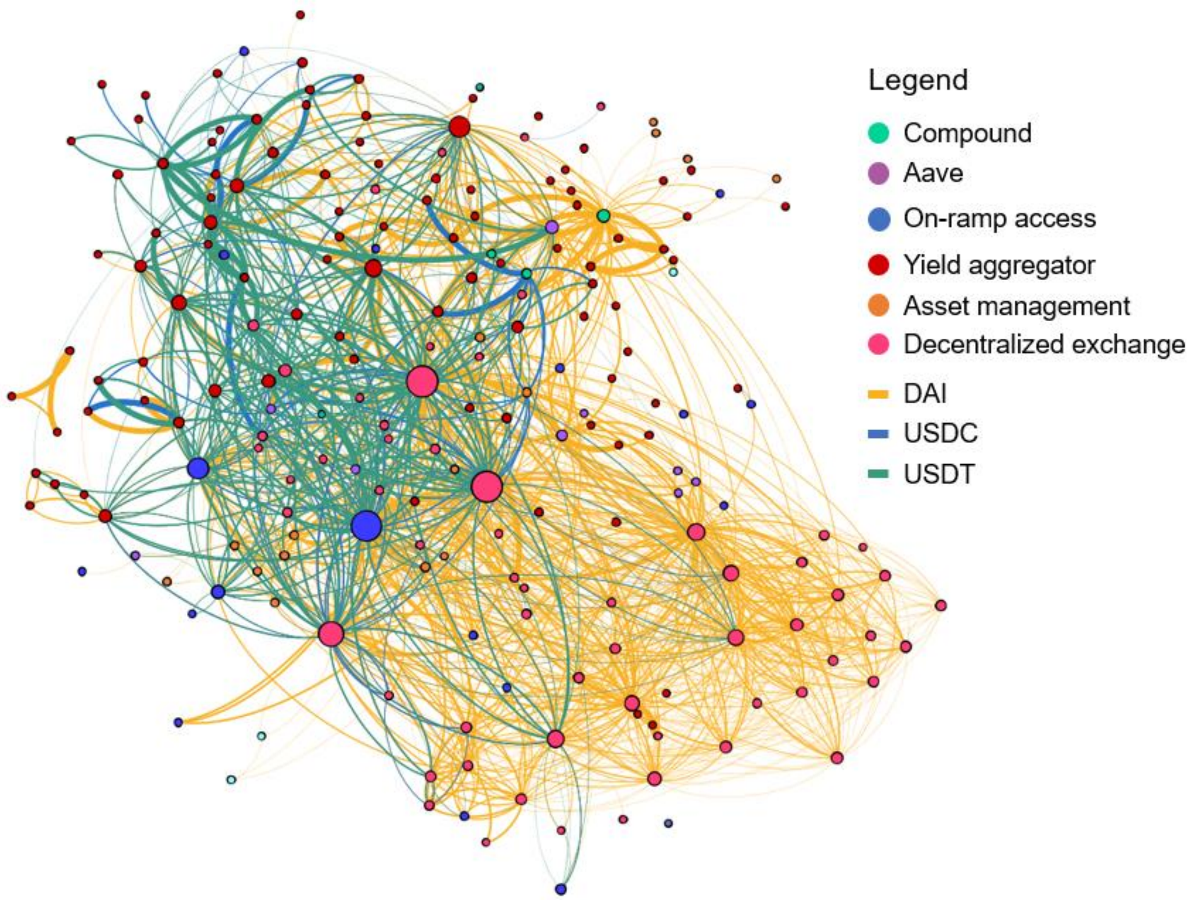
	ETH	WBTC	DAI	USDC	USDT	SAI	TUSD	COMP	BAT	LINK	REP	UNI	ZRX	All
Large wallet	47.7%	33.3%	15.4%	13.1%	43.3%	12.5%	10.8%	10.0%	16.7%	10.0%	2.0%	21.7%	19.6%	12.7%
Small wallet	23.8%	17.2%	13.1%	17.5%	10.7%	3.5%	6.8%	0.3%	16.1%	6.2%	3.0%	11.5%	7.7%	9.9%
Yield aggregator			0.0%	13.9%			14.8%			23.1%	0.0%	90.2%		37.1%
On-ramp access	27.6%		57.5%	11.9%		0.0%	62.5%		0.0%	16.5%	0.0%	0.0%	0.0%	27.4%
Decentralized exch.			100.0%											100.0%
Asset management										0.0%				0.0%
Unidentified contracts	58.0%	0.0%	47.9%	41.7%	62.5%	57.1%	4.3%		16.0%	41.7%	3.2%	21.0%	22.2%	39.3%
All	25.3%	18.5%	14.5%	17.4%	16.3%	5.5%	7.3%	0.6%	15.9%	6.9%	2.9%	13.6%	8.4%	10.7%

Table 8: Determinants of loan redeposits.

This table reports the logistic regression output of Redeposit, an indicator variable which takes value of one if the address makes a deposit in the same token as the loan taken out on the same day of the loan. Only top-five tokens are included in this analysis. Control variables include log dollar value of loan taken out on the loan day, lagged supply (deposit) rate for each token, log COMP price, log ETH price, 7-day ETH return, and 30-day ETH volatility (measured in percentage point). Address type fixed effects (large wallet, small wallet, yield aggregator, on-ramp access, decentralized exchange, asset management and unidentified smart contracts) are included. Standard errors are clustered at address level and reported in parenthesis. Stars correspond to statistical significance level, with *, ** and *** representing 10%, 5% and 1% respectively.

	(1) ETH	(2) WBTC	(3) DAI	(4) USDC	(5) USDT
ln($ amount of loan)	-0.028*	0.072**	0.258***	0.257***	0.072*
	(0.01)	(0.03)	(0.02)	(0.02)	(0.04)
Lagged rate	-0.812*	0.091***	-0.007	-0.040***	0.096***
	(0.45)	(0.03)	(0.01)	(0.01)	(0.02)
ln(COMP)	-0.217*	-0.105	-0.148*	0.318***	0.182
	(0.12)	(0.27)	(0.08)	(0.12)	(0.13)
ln(ETH)	0.304***	0.686***	-0.779***	-0.410***	-1.78***
	(0.10)	(0.26)	(0.09)	(0.11)	(0.19)
ETH return (7d)	0.093	-0.702	-0.130	0.055	-2.90***
	(0.24)	(0.51)	(0.20)	(0.19)	(0.86)
ETH volatility (30d)	4.28	0.058	3.12	9.63***	-8.75
	(2.66)	(6.42)	(2.45)	(2.13)	(9.17)
Observations	7,038	2,282	30,372	27,609	15,390
Pseudo R-squared	0.0127	0.0640	0.1440	0.0913	0.2050

Figure 6: Network diagram of DeFi stablecoins.
This figure plots the stablecoins (DAI, USDC and USDT) flows between smart contracts identified as part of Compound, Aave (a lending protocol), yield aggregator protocols, asset management protocols, decentralized exchange (DEX) protocols, on-ramp access points, and other smart contracts that exist between May 2019 and June 2021.



6. Conclusion

In this paper, we outline how Compound, a DeFi lending/money market protocol, works, how activities in the protocol are influenced and who its users are. Between May 2019 and June 2021, $61.4 billion of loans in multiple tokens are lent for an average duration of 31 days. Like its traditional counterparts, the distribution of users in DeFi seems to also be characterizable by skewness, with the top 100 depositor addresses accounting for 75% of all deposits and the top 100 borrower addresses 78% of all loans. We show that net demand for deposits is not systematically determined by market conditions, except for the connectivity between MakerDAO and Compound via DAI, while loan demand is related to market volatility, consistent with liquidation risk of volatile collateral. We show that COMP incentive is more attractive to borrowers, not depositors. We attempt to shine light on who the borrowers are and their reasons for doing so. Flexible borrow interest rates that vary almost real-time and liquidation risk limits the potential uses. The short loan durations observed in the data combined with the propensity to redeposit borrowed tokens suggests that some of this demand may arise from leveraged investment strategies. Taken together with the vulnerability of DeFi to tacit leverage documented by Saengchote (2021b), the availability of explicit leverage on-chain that is directly connected with yield farming warrants further investigation into whether DeFi composability lends itself to systemic risk.

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APPENDIX

Smart contract and DeFi protocol classification

In this appendix, we briefly explain the nature of DeFi protocols and how their incentives are distributed so readers can understand the distinctions and the reason behind the classification scheme.

1. **Yield aggregator**

Yield aggregator protocols are similar to mutual funds. Claiming reward tokens is a blockchain transaction which costs gas, and gas cost depends on computation complexity, not the monetary value of the transaction, so users with small transactions will not find it economical to claim rewards often, missing out on the compounding effect. With larger pool of tokens, yield aggregators can claim more frequently, and thus earn more yield overtime. In addition, yield aggregators can deploy complex strategies such as using explicit leverage or staking wrapped tokens across multiple protocols, earning multiple token yields. In return, the protocol will take a cut of the yield (like hedge fund carry). Some strategies are illiquid, so mechanisms such as load fees are often designed into protocol to encourage users to lock their tokens for longer. Examples of such protocols are Akropolis, Alpha Homora, Harvest, Idle and Yearn.finance.

Users deposit their tokens into the protocol's vault (creating a wrapped token in the process), which would then be deployed according to the strategies set forth by the protocol. When the tokens are redeemed, users would get back a pro-rata share of pool. Like Compound's cToken and Aave's aTokens, these depository receipts are tradeable and can be deposited into protocols that accept them. For the case of Yearn.finance, their wrapped tokens are yTokens.

Yield aggregators may also team up with other protocols. For example, Yearn.finance created its governance token YFI in July 2020, but it was only available by staking yTokens (all wrapped stablecoins) in Curve's liquidity pool. This type of interoperability is possible if smart contracts grant permissions to interact with one another.

Yield aggregator protocols in this paper are: 88mph, DeFi Saver, Furucombo, Harvest, Idle, Inverse, Mushroom, PoolTogether, Rain Capital, Robo, Shell, Volatility and Yearn.

2. **On-ramp service providers**

On-ramp service providers are addresses that identify themselves as belonging to centralized exchanges such as Binance and Coinbase, as well as semi-centralized service such as InstaDapp. They aggregate orders and transact on behalf of clients, providing access points to the DeFi ecosystem.

On-ramp service providers in this paper are: Binance, Dharma Finance, Eth2Dai, and InstaDapp.

3. **Decentralized exchange (DEX)**

Decentralized exchange protocols are sometimes referred to as automated market maker (AMM) protocols as they facilitate token exchanges without the need for a centralized institution that typically use order book matching system. The inherent reason why order book matching in DeFi is not popular is because order flows generate data trails that are extremely costly to record on the blockchain (any information updating on blockchain requires users to pay gas, whether that transaction has any monetary value or not) and can lead to network congestion. Consequently, an alternative method is required.

Just as the name suggests, participants are, in fact, market makers who must then face inventory risk. Users who provide liquidity in a pool (by depositing or staking tokens) are willing counterparties for users who wish to exchange their tokens (a peer-to-pool transaction). In the order book matching system, users send in the desired orders, which are then matched to counterparties with the same terms of trade, providing price certainty at the expense of execution uncertainty. In AMM, users send one type of token she wishes to exchange, and the pool will send the other type of token in return. A bonding curve (pricing function) will determine how many tokens of the other type she will receive. In other words, the user will have execution certainty (provided that she pays enough gas and the pool has sufficient liquidity) but faces price uncertainty since price is a mathematical output of the bonding function.

The bonding curve is a function of quantities of tokens available in the pool, so large transactions *will* result in price slippage, and an illiquid pool can have wild swings in prices that are out-of-sync with other trading venues. Bonding curves (e.g. the constant product function $xy = k$) generate relative token prices that make the token type in low supply prohibitively expensive to acquire (and vice versa). With DeFi openness, arbitrageurs would restore price equilibrium relative to other trading venues (which is likely why Uniswap introduced flash swap in its V2 upgrade). The constant product function earlier (the most popular, used by many protocols such as Uniswap and SushiSwap) permits only a pair of tokens, but generalized bonding curves can allow for more tokens (such as Curve and Balancer). As market prices change, the ratios of tokens in liquidity pools will change to keep up with market prices. Consequently, DEX protocols can also be viewed as asset management (automatic portfolio rebalancing) protocol that allows users to change their portfolio composition without paying gas.

As protocol performance directly depends on liquidity, protocol sponsors often provide generous staking incentives for users willing to provide liquidity, especially when the market is thin (liquidity mining). In fact, some of the most generous rewards are often found in the nascent days of a DEX protocol as it tries to attract liquidity.[9] Rewards could be provided in the protocol's native tokens, or other protocol's native tokens if a partnership between protocols can be formed. For example, the Aave liquidity pool on Curve (which accepts aDAI, aUSDC, and aUSDT) provides CRV (Curve's governance token) and stkAAVE (staked version of AAVE) as reward.

When tokens are deposited, users receive a depository receipt (often referred to as an LP token) which represents a pro-rata share of the pool. Most DEX pools accrue transaction fees, so users will also get their share of fees upon redemption. However, if one compares the ratio of

[9] For example, Uniswap only provided liquidity mining reward for two months in 2020. Source: https://www.theblockcrypto.com/linked/84762/dex-uniswap-liquidity-mining-over, accessed on July 26, 2021.

tokens deposited to the ratio of tokens redeemed, there may be a discrepancy in value referred to as “impermanent loss” or “divergent loss”. This results from movements along the bonding curve and is more likely for token pairs with divergent prices, which is an unavoidable feature of DEX. Consequently, stablecoin pools tend to be more popular among users (but because of their popularity, they also tend to provide little or no reward for liquidity mining).

The reliance on deep liquidity is not limited to DEX but a general feature of peer-to-pool transactions. Lending protocols also require liquidity (measured as utilization ratio), otherwise interest rates will skyrocket. This highlights the nature of DeFi that smart contracts are simply intermediaries; it is users who are the participants, but rules of engagement must be explicitly written into smart contracts, and no discretion is allowed. This is what it means to be a decentralized autonomous organization. In any case, it is in a protocol’s interest to build up liquidity, but with DeFi openness akin to perfect token mobility, offering staking rewards (expressed as nominal dollar-like yield) using tokens that can be minted by protocols becomes a popular strategy to attract yield-chasing “hot money” into protocols.

DEX protocols in this paper are: 1inch, BlackHoleSwap, Curve, and ParaSwap.

4. Asset management

Asset management protocols are like indexed funds: they allow users to maintain a balanced exposure to a basket of tokens or a specific strategy. Examples of such protocols are Set Protocol and Balancer. There are few protocols under this category because liquidity pools in decentralized exchanges can also be considered asset management protocols, but the permissible baskets are much more limited (e.g. only two tokens, or stablecoins only). Under this definition, stablecoin protocols (e.g. mStable) can also be considered an asset management protocol, as it is indexed to the value of US dollar.

This highlights another facet of DeFi: underneath various product classifications, many protocols’ smart contracts work in the same way. Typical processes are (1) deposit a token into a smart contract and mint a derivative token as depository receipt, or (2) deposit multiple tokens into a smart contract and receive different tokens of equivalent value when redeemed. The principle of equivalent (or sufficiently collateralized) exchange is at the heart of DeFi transactions.

Asset management protocols in this paper are: BasketDAO, DeFiner, Index Coop, Origin Dollar, PieDAO, Set Protocol and mStable.

5. Unidentified smart contracts

Ethereum addresses that have codes written inside are identified as smart contracts rather than wallets. This information is visible on blockchain explorer websites such as Etherscan.io. However, not all smart contracts disclose their source codes and their affiliations, and all we can see is binary data. One example is address ‘0x0000006daea1723962647b7e189d311d757Fb793’ which, as of July 26, 2021, holds records of over 546,400 transactions and 124 types of tokens worth over $104 million. However, nothing else about the address is known. Nevertheless, not all contracts are as active and valuable as this example.