Piercing the Veil of TVL: DeFi Reappraised

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Abstract. Total value locked (TVL) is widely used to measure the size and popularity of decentralized finance (DeFi). However, TVL can be manipulated and inflated through "double counting" activities such as wrapping and leveraging. As existing methodologies addressing double counting are inconsistent and flawed, we propose a new framework, termed "total value redeemable (TVR)", to assess the true underlying value of DeFi. Our formal analysis reveals how DeFi's complex network spreads financial contagion via derivative tokens, increasing TVL's sensitivity to external shocks. To quantify double counting, we construct the DeFi multiplier, which mirrors the money multiplier in traditional finance (TradFi). This measurement reveals substantial double counting in DeFi, finding that the gap between TVL and TVR reached \$139.87 billion during the peak of DeFi activity on December 2, 2021, with a TVL-to-TVR ratio of approximately 2. We conduct sensitivity tests to evaluate the stability of TVL compared to TVR, demonstrating the former's significantly higher level of instability than the latter, especially during market downturns: a 25% decline in the price of Ether (ETH) leads to a \$1 billion greater decrease in TVL compared to TVR via the liquidations triggered by derivative tokens. We also document that the DeFi money multiplier is positively correlated with crypto market indicators and negatively correlated with macroeconomic indicators. Overall, our study suggests that TVR is more reliable and stable than TVL.

Keywords: Blockchain · Decentralized Finance · Total Value Locked.

1 Introduction

Total value locked (TVL) is one of the most widely adopted metrics for assessing both the size and popularity of DeFi. Analogous to the concept of assets under management (AUM) in TradFi [38], TVL is a similar measure of assets pooled for yield generation (see Definition 1) [8,40,39]. According to DeFiLlama, the entire DeFi TVL stands at approximately \$230 billion as of February 15, 2025. However, TVL can be easily manipulated due to "double counting", caused by practices such as token wrapping and redepositing of borrowed tokens. These practices are highly incentivized [8,40] and incur minimal costs, enabling the TVL of a protocol, a blockchain, or even the entire DeFi system to be artificially

Table 1: Survey of DeFi tracing websites with a focus on protocols coverage and TVL-related information disclosure as of February 15, 2025.

DeFi Tracing Website	Protocol Coverage	TVL-related Information						
	Number	TVL Presented	Overall Methodology	Protocol-specific Methodology	Token Price Sources	Constituent Protocols	Code	Double Counting Solution
DeFiLlama	4,477	●	●	●	●	●	●	●
L2BEAT	N/A	●	●	○	○	○	●	○
DappRadar*	4,588	●	○	○	○	●	○	○
Stelareum	309	●	○	○	○	●	○	○
DeFiPulse	N/A	○	●	○	○	○	○	●

∗: Although DappRadar tracks over 4,000 protocols, it discloses the TVL for only around 500 ones.
●: Disclosure. ○: No disclosure.

inflated in the absence of any new capital inflows. Consequently, TVL can be a deceptive metric, misleading investors to make financial decisions based on distorted valuations.[4] Moreover, the culprit for double counting, the "derivative tokens" (see Definition 3), also serve as channels for financial contagion, making TVL highly sensitive during market downturns. Unfortunately, the methods for different DeFi tracing platforms to calculate TVL are unstandardized, non-transparent, and often biased (see Table 1), obscuring DeFi's true economic value.

The double counting problem in DeFi is a crucial yet understudied topic in the literature. Many studies use TVL for protocols valuation and risk monitoring [21,33,24,35] but overlook the issue of double counting within TVL. While some existing studies document the complexity and interconnections within DeFi at the token level [30], protocol level [36] and sector level [2], most of them focus on analyzing the topological features and associated risks of DeFi networks rather than their impacts on TVL. Although a theoretical production-network model has been applied to assess the value added and service outputs across various DeFi sectors on Ethereum [6], it fails to address double counting within individual sectors.

In this paper, we propose a novel yet effective measurement framework, termed total value redeemable (TVR), to address the double counting problem at the finest granularity—the token level. TVR excludes the value of complex DeFi derivatives and borrowed tokens, focusing only on the asset component that contributes directly to the underlying value of DeFi that can ultimately be redeemed. By eliminating derivatives, TVR also avoids the inclusion of financial contagion risk, making it a more stable metric than TVL.

We reappraise the DeFi system's value using the TVR framework with data from 3,570 protocols over five years from DeFiLlama and token categories from CoinMarketCap. We employ the token category data fetched from CoinMarketCap to identify "plain tokens", i.e. tokens that do not entail one or more underlying tokens. The values of these tokens are then aggregated to calculate the TVR for the entire DeFi system. Inspired by TradFi money multiplier, we introduce the DeFi money multiplier, which is defined as the ratio of TVL to

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[4] Value inflation in the blockchain space has also been observed in other metrics, such as throughput [27].

TVR. This metric quantifies the extent of double counting in DeFi. Through formalization and sensitivity tests, we compare the stability of TVL with that of TVR. The formalization reveals that TVL is highly sensitive to price shocks such as ETH price decline. This sensitivity arises from the endogeneity of the derivative token price and the quantity of derivative tokens staked in protocols for loanable funds (PLF). We then conduct simulations to assess the stability of TVL compared to TVR. The simulation results align with our formalization.

We summarize our main contributions as follows:

1. By modeling and formalizing TVL, we reveal the double counting mechanism and financial contagion risk under the TVL framework. We find existing methodologies addressing double counting either inconsistent or flawed.
2. To the best of our knowledge, we are the first to introduce an enhanced measurement framework to evaluate value locked within a DeFi system without double counting. Our analysis of 3,570 protocols over five years finds a substantial double counting within the DeFi system, with a maximum of \$139.87 billion with a TVL-TVR ratio of around 2. This contribution provides DeFi users with more accurate and complete information about the value locked in DeFi, which supports better decision-making within the community.
3. Our sensitivity tests reveal that TVL is highly sensitive to market downturns compared to TVR. A 25% drop in ETH price leads to a significant divergence, resulting in approximately a \$1 billion greater decrease in TVL compared to TVR in a system of six representative DeFi protocols in Ethereum.
4. We are also the first to build the DeFi money multiplier based on TVR and TVL in parallel to the TradFi macroeconomic money multiplier to quantify the double counting. We document that the DeFi money multiplier is positively correlated with crypto market indicators and negatively correlated with macroeconomic indicators.

2 Key DeFi Concepts

In this section, we explain key concepts in DeFi. DeFi is an ecosystem of protocols operating autonomously through smart contracts, popularized by Ethereum [15]. These protocols are decentralized applications inspired by traditional centralized finance systems [42,38].

2.1 TVL

Based on definitions and descriptions from existing literature [13,44], we define TVL as follows:

Definition 1 (Total Value Locked). *The total value of assets staked in or held by a DeFi protocol, a blockchain, or the entire DeFi ecosystem at a specific moment for yield generation purposes.*

TVL of the DeFi system can be expressed as

$$TVL = \mathbf{1}^T \mathbf{Q}^T \mathbf{p}, \tag{1}$$

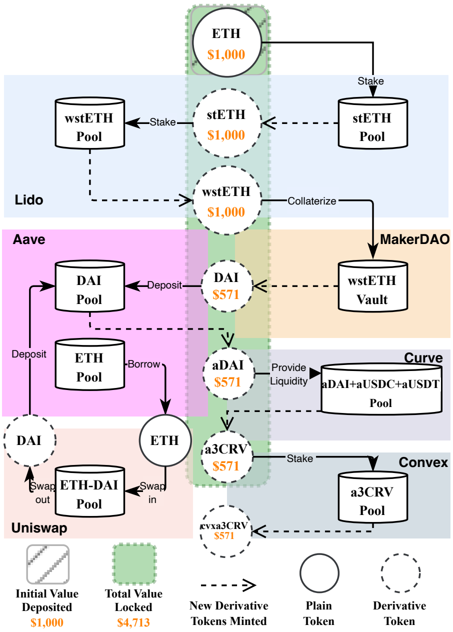
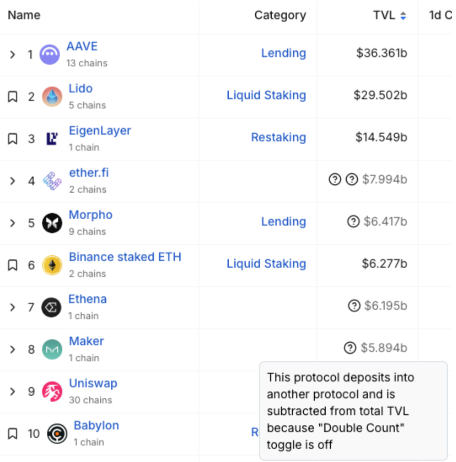


Fig. 1: An example of actions a DeFi user can take to maximize interest, enabled by the DeFi composability.



Name	Category	TVL	1d C
1 AAVE 13 chains	Lending	$36.361b	
2 Lido 5 chains	Liquid Staking	$29.502b	
3 EigenLayer 1 chain	Restaking	$14.549b	
4 ether.fi 2 chains		ⓘ ⓘ $7.994b	
5 Morpho 9 chains	Lending	ⓘ $6.417b	
6 Binance staked ETH 2 chains	Liquid Staking	$6.277b	
7 Ethena 1 chain		ⓘ $6.195b	
8 Maker 1 chain		ⓘ $5.894b	
9 Uniswap 30 chains			
10 Babylon 1 chain	R		

This protocol deposits into another protocol and is subtracted from total TVL because "Double Count" toggle is off

Fig. 2: DeFiLlama's TVL dashboard after deactivating the "Include in TVL: Double Count" toggle. When a user deactivates this toggle, protocols that deposit into another protocol will be excluded from the total TVL calculation, and their TVL numbers will be displayed in grey.

where $\mathbf{1}$ is the vector of ones; $\mathbf{Q} = [q_{i,j}]_{m \times n}$ denotes the matrix of staked tokens quantity across all DeFi protocols, with m being the number of token types and n the number of DeFi protocols; $\mathbf{p} = [p_i]_{m \times 1}$ denotes the vector of token prices for the m token types. We select Lido, MakerDAO, Aave V2, Uniswap V2, Curve, and Convex as an example system (see Fig. 1) to illustrate the complexity of the TVL ecosystem. At the time of writing this paper,, these protocols have the highest TVL and are the most representative within their category, collectively accounting for approximately 68% of the total TVL [9]. In Fig. 1, the TVL of these protocols is the sum of all the numbers in orange, totaling \$4,747.4 — equivalent to 4.7474 times the initial ETH value deposited.

DeFi tracing websites disclose key metrics of DeFi protocols including TVL, as shown in Table 1. DeFiLlama, a leading DeFi tracing website, attempts to eliminate double counting by excluding protocols categorized under those feeding tokens into other protocols. DeFiLlama's TVL dashboard includes the "Include in TVL: Double Count" toggle, allowing users to filter out the TVL of protocols that deposit into another protocol, as shown in Fig. 2. When such protocols are excluded, the dashboard displays the chain-level DeFiLlama-adjusted TVL (TVL^{Adj}), instead of the standard DeFiLlama TVL that includes double counting (TVL). While DeFiLlama makes efforts to address the issue, it may not fully eliminate double counting. Since different protocols have different degrees

(a) Wrapping in DeFi.

(b) Rehypothecation in TradFi.

Fig. 3: Wrapping and its corresponding TradFi analogies. The process of wrapping in DeFi, as illustrated in Fig. 3a, mirrors the rehypothecation process in TradFi, as shown in Fig. 3b. The black circle (●) with a white number indicates the step.

Table 2: Protocol-perspective balance sheets of the wrapping scenario. We highlight the components included in the TVL calculation in red.

(a) Lido.

Immediately After	❷	❹
Assets	$	$
Value Locked - stETH	1,000	1,000
Total Assets	1,000	1,000
Liabilities	$	$
Payables - wstETH	1,000	1,000
Total Liabilities	1,000	1,000

(b) MakerDAO.

Immediately After	❷	❹
Assets	$	$
Value Locked - wstETH	-	1,000
Receivables - DAI	-	571
Total Assets	-	1,571
Liabilities	$	$
Payables - wstETH	-	1,000
New Money - DAI	-	571
Total Liabilities	-	1,571

(c) Consolidated.

Immediately After	❷	❹
Assets	$	$
Value Locked	1,000	1,000
Receivables	-	571
Total Assets	1,000	1,571
Liabilities	$	$
Payables	1,000	1,571
Total Liabilities	1,000	1,571

of double counting, simply excluding a particular category of protocols does not suffice to address the problem of double counting comprehensively.

2.2 Wrapping

Wrapping and leveraging are two DeFi mechanisms that can result in TVL double counting. As leveraging is less prevalent and has been well documented in [26], we provide its explanation in Appendix §A. Wrapping means DeFi users depositing existing tokens, including tokens that have been wrapped, into smart contracts to generate new tokens. Enabled by DeFi composability, users can repeatedly perform this operation to sustain their liquidity and maximize their interest [8,43,40]. DeFi composability refers to the ability of one DeFi protocol to accept tokens generated from another protocol seamlessly, allowing DeFi tokens to be chained and integrated to create new tokens and financial services. Fig. 3a depicts a scenario where an investor initially supplies \$1k worth of stETH to Lido (step ❶), which is then converted into \$1k worth of wstETH (step ❷). Subsequently, the investor deposits this wstETH into MakerDAO (step ❸) and issues up to \$571 worth of DAI (step ❹)[5]. The wrapping in DeFi is similar to the

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[5] The calculation of DAI amount is based on the loan-to-value ratio (LTV) of the wstETH low fee vault at the time of this paper and the collateral value.

rehypothecation process in TradFi, illustrated in Fig. 3b. This works as follows. In rehypothecation, lenders who provide loans to borrowers (step ❶) against a promissory note (step ❷), pledge the promissory note (step ❸) and borrow money from the bank (step ❹) [3].

To illustrate the TVL double counting during wrapping, we use a balance-sheet approach to consolidate double-entry bookkeeping (see e.g. [29]) and describe its financial condition for each protocol. Appendix §B provides a detailed list of bookkeeping entries for common transactions in DeFi protocols. The aggregate value locked can be regarded as a significant element on the asset side of a DeFi protocol's balance sheet [41]. In the context of a DeFi system, we apply the principles of consolidated balance sheets to depict its financial status on an aggregated basis. This type of balance sheet represents the combined financial position of a group, presenting the assets, liabilities, and net position of both the parent company and its subsidiaries as those of a unified economic entity. By employing the principle of non-duplication used in consolidated balance sheet accounting (whereby, accounting entries that are recorded as assets in one company and as liabilities in another are eliminated, before aggregating all remaining items) [32], we can effectively eliminate instances of double counting within a DeFi system. Table 2 shows the balance sheets of Lido and MakerDAO, and the consolidated balance sheet of the DeFi system consists of Lido and MakerDAO. In $\mathcal{S}_{\mathrm{W}}^{(1)}$, the value of the DeFi system is \$1k. However, if we deposit the receipt token wstETH from Lido into MakerDAO to issue another receipt token DAI, the TVL will be \$2k under the traditional TVL measurement. The balance sheets are expanded and the TVL is double-counted due to the existence of wstETH. In the consolidated balance sheet, the TVL is adjusted to \$1k after eliminating the value associated with the wstETH.

3 Enhanced Measurement Framework

In this section, we formalize the double counting problem, identify the instability of TVL, and introduce our enhanced measurement framework TVR.

3.1 Double Counting Problem

We initially classify DeFi tokens into plain tokens and derivative tokens. We provide the following definitions for the plain and underlying tokens:

Definition 2 (Plain Token). *A DeFi token without any underlying tokens.*

Definition 3 (Derivative Token). *A DeFi receipt token, also known as an I-owe-you (IOU) token or a depositary receipt token, that is generated in a specified ratio by depositing a designated quantity of underlying tokens into the smart contract of a protocol.*

In the example used in Fig. 1, ETH is considered as a plain token because it is initially deposited into the system without having an underlying token. In contrast, other tokens (stETH, wstETH, DAI, aDAI, a3CRV, and cvxa3CRV) are considered derivative tokens since they have underlying tokens. Let $\boldsymbol{\tau} = [\tau_i]_{m\times 1}$, where m is the number of unique tokens and $\tau_i = 1$ if token i is a plain token and 0 otherwise, denotes the logical vector of plain tokens. By decomposing the TVL value, as defined in Eq. 1, into the plain token value and the derivative token value, we can further express the TVL as $TVL = \mathbf{1}^T\mathbf{Q}^T(\mathbf{p}\odot\boldsymbol{\tau}) + \mathbf{1}^T\mathbf{Q}^T[\mathbf{p}\odot(\mathbf{1}-\boldsymbol{\tau})]$, where $\odot$ denotes the element-wise product. Since the value of derivative tokens can be easily created and inflated through wrapping without injecting any capital into the DeFi system according to §2.2, there is an urgent need to design a new framework that excludes this inflated value. The new framework should ensure that the underlying value, which cannot be easily manipulated, is accurately reflected.

3.2 Instability of TVL

In addition to the inflation issue, derivative tokens can act as channels for the spread of financial contagion, making the TVL highly sensitive to market downturns. The prices of derivative tokens are endogenously determined by the prices and quantities of their underlying tokens. The pricing mechanism can be described as follows: (i) If the derivative token is a stablecoin generated from a collateralized debt position (CDP) and the aggregate value of its underlying tokens meets or exceeds the value of the stablecoin, the token's price is pegged to its predetermined fiat currency. This peg is maintained through an overcollateralization mechanism, as discussed in Appendix §C. (ii) Otherwise, the token price is determined by the ratio of the underlying tokens' total value to the derivative token's circulating supply. In both cases, a short-term fluctuation term ϵ_d, should be included to account for temporary price variations.

We write the derivative token price as

$$p_d(\mathbf{p}_u, \mathbf{q}_u) = \begin{cases} c_d + \epsilon_d & \text{if } d \text{ is a CDP stablecoin and } \frac{\mathit{\Gamma}}{c_d} \geq 1 \\ \mathit{\Gamma} + \epsilon_d & \text{otherwise} \end{cases}, \tag{2}$$

where $\mathit{\Gamma} = \frac{\mathbf{p}_u^T \mathbf{q}_u}{q_d}$. p_d and q_d are the price and circulating supply of derivative token d. $\mathbf{p}_u = [p_i]_{m\times 1}$ and $\mathbf{q}_u = [q_i]_{m\times 1}$ are the vector of d's underlying token prices and quantities, respectively. c_d is the theoretical pegging price of a CDP stablecoin in USD. The short-term fluctuation ϵ_d is exogenous, associated with the token's supply and demand dynamics as well as the liquidity. For example, the price of stETH deviated from its reference point temporarily in 2022 due to selling pressure from Celsius and market illiquidity [16]. Appendix §D explains in detail the derivative token pegging mechanism that supports Eq. 2. For CDP stablecoins, the deviation of its price, i.e. "depegging", from the predetermined reference point due to the undercollateralization, is denoted as $\frac{\mathit{\Gamma}}{c_d} < 1$.

DeFi composability allows the underlying token of a derivative token to serve as the derivative token of another token, as illustrated in Fig. 1 and Fig. 3a (e.g. wstETH is the derivative token of stETH, while stETH is the derivative token of ETH). We can derive the derivative token price function in terms of its ultimate underlying plain token prices and quantities: $p_d(\mathbf{p}_u, \mathbf{q}_u) = \left[p_d \circ p_{d_1} \ldots \circ p_{d_j}\right](\mathbf{p}_u, \mathbf{q}_u)$, where $\mathbf{p}_u = [p_i]_{v\times 1}$ is the vector of d's ultimate underlying token prices via the recursion of Eq. 2. $\circ$ is the function composition operator. $[p_d \circ p_{d_1} \ldots \circ p_{d_j}]$ means we recurse Eq. 2 multiple times until we find the ultimate underlying plain tokens (e.g. ETH as the ultimate plain token of wstETH).

Tokens staked in a PLF, including CDPs such as MakerDAO or lending protocols such as Aave, have a token quantity determined by its token price due to the liquidation mechanism [43,41,4]. Detailed definitions of PLF and its liquidation mechanism are provided in Appendix §C. According to Appendix §C, a change in collateral price $p_{i,t} \to p_{i,t+1}$ will lead to the change of the account's health factor $h(p)$ and the liquidation profit $\mathit{\Pi}(p)$, leading to different scenarios. In liquidation, we should consider the quantity of both collateral tokens and repaid tokens since the liquidator not only withdraws collaterals but also injects liquidity into the protocol via the repayment. For ease of notation, we will omit indexes of account i, token j, and time $t+1$.

When $h(p) \geq 1$, the account is deemed safe and the quantity of collateral j in the account remains unchanged, represented by q. When $h(p) < 1$ and the liquidation profit $\mathit{\Pi}(p) \leq 0$, the liquidation is considered unprofitable for liquidators, rendering the liquidation unviable and the quantity of collateral in the account also unchanged, represented by q.

When $h(p) < 1$, the user may face liquidation, where the smart contract transfers and sells varying proportions of collateral to maintain the solvency of PLF. Additionally, when the liquidation profit $\mathit{\Pi}(p) > 0$, the total collateral value is sufficient to cover the total debt value. In this scenario, the liquidation is deemed profitable for liquidators, leading to a successful liquidation. In a liquidation, the token quantity obeys the following law of motion when $t \to t+1$:

$$q_{t+1}(p_{t+1}) = \begin{cases} q_t + \mathit{\Delta}_{t+1} & \text{if } h_{t+1} < 1 \text{ and } \mathit{\Pi}_{t+1} > 0 \\ q_t & \text{otherwise} \end{cases}. \tag{3}$$

$\mathit{\Delta}$ and $\mathit{\Pi}$ depend on the type of PLF and tokens as shown in Table 3a, as explained in Appendix §E.

Given the endogeneity mentioned above, we can then further split the TVL into the following four categories: the value of plain tokens staked in non-PLFs, plain tokens staked in PLFs, derivative tokens staked in non-PLFs, and derivative tokens staked in PLFs:

$$TVL = \underbrace{(\mathbf{p} \odot \boldsymbol{\tau})^T [\mathbf{Q}(\mathbf{1} - \boldsymbol{\omega})]}_{\substack{\text{plain tokens} \\ \text{staked in non-PLFs}}} + \underbrace{(\mathbf{p} \odot \boldsymbol{\tau})^T (\mathbf{Q} \cdot \boldsymbol{\omega})}_{\substack{\text{plain tokens} \\ \text{staked in PLFs}}} + \underbrace{[\mathbf{p} \odot (\mathbf{1} - \boldsymbol{\tau})]^T [\mathbf{Q}(\mathbf{1} - \boldsymbol{\omega})]}_{\substack{\text{derivative tokens} \\ \text{staked in non-PLFs}}} + \underbrace{[\mathbf{p} \odot (\mathbf{1} - \boldsymbol{\tau})]^T (\mathbf{Q} \cdot \boldsymbol{\omega})}_{\substack{\text{derivative tokens} \\ \text{staked in PLFs}}}, \tag{4}$$

where $\omega_i = 1$ if protocol i is a PLF and 0 otherwise, denotes the logical vector of PLF. The derivative token price depends on its underlying token's price $\mathbf{p}_u$ and quantity (see Eq. 2): $\mathbf{p} \odot (\mathbf{1} - \boldsymbol{\tau}) = [x_i]_{m\times 1}$, $x_i \in \{p_i(\mathbf{p}_u), 0\}$. In addition, the tokens quantity staked within a PLF is determined by their own price (see

Table 3: $\mathit{\Delta}_{t+1}$ and $\mathit{\Pi}_{t+1}$ in different scenarios, where $V_{\text{liq}} = \min\{\frac{V_c}{1+b}, \delta V_d\}$ represents the maximum amount of debt that a liquidator can repay at a single liquidation in a lending protocol. b represents the liquidation bonus. δ denotes the close factor. $V_c = \mathbf{c}^T \mathbf{p}_c$ and $V_d = \mathbf{d}^T \mathbf{p}_d$ represents the total collateral value and total debt value of the position, respectively, as mentioned in Appendix §C. $gasFees$ denotes the gas costs of liquidation.

(a) $\mathit{\Delta}_{t+1}$ for collateral token and repaid token in a CDP or a lending protocol.

	$\boldsymbol{\mathit{\Delta}_{t+1}}$ of Repaid Token	**$\boldsymbol{\mathit{\Delta}_{t+1}}$ of Collateral Token**
CDP	0	$-q_t$
Lending Protocol	$\frac{V_{\text{liq}} q}{V_d}$	$-\frac{(1+b)V_{\text{liq}} q}{V_c}$

(b) Liquidation profit $\mathit{\Pi}_{t+1}$ in a CDP or a lending protocol.

	$\boldsymbol{\mathit{\Pi}_{t+1}}$
CDP	$V_c - V_d - gasFees$
Lending Protocol	$V_{\text{liq}} b - gasFees$

Eq. 3): $\mathbf{Q} = [x_i]_{m\times 1}$, $x_i \in \{q_i(p_i), 0\}$. Therefore, the TVL ultimately depends on the prices and quantities of the underlying tokens. Price and quantity shocks to the underlying tokens can lead to a decline in token value, trigger liquidations, and cause depegging for derivative tokens due to the endogenous relationship between derivative and underlying tokens. Derivative tokens amplify the impact of such shocks on the TVL, making the TVL highly sensitive to changes in the prices of plain tokens. Consequently, the existence of derivative tokens not only inflates the TVL but also serves as the channel for the spread of decentralized financial contagion, making the TVL unstable.

3.3 Total Value Redeemable (TVR)

To address the double counting problem and avoid incorporating the risk of decentralized financial contagion, we introduce the metric TVR.

Definition 4 (Total Value Redeemable). *Token value that can be ultimately redeemed from a DeFi protocol or a DeFi ecosystem.*

We can express the TVR of the entire DeFi ecosystem as the sum of the total value of plain tokens including governance tokens, native tokens, and non-crypto-backed (NCB) stablecoins held by smart contracts in the DeFi ecosystem:

$$TVR = \mathbf{1}^T \mathbf{Q}'^T (\mathbf{p} \odot \boldsymbol{\tau}) = \underbrace{(\mathbf{p} \odot \boldsymbol{\tau})^T [\mathbf{Q}'(\mathbf{1} - \boldsymbol{\omega})]}_{\substack{\text{plain tokens held by} \\ \text{smart contracts in non-PLFs}}} + \underbrace{(\mathbf{p} \odot \boldsymbol{\tau})^T (\mathbf{Q}' \cdot \boldsymbol{\omega})}_{\substack{\text{plain tokens held by} \\ \text{smart contracts in PLFs}}} , \tag{5}$$

where $\mathbf{Q}' = [q'_{i,j}]_{m\times n}$, with m representing the number of token types and n is the number of DeFi protocols, denotes the matrix of tokens quantity held by smart contracts across all DeFi protocols. Compared to TVL, TVR excludes the value of derivative and borrowed tokens, considering only the value of plain tokens held by smart contracts to address the double counting problem. The exclusion of inflated values also decreases the complexity of the interplay within the DeFi system, mitigating the high sensitivity of the metric concerning the ultimate underlying plain tokens. We also introduce the protocol-level TVR to address the intra-protocol double counting, as discussed in Appendix §F.

DeFiLlama provides TVL adjusted for double counting of blockchains. Additionally, it aggregates chain-level TVL to compute the adjusted TVL for the entire DeFi ecosystem. However, it does not offer adjusted TVL for specific protocols. Compared to DeFiLlama's adjusted TVL, TVR eliminates double counting with finer granularity by selectively including or excluding tokens during the calculation, resulting in significantly higher accuracy. We provide a detailed comparison in calculation methods between DeFi space ecosystem-wide TVR and DeFiLlama-adjusted TVL in Appendix §G.

To examine the stability of TVL and TVR, we perform comparative sensitivity analyses on the changes in TVL ($\Delta TVL_{t+1} = TVL_{t+1} - TVL_t$) and TVR ($\Delta TVR_{t+1} = TVR_{t+1} - TVR_t$) in response to shocks in the price of plain tokens. These tests are conducted using six representative protocols, as selected in §2.1. For the plain token price shock, we use the decline in ETH price as the independent variable because ETH is the native token of Ethereum and is widely used across the platform. Subsequently, we update the token price vector $\mathbf{p}$ from Eq. 2, quantity matrix $\mathbf{Q}$ from Eq. 3, and $\mathbf{Q}'$ from Eq. 5. Finally, we calculate ΔTVL_{t+1} and ΔTVR_{t+1}.

4 Empirical Analyses

This section details the data used for measurements and presents empirical results under both the traditional TVL framework and our proposed TVR framework. We also introduce the DeFi money multiplier to quantify double counting in DeFi and provide measurement results for individual altchains.

4.1 Data

We fetch the TVL data about DeFi protocols broken down by token and adjust TVL (TVL_t^{Adj}) from 1st January 2021 to 1st March 2024 using DeFiLlama API. DeFiLlama offers the most comprehensive universe of DeFi protocols of all blockchains compared to all other DeFi-tracing websites, as discussed in Table 1. TVL_t^{Adj} is DeFiLlama's improved metric aimed at mitigating the double counting problem and is regarded as flawed in §2.1. We then aggregate the TVL breakdown of each protocol to obtain the unadjusted TVL per protocol per day ($TVL_{i,t}$). Additionally, we retrieve token categorization lists for native tokens (layer-one and layer-two) and governance tokens from CoinMarketCap, and obtain stablecoin classifications from DeFiLlama. These lists are then used as filters to extract plain tokens from the TVL breakdown data provided by DeFiLlama to calculate the TVR (TVR_t). We also retrieve the blockchain states from an Ethereum archive node for three key dates: December 2, 2021, marking the peak of DeFiLlama's unadjusted TVL; May 9, 2022, denoting the end of the

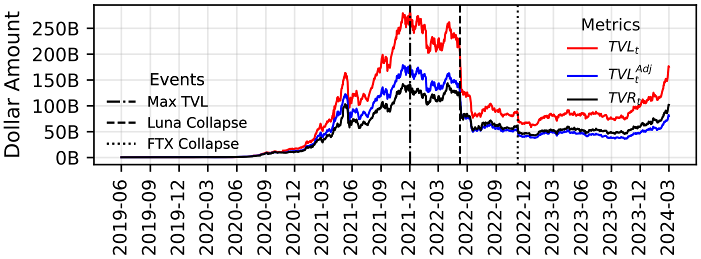


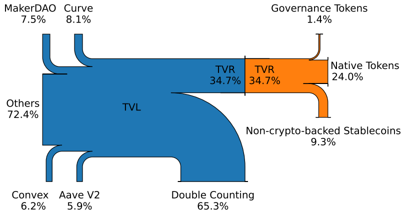
Fig. 4: TVL and TVR over time, where the red, blue, and black lines represent the DeFiLlama TVL subjected to double counting, DeFillama-adjusted TVL, and TVR.

Luna collapse; and November 8, 2022, representing the end of the FTX collapse. In Appendix §H, we explore methods to automate this process and eliminate reliance on third-party data.

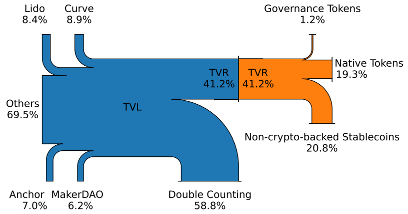
For the risk analysis, we retrieve the data by crawling blockchain states (e.g. MakerDAO vaults data) and blockchain events (e.g. Aave deposit events) from an Ethereum archive node. Our sample of risk analysis constitutes six leading DeFi protocols with the highest TVL within each respective DeFi protocol category, as shown in Fig. 1. Appendix §I reports the statistics of accounts in sensitivity tests in MakerDAO and Aave on three representative dates.

4.2 TVL, Adjusted TVL, and TVR

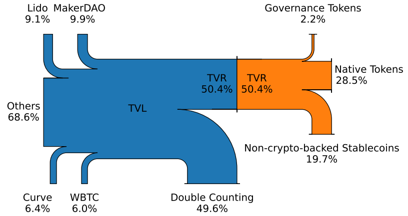
Based on the enhanced measurement framework, we build TVR from DeFiLlama TVL breakdown data. Our framework calculates DeFi space ecosystem-wide TVR by summing the value of all **eligible tokens** as described in §3.3, specifically plain tokens. In contrast, DeFiLlama-adjusted TVL is calculated by first aggregating the TVL of all **eligible protocols** and then summing the TVL across all blockchains, where protocol eligibility is arbitrarily determined by DeFiLlama whose validity we challenge. For instance, although MakerDAO holds both plain tokens (e.g. ETH) that directly contribute to DeFi's underlying value and derivative tokens (e.g. wstETH) that should be excluded, its entire TVL is excluded from the DeFiLlama-adjusted TVL, as illustrated in Fig. 2. Appendix §G conducts a detailed comparison in calculation methods between system-wide TVR and DeFiLlama-adjusted TVL. Fig. 4 shows the DeFiLlama unadjusted TVL (TVL), DeFiLlama-adjusted TVL (TVL^{Adj}), and TVR (TVR) for the entire blockchain ecosystem over time. Our empirical measurement reveals the level of double counting within the DeFi ecosystem, with TVL-TVR discrepancies reaching up to \$139.87 billion, and a TVL-TVR ratio of around 2 when the unadjusted TVL reached its maximum value. Moreover, there is a divergence between DeFiLlama-adjusted TVL and the TVR due to differences in methodology. In June 2022, the TVR exceeds DeFiLlama-adjusted TVL because the token value deposited of removed protocols under DeFiLlama's methodology is



(a) Max TVL.

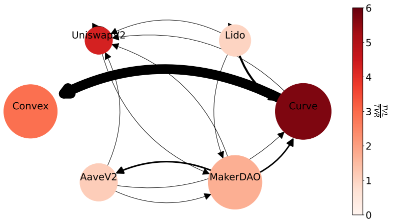


(b) Luna Collapse.

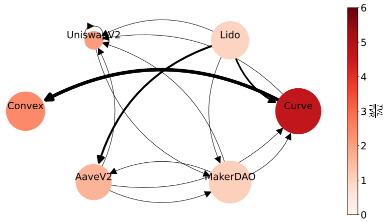


(c) FTX collapse.

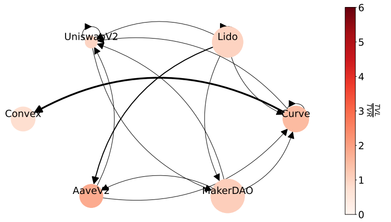
Fig. 5: Decomposition of TVL of the entire DeFi system. We identify four protocols with the highest TVL and group the remaining protocols under the category of "Others". The band width represents the dollar value of tokens. The blue band represents the TVL value, while the orange band represents the TVR value.



(a) Max TVL.



(b) Luna Collapse.



(c) FTX Collapse.

Fig. 6: Token wrapping network of six representative protocols. Node size corresponds to the TVL, edge width represents the dollar amount of tokens generated from the source protocol and staked in the target protocol, and node color reflects the ratio between TVL and TVR. A darker color indicates a higher level of double counting.

lower than the actual value that needs to be removed within the TVR framework. Conversely, after June 2022, the TVR falls below DeFiLlama's adjusted TVL because the token value deposited of protocols removed by DeFiLlama is higher than the actual value that needs to be removed within the TVR framework. This discrepancy highlights the inaccuracies in DeFiLlama's methodology, which we document in §3.3.

However, all three metrics show a similar trend, with a surge during the DeFi summer due to increased investor activity and sharp declines following the Luna collapse and the FTX collapse. Fig. 5 illustrates the decomposition of TVL in the DeFi system on three key dates. The dominance of the top four protocols increases following the collapse of the Luna and FTX, while the double-counting proportion decreases after these events. The proportion of governance tokens in

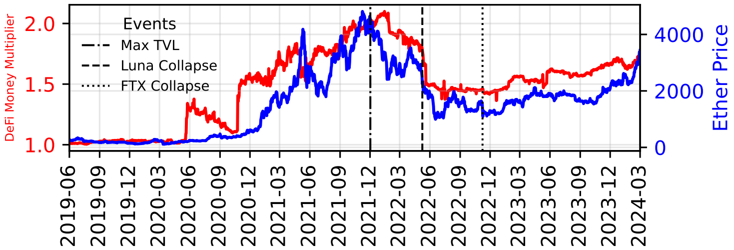


Fig. 7: DeFi money multiplier (red line) and ETH price (blue line).

TVR remains small. The proportion of native tokens decreases after the Luna collapse but increases following the FTX collapse. Conversely, the proportion of NCB stablecoins rises after the Luna collapse but declines after the FTX collapse. To gain a broader understanding of the double-counting issue, we also analyze two niche alternative chains (Altchains) in Appendix §J.

4.3 DeFi Money Multiplier

The M2 to M0 ratio, known as the traditional money multiplier, indicates the extent to which banks can utilize investor deposits [12]. M0 denotes the money base, which includes cash and bank reserves. M2 denotes the supply of private money, which includes cash, checking deposits, and other short-term deposits. Drawing a parallel, we can divide TVL by TVR to compute the DeFi money multiplier. This ratio reflects the degree of double counting and wrapping effects within the DeFi ecosystem, analogous to the money multiplier in TradFi. Fig. 7 plots the DeFi money multiplier.

Table 4 lists the Spearman's rank correlation coefficients [34] between the DeFi money multiplier (M^{DeFi}), key macroeconomic indicators in the US, and representative crypto market indicators. Notably, there is a significant positive correlation between the DeFi money multiplier and cryptocurrency market indicators, such as the S&P Cryptocurrency Broad Digital Market Index ($S\&P$) and Ethereum price (ETH). This suggests that during bullish periods in the cryptocurrency market, investors tend to increase their investments in DeFi and actively engage in leveraged positions. Conversely, the DeFi money multiplier is significantly negatively correlated with the TradFi money multiplier (M^{TradFi}). However, the DeFi money multiplier does not exhibit a significant correlation with the Consumer Price Index (CPI) or the CBOE Volatility Index (VIX). As a robustness test, we also calculate Spearman's rank correlation coefficients [34] between the natural logarithmic return of these indicators to make variables stationary, which is shown in Appendix §K.

Table 4: Spearman's rank correlation coefficients [34] between macroeconomic indicators, cryptocurrency market indicators, and DeFi money multiplier computed from TVL and TVR.

	Macroeconomic / TradFi indicators			Cryptocurrency / DeFi indicators		
	CPI_t	VIX_t	M_t^{TradFi}	ETH_t	$S\&P_t$	M_t^{DeFi}
CPI_t	1.00***	-0.19	0.06	0.28*	0.07	0.25
VIX_t	-0.19	1.00***	-0.15	-0.21	-0.19	-0.18
M_t^{TradFi}	0.06	-0.15	1.00***	-0.66***	-0.70***	-0.76***
ETH_t	0.28*	-0.21	-0.66***	1.00***	0.95***	0.91***
$S\&P_t$	0.07	-0.19	-0.70***	0.95***	1.00***	0.91***
M_t^{DeFi}	0.25	-0.18	-0.76***	0.91***	0.91***	1.00***

***, **, and * denote the 1%, 5%, and 10% significance levels, respectively.

5 Risk Analyses

In this section, we present the outcomes of the comparative sensitivity tests. Using the data for the six leading DeFi protocols in Fig. 1, these tests are conducted on three representative date snapshots, each with a different set of parameters. We discuss the default value of certain parameters in Appendix §I. To provide an overview of the simulation environment, we visualize the wrapping network of these protocols in Fig. 6. From this visualization, we observe that both TVL and TVL-to-TVR ratio of protocols excluding Lido decreases from the point when TVL reaches the maximum value to the subsequent collapse of LUNA and FTX. This trend suggests a reduction in both the overall size of the system and the extent of double-counting within it, which are aligned with the broader dynamics of the overall DeFi system, as depicted in Fig. 4 and Fig. 5.

Fig. 8 shows how ΔTVL and ΔTVR vary with d_{ETH}. The ΔTVL and ΔTVR curves with the default parameter setting in Appendix §I are compared with those with hypothetical parameters. Irrespective of parameter values, the ΔTVL curve is more sensitive to d_{ETH} than the ΔTVR curve due to the financial contagion effect of the derivative tokens, which aligns with the reasoning in §3.

We then discuss how other parameters in Eq. 3 affects ΔTVL and ΔTVR:

1. Close factor (δ): The close factor δ in a lending protocol represents the portion of a loan that a liquidator is allowed to repay when a borrower's health factor falls below one. For instance, consider a liquidable loan position where the loan amount is 100 USD and the close factor is 0.8; the maximum amount that can be liquidated is then 80 USD worth of tokens. As shown in Fig. 8, higher δ leads to a greater drop in ΔTVL and ΔTVR, ceteris paribus. This effect is observed for both δ_{AAVE} and δ_{MKR}. The drop in ΔTVL is more sensitive to δ_{MKR} than δ_{AAVE} since the MakerDAO has greater exposure to a decline of ETH price compared to Aave V2.
2. Gas fees ($gasFees$). We first calculate the gas fee using $\overline{gasFees} = gasLimit \times gasPrice$, and then adjust it by scaling with factors of 0.1, 1, and 10. As shown in Fig. 8, the variations in $gasFees$ have a minimal impact on ΔTVL and ΔTVR. This indicates that transaction fees are generally negligible compared to the change of collateral value for most positions.

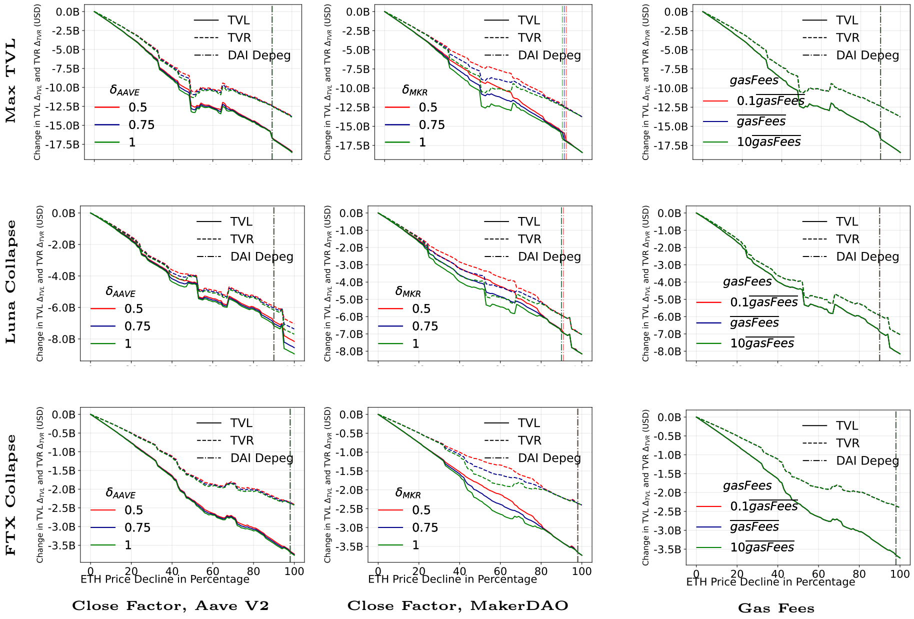


Fig. 8: Change in TVL Δ_{TVL} and TVR Δ_{TVR} as a function of ETH price decline in percentage d on three representative point with different parameter values. Subfigures within a row represent sensitivity tests conducted under the same snapshot, whereas subfigures within a column display sensitivity tests implemented under three different sets of values for a given parameter. Vertical dashed lines indicate the timing of the DAI depeg under different parameter settings.

6 Related Work

The issue of double counting was first explored in the field of macroeconomics. Schneider et al. [31] emphasize the pivotal role of addressing double counting in achieving the goals of the Paris Agreement and identifying key elements for a robust resolution that ensures environmental effectiveness and enables cost-effective mitigation. However, employing standard input-output data [19,18,20] as a traditional framework to address double counting is inefficient for DeFi. Therefore, a tailored measurement framework is required to address the DeFi double counting problem.

Several studies explore the role of TVL in DeFi valuation and risk monitoring. Metelski et al. [21] and Xu et al. [45] investigate the causal relationship between key DeFi performance metrics, such as TVL, protocol revenues, and the DeFi protocol valuations. Stepanova et al. [35] conduct preliminary descriptive and comparison work on TVL of 12 most popular DeFi protocols. Maouchi et al.[24] shows that TVL can work as a valuable tool for monitoring market dynamics and assessing the risk of bubbles in the digital financial landscape. Şoiman et al. [33] use TVL divided by market capitalization for DeFi valuation and examine whether this metric drives the DeFi returns. While these studies provide valuable insights into the use of TVL for protocol valuations, they largely overlook the issue of double counting within TVL, which can lead to valuation biases.

Some studies examine the DeFi composability and TVL double counting problem in a limited scope. Kitzler et al. [17] measure the composition of DeFi protocols. Saengchote [30] examines the flow of DAI, a DeFi stablecoin, between protocols using high-frequency transaction-level data. The study also explains how TVL accounts for repeat value through the wrapping of DAI. Alexander [2] explains how TVL is double-counted in DeFi leveraged staking-restaking. Although these studies identify the double counting problem using simple examples, they are limited to single token types or sectors and do not formalize and quantify the degree of double counting. Chiu et al. [6] use a standard theoretical production-network model to assess the value added and service outputs across various DeFi sectors on Ethereum. Although their work quantifies the value added at a sector level on Ethereum, their analysis overlooks the double counting within the sector and on blockchains other than Ethereum, failing to reflect the actual value of DeFi ecosystem. Our study addresses these gaps by systematically formalizing the double counting problem and proposing an enhanced measurement framework to quantify it at the token level across all blockchains.

7 Conclusion

This paper presents a novel yet effective measurement framework, TVR, to thoroughly address the double counting problem in DeFi. TVR excludes the value of derivative and borrowed tokens, focusing solely on plain tokens that contribute directly to the underlying value of DeFi and can ultimately be redeemed from DeFi. Using a dataset of 3,570 protocols over five years and the token category data, we measure the value of both the entire DeFi system and individual protocols without double counting. For the entire DeFi system, we employ the token category data fetched from CoinMarketCap to isolate the value of plain tokens, which were then aggregated into the TVR for the entire DeFi system. We also conducted sensitivity tests to evaluate the stability of TVL compared to TVR. Our measurements are informative: We find a substantial amount of double counting within the DeFi system. Our sensitivity tests show that TVL is highly sensitive during market downturns. We also document that the DeFi money multiplier is positively correlated with crypto market indicators and negatively correlated with macroeconomic indicators. Overall, our findings suggest that TVR is more reliable and stable than TVL.

Acknowledgments. This material is based upon work partially supported by Ripple UBRI [11]. We thank Antoine Mouran for his valuable insights on the double counting problem and related literature. We also appreciate the valuable comments provided by Carol Alexander, Wenzhi Ding, Francesca Medda, Chao Liu, Hui Gong, Kamil Tylinski, Walter J. Hernandez, Alice Ng, Yitian Wang, and Honglin Fu.

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APPENDIX

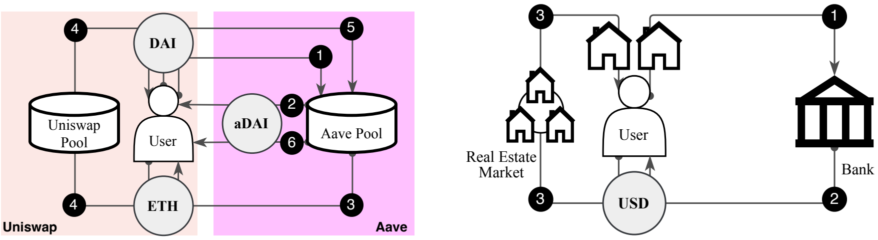
A Leveraging

Leveraging is the other mechanism that can lead to TVL double counting. It means investing with borrowed assets. The leveraging operation in DeFi is similar to that in TradFi. In the TradFi leveraging scenario illustrated in Fig. 9b, the investor can use her house as collateral (step ❶) to borrow cash (step ❷) and then use cash to buy another house (step ❸). In the DeFi leveraging scenario illustrated in Fig. 9a, we assume that liquidity providers have already supplied \$900 ETH to Aave and \$1.8k ETH along with \$1.8k DAI to Uniswap to facilitate swaps and borrowing (step ⓿). Initially, Aave has \$900 ETH in assets and \$900 worth of aETH in liabilities, while Uniswap holds \$1.8k ETH and \$1.8k DAI in assets and \$1.8k worth of ETH-DAI LP tokens in liabilities. An investor provides \$2k DAI (step ❶) as collateral to borrow \$900 ETH (step ❸) in Aave, swaps the borrowed \$900 ETH to \$900 DAI (step ❹) in Uniswap, and then deposits \$900 DAI (step ❺) from Uniswap in the Aave to issue the receipt token aDAI (step 6).

Table 5 shows the balance sheets of Aave and Uniswap, and the consolidated balance sheet of the DeFi system consisting of Aave and Uniswap. In $\mathcal{S}_{\mathrm{L}}^{(1)}$, the value of the DeFi system is \$5.6k. However, if the user borrows \$900 ETH, swaps the ETH into DAI, and deposits the DAI into Aave, the TVL will be \$6.5k under the traditional TVL measurement. This TVL is also double-counted because it includes DAI. In the consolidated balance sheet, the TVL is adjusted to \$5.6k after eliminating the value associated with DAI.

B DeFi Bookkeeping

We model value transfers of common transactions in DeFi protocols via the double-entry bookkeeping of the traditional accounting framework in Table 6.



(a) Leveraging in DeFi. (b) Leveraging in TradFi.

Fig. 9: Leveraging and its corresponding TradFi analogies. Both DeFi and TradFi involve leveraging processes, depicted in Fig. 9a and Fig. 9b, respectively. The black circle (●) with a white number indicates the step.

Table 5: Protocol-perspective balance sheets of the leveraging scenario. We highlight the components included in the TVL calculation in red.

(a) The balance sheet of Aave.

Immediately After	③	⑤
Assets	$	$
Value Locked - DAI	2,000	2,900
Receivables - dETH	900	900
Total Assets	2,900	3,800
Liabilities	$	$
Payables - aDAI	2,000	2,900
Payables - aETH	900	900
Total Liabilities	2,900	3,800

(b) The balance sheet of Uniswap.

Immediately After	③	⑤
Assets	$	$
Value Locked - ETH	1,800	2,700
Value Locked - DAI	1,800	900
Total Assets	3,600	3,600
Liabilities	$	$
Payables - ETH-DAI-LP	3,600	3,600
Total Liabilities	3,600	3,600

(c) Consolidated balance sheet.

Immediately After	③	⑤
Assets	$	$
Value Locked	5,600	5,600
Total Assets	5,600	5,600
Liabilities	$	$
Payables	5,600	5,600
Total Liabilities	5,600	5,600

The double-entry booking keeping has two equal journal entries known as debit (Dr.) and credit (Cr.), which represent a transfer of value to and from that account, respectively [7]. The credit side should be indented.

C Overcollateralization and Liquidation

PLF are DeFi protocols that allow users to supply and borrow cryptocurrency [28]. Analogous to a pawnshop, a PLF adheres to the overcollateralization mechanism, which means the borrower has to pledge collateral of higher total value than the loan [25]. The ratio of the maximum amount of tokens that can be borrowed to the amount of collateral is referred to as the LTV. PLF includes CDP such as MakerDAO (orange block in Fig. 1) and lending protocols such as Aave (purple block). In contrast, Lido, Uniswap V2, Curve, and Convex are not considered a PLF. In a PLF, a user's account can have multiple collaterals and debts, which are called its position. We can express the quantities of collaterals of a position as a vector: $\mathbf{c} = [q_i]_{k\times 1}$, where k are the number of collateral types. To convert token quantity into token value in USD, let p denotes the collateral price. By integrating all collateral prices into a vector $\mathbf{p}_c = [p_i]_{k\times 1}$, we can express the value of an account's collateral as $\mathbf{c}^T\mathbf{p}_c$. Similarly, we can express the quantities, prices, and total value of debt of a position as $\mathbf{d}$, $\mathbf{p}_d$, and $\mathbf{d}^T\mathbf{p}_d$. Unlike a lending protocol, a CDP uses staked collateral to issue stablecoins. Stablecoins are a type of crypto asset with a value pegged to a reference point, such as a fiat currency or another cryptocurrency.

During a market downturn, the position can be liquidated, resulting in a portion of the collateral being purchased by the liquidator at a discount when the liquidation is profitable. Whether an account is liquidated depends on its position's health ratio and liquidation profit. Each type of collateral has its own liquidation threshold $\alpha \in [0, 1)$, which represents its borrowing capacity. Let $\boldsymbol{\alpha} = [\alpha_i]_{k\times 1}$ represents the vector of liquidation thresholds for all types of collaterals in a PLF. Health factor h describes the financial health of an account,

Table 6: Journal entries of common transactions in DeFi protocols.

Protocol	Transaction	Definition	Journal Entry	Amount	Type	Example Transaction
Lido	Staking.	User stakes q_T tokens T with dollar price p_T to issue q_R receipt token R with dollar price p_R.	Dr. Value Locked – T Cr. Payables – R	$q_T p_T$ $q_R p_R$	Assets Liabilities	0x85d...c697
	Burning.	User burns q_R receipt token R with dollar price p_R to redeem q_T tokens T with dollar price p_T.	Dr. Payables – R Cr. Value Locked – T	$q_R p_R$ $q_T p_T$	Liabilities Assets	0x214...1c6f
MakerDAO	Borrowing.	User supplies q_T tokens T with dollar price p_T as collateral to mint q_S stablecoins S with dollar price p_S.	Dr. Receivables – S Dr. Value Locked – T Cr. New Money – S Cr. Payables – T	$q_S p_S$ $q_T p_T$ $q_S p_S$ $q_T p_T$	Assets Assets Liabilities Liabilities	0x959...0adb
	Stability fee accrual.	Debt accrues I_S when its dollar price is p_S.	Dr. Receivables – S Cr. Unrealized Gain – S	$I_S p_S$ $I_S p_S$	Assets Equities	-
	Repayment and collateral withdrawal.	User repays q_S stablecoins S with dollar price p_S and withdraws q_T collateral T with dollar price p_T.	Dr. New Money – S Dr. Payables – T Cr. Receivables – S Cr. Value Locked – T	$q_S p_S$ $q_T p_T$ $q_S p_S$ $q_T p_T$	Liabilities Liabilities Assets Assets	0x284...701e
	Collateral price appreciation.	q_T collateral experiences price appreciation Δ_p.	Dr. Value Locked – T Cr. Payables – T	$q_T \Delta_p$ $q_T \Delta_p$	Assets Liabilities	-
	Collateral price depreciation.	q_T collateral experiences price depreciation Δ_p.	Dr. Payables – T Cr. Value Locked – T	$q_T \Delta_p$ $q_T \Delta_p$	Liabilities Assets	-
	Liquidation penalty.	A liquidation penalty ζ applies to the initial debt and accrual stability fee when the collateral-to-debt ratio of the user's vault is lower than the liquidation ratio.	Dr. Receivables – S Cr. Unrealized Gain – S	$\zeta(q_S + I_S)p_S$ $\zeta(q_S + I_S)p_S$	Assets Equities	-
	Liquidation settlement.	The liquidator wins in the debt auction, sells q_T collateral with dollar price p_T, and repays debt q_S, liquidation penalty $\zeta(q_S + I_S)$ and stability fee I_S with dollar price p_S of the liquidated vault.	Dr. New Money – S Dr. Unrealized Gain – S Dr. Payables – T Cr. Receivables – S Cr. Value Locked – T	$q_S p_S$ $(I_S + \zeta(q_S + I_S))p_S$ $q_T p_T$ $(1 + \zeta)(q_S + I_S)p_S$ $q_T p_T$	Liabilities Equities Liabilities Assets Assets	0x4d0...cbb4
Aave	Supplying.	User supplies q_T tokens T with dollar price p_T as collateral to issue q_A aToken A with dollar price p_A	Dr. Value Locked – T Cr. Payables – A	$q_T p_T$ $q_A p_A$	Assets Liabilities	0xd49...8a04
	Borrowing.	A user borrows q_B tokens B with dollar price p_B in a lending protocol to receive q_D debt tokens D with dollar price p_D.	Dr. Receivables – D Cr. Value Locked – B	$q_D p_D$ $q_B p_B$	Assets Assets	0xf7d...a661
	Debt interest accrual.	Debt token accrues I_D when its dollar price is p_D, representing debt accruals I_B when its dollar price is p_B	Dr. Receivables – D Cr. Unrealized Gain – B	$I_D p_D$ $I_B p_B$	Assets Equities	-
	Repayment.	A user repays q_B tokens B with dollar price p_B to burn q_D debt tokens D with dollar price p_D.	Dr. Value Locked – B Cr. Receivables – D	$q_T p_T$ $q_D p_D$	Assets Assets	0x95e...f410
	Collateral price appreciation.	q_T collateral experiences price appreciation Δ_p.	Dr. Value Locked – T Cr. Payables – T	$q_T \Delta_p$ $q_T \Delta_p$	Assets Liabilities	-
	Collateral price depreciation.	q_T collateral experiences price depreciation Δ_p.	Dr. Payables – T Cr. Value Locked – T	$q_T \Delta_p$ $q_T \Delta_p$	Liabilities Assets	-
	Liquidation settlement.	When the health factor of an Aave user is lower than one, the liquidator will trigger the liquidation. The liquidator repays $\delta p_B(q_B+I_B)(1+b)$ worth of debt to receive $\delta p_B(q_B + I_B)(1 + b)$ collateral, where δ is the close factor and b is the liquidation bonus. The accrual interest is realized via minting atoken.	Dr. Value Locked – B Dr. Unrealized Gain – B Dr. Payables – A Cr. Receivables – D Cr. Realized Gain – A Cr. Value Locked – T	$\delta(q_B + I_B)p_B$ $I_B p_B$ $\delta(q_B + I_B)(1 + b)p_B$ $\delta(q_B + I_B)p_B$ $I_B p_B$ $\delta(q_B + I_B)(1 + b)p_B$	Assets Equities Liabilities Assets Equities Assets	0x682...7459
Uniswap / Curve	Liquidity provision.	User supplies q_A tokens A with dollar price p_A and q_B tokens B with dollar price p_B to issue q_{A-B-LP} A-B-LP tokens with dollar price p_{A-B-LP}.	Dr. Value Locked – A Dr. Value Locked – B Cr. Payables – A-B-LP	$q_A p_A$ $q_B p_B$ $q_{A-B-LP} p_{A-B-LP}$	Assets Assets Liabilities	0xfb4...7928
	Liquidity removal.	User burns q_{A-B-LP} receipt token R with dollar price p_{A-B-LP} to redeem q_A tokens A with dollar price p_A and q_B tokens B with dollar price p_B.	Dr. Payables – A-B-LP Cr. Value Locked – A Cr. Value Locked – B	$q_{A-B-LP} p_{A-B-LP}$ $q_A p_A$ $q_B p_B$	Liabilities Assets Assets	0x11a...f58f
	Swapping.	User swaps q_A tokens A with dollar price p_A for q_B tokens B with dollar price p_B.	Dr. Value Locked – B Cr. Value Locked – B	$q_B p_B$ $q_A p_A$	Assets Assets	0x61f...291f
Convex	Staking.	User stakes q_T tokens T with dollar price p_T to issue q_R receipt token R with dollar price p_R.	Dr. Value Locked – T Cr. Payables – R	$q_T p_T$ $q_R p_R$	Assets Liabilities	0x46b...5544
	Burning.	User burns q_R receipt token R with dollar price p_R to redeem q_T tokens T with dollar price p_T.	Dr. Payables – R Cr. Value Locked – T	$q_R p_R$ $q_T p_T$	Liabilities Assets	0xa80...72e2

Table 7: Derivative token pegging mechanism. Each subtable illustrates the strategy an arbitrager will adopt in the corresponding scenario. Different strategies for corresponding scenarios underpin the pricing formula Eq. 2.

Arbitrager's Strategy 1 $\epsilon_d < 0, \quad p'_d = p_d + \epsilon_d$
1: **Buy** λ derivative tokens d at price p'_d from the market using $\lambda \cdot p'_d$ (scalar λ depends on the budget).
2: **Burn** derivative tokens d to **redeem** all underlying tokens in the liquidity pool.
3: **Sell** all underlying tokens d to get $\lambda \cdot p_d$ dollar and **increase** derivative token price p'_d.
4: **Earn** profit $\lambda(p_d - p'_d)$ and **repeat** steps 1 to 5 until $p'_d = p_d$, i.e. $\epsilon_d = 0$.
Arbitrager's Strategy 2 $\epsilon_d > 0, \quad p'_d = p_d + \epsilon_d$
1: **Buy** all its underlying tokens from the market using $\lambda \cdot p'_d$ (scalar λ depends on the budget).
2: **Lock** all underlying tokens u to **issue** λ derivative token d in the liquidity pool.
3: **Sell** λ derivative token d to get $\lambda \cdot p_d$ dollar and **reduce** derivative token price p'_d.
4: **Earn** profit $\lambda(p'_d - p_d)$ and **repeat** steps 1 to 5 until $p'_d = p_d$, i.e. $\epsilon_d = 0$.
Vault Owner's Strategy $\epsilon_d = 0, \quad \frac{\mathit{\Gamma}}{c_d} = \frac{\mathbf{p}_u^T \mathbf{q}_u}{c_d q_d} \leq 1, \quad p'_d = p_d + \epsilon_d$
1: **Observe** that the value of issued crypto-backed stablecoin, $p_d q_d$, exceeds that of collateral, $p_u q_u$, in the vault. As a result, liquidators are disincentivized from liquidating the vault.
1: **Sell** q_d crypto-backed stablecoins d at price p_d in the market.
3: **Earn** a profit of $p_d q_d - p_u q_u$ and **decrease** the token price of d by increasing its supply.

which can be expressed as

$$h = \frac{\mathbf{c}^T \left(\boldsymbol{\alpha} \odot \mathbf{p}_c\right)}{\mathbf{d}^T \mathbf{p}_d}, \tag{6}$$

where $\odot$ denotes the element-wise product. The position will be liquidated if $h \leq 1$ and the liquidation profit $\mathit{\Pi}$ is positive.

D Derivative Token Pegging Mechanism

In cases where the market value of the derivative token temporarily deviates from the pegged value due to the short-term demand and supply shock ($\epsilon_d \neq 0$), it becomes subject to the arbitrage processes outlined in Arbitrager's Strategy 1 for market value below the pegged value ($p'_d < p_d$) and Arbitrager's Strategy 2 for market value above the pegged value ($p'_d > p_d$) in Table 7. These two strategies will return the derivative token price to the pegged price ($p'_d = p_d$). To enhance liquidity and pegging stability, some CDPs deploy pools to lock NCB stablecoins and issue crypto-backed stablecoins (e.g., MakerDAO's peg stability module [23]). This setup enables Arbitrager's Strategies 1 and 2 to facilitate the pegging of crypto-backed stablecoins. In the case of CDP undercollateralization where the total value of underlying tokens (i.e. collateral) is lower than that of the issued crypto-backed stablecoins $\mathit{\Gamma} < 1$, the derivative token depeg permanently in proportion to $\mathit{\Gamma}$ due to vault owners employing the Vault Owner's Strategy. Different strategies for corresponding scenarios, as outlined in Table 7, underpin the pricing formula Eq. 2.

E Derivation of $\boldsymbol{\mathit{\Delta}}$ and $\boldsymbol{\mathit{\Pi}}$

If liquidation happens in a CDP, a liquidator will repay all debts of the position, with their value denoted as $V_d = \mathbf{d}^T \mathbf{p}_d$ according to §C. Simultaneously, the CDP receives and burns all repaid stablecoins (see journal entries of MakerDAO liquidation in Table 6). Therefore, the repaid token quantity remains unchanged, hence $\mathit{\Delta}_{t+1} = 0$ for the repaid token. Next, the liquidator withdraws all collaterals from the CDP, with their value denoted as $V_c = \mathbf{c}^T \mathbf{p}_c$ according to §C. The decrease of the collateral token quantity is as follows: $\mathit{\Delta}_{t+1} = -q_t$. Before initiating the liquidation, the rational liquidator will compare the bonus $V_c - V_d$ with the gas fee $gasFees$. If the liquidation profit $\mathit{\Pi} = V_c - V_d - gasFees > 0$, the liquidator will trigger the liquidation.

If liquidation happens in a lending protocol, a liquidator will first repay V_{liq} worth of debt and then receive $V_{\text{liq}}(1+b)$ worth of collateral. Here, the liquidation spread b represents the proportion of the bonus that a liquidator can collect relative to the debt during the liquidation. Before initiating the liquidation, the rational liquidator will compare net revenue $V_{\text{liq}}b$ with the transaction fee $gasFees$. If the profit $\mathit{\Pi} = V_{\text{liq}}b - gasFees > 0$, the liquidator will trigger the liquidation.

Theoretically, the lending protocol establishes an upper bound for V_{liq}, defined as δV_d. Here, the close factor δ denotes the maximum proportion of the debt allowed to be repaid in a single liquidation. To obtain an analytic result, we assume the liquidator repays exactly this maximum amount, leading to $V_{\text{liq}} = \delta V_d$. However, we should also consider the scenario in which the actual collateral value V_c is lower than the expected collateral $V_{\text{liq}}(1+b)$ that the liquidator wants to receive when preparing to liquidate the theoretical maximum amount of debt δV_d. Consequently, the maximum amount of debt that can be covered is determined by the lesser of $\frac{V_c}{1+b}$ and δV_d, expressed as $V_{\text{liq}} = \min\{\frac{V_c}{1+b}, \delta V_d\}$. Given that a position may include multiple types of collateral and borrowed tokens, we assume the liquidator withdraws and repays each proportionally to their share of the total collateral and debt, respectively. Consequently, the repaid token quantity increase by $\frac{V_{\text{liq}}q}{V_d}$, while the collateral token decreases by $\frac{(1+b)V_{\text{liq}}q}{V_c}$.

F Protocol-Level TVR

To avoid intra-protocol double counting, we can employ the notations in the account-perspective balance sheet to accurately evaluate the redeemable value

Table 8: Account-perspective balance sheets of the Lido user and the Aave user. In the Lido scenario, the user deposits 1,000 USD ETH to receive 1,000 USD stETH and further deposits 1,000 USD stETH to generate 1,000 wstETH. The Aave scenario aligns with the process in Fig. 9a. We highlight receivables in green and payables in red.

(a) Lido user.

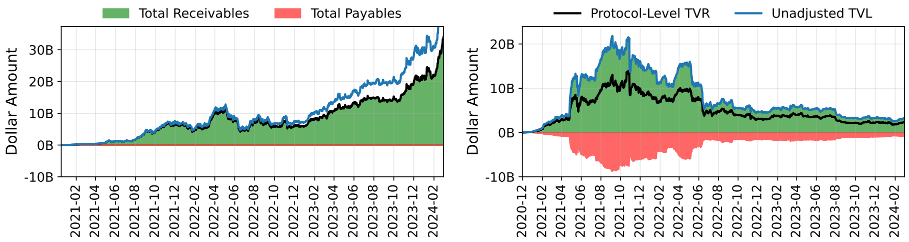
Immediately After	❷	❹
Assets	$	$
Receivables - stETH	1,000	0
Receivables - wstETH	-	1,000
Total Assets	1,000	1,000
Liabilities	$	$
Total Liabilities	0	0
Net Positions	$	$
Initial Deposit Value - ETH	1,000	1,000
Total Net Positions	1,000	1,000

(b) Aave user.

Immediately After	⓿	❸	❺
Assets	$	$	$
Cash - DAI	2,000	0	0
Cash - ETH	-	900	0
Receivables - aDAI	-	2,000	2,000
Receivables - aETH	-	-	900
Total Assets	2,000	2,900	2,900
Liabilities	$	$	$
Payables - dETH	-	900	900
Total Liabilities	0	0	0
Net Positions	$	$	$
Initial Deposit Value - DAI	2,000	2,000	2,000
Total Net Positions	2,000	2,000	2,000

of the individual protocol. We choose Lido as the case study to illustrate intra-protocol wrapping and Aave to show leveraging because they represent the largest protocols where these instances of double counting could occur. Table 8a shows the account-perspective balance sheets of the Lido user in the intra-protocol wrapping scenario. In this scenario, a user deposits $1k ETH (step ❶) to receive $1k stETH in state $\mathcal{S}_{\mathrm{W}}^{(2)}$ (step ❷). Subsequently, the user deposits $1k stETH (step ❸) to generate $1k wstETH (step ❹). From the user's standpoint, irrespective of the frequency of intra-protocol token wrapping, the total value of receivables remains constant at $1k in this scenario. Table 8b shows the account-perspective balance sheets of the Aave user in the leveraging scenario, as illustrated in Fig. 9a. When users take leverage to expand both protocols (see Table 5a) and their account's balance sheet, the total value of payables indicates the extent to which receivables are inflated, which is $900 in the scenario. Therefore, the TVR of an individual DeFi protocol i at time t can be expressed as follows: $TVR_i = \sum_{j \in \mathcal{A}_i} R_j - \sum_{j \in \mathcal{A}_i} P_j$, where P_i and R_i denote the total payables and receivables in the balance sheet of account i.

We measure the protocol TVR for two representative protocols Lido and Aave V2 using the on-chain data. Fig. 10 shows the total receivables, total payables, unadjusted TVL, and protocol-level TVR of Lido and Aave V2 in the Ethereum. The protocol TVR of Lido is equivalent to the value of total receivables as Lido does not engage in token lending and its users do not have any payables. Users of Aave V2, a lending protocol, may have payables. Therefore, the value of these payables must be subtracted from the total receivables. We can observe



(a) Lido. (b) Aave V2.

Fig. 10: Total receivables, total payables, unadjusted TVL, and protocol-level TVR of Lido and Aave V2 in Ethereum.

the intra-protocol double counting in both Lido and Aave V2, evident from the discrepancies between the unadjusted TVL and the protocol-level TVR.

G Comparison between TVR and DeFiLlama-adjusted TVL

Table 9 reports the comparison of calculation methods between DeFiLlama-adjusted DeFi space ecosystem-wide TVL and TVR. Although MakerDAO and Convex have both plain and derivative tokens, they are classified as protocols depositing into another protocol and are therefore excluded from the DeFiLlama-adjusted TVL calculation. In contrast, while Lido, Uniswap V2, and Curve also have derivative tokens, all their tokens are included in the DeFiLlama-adjusted TVL calculation. As a result, the DeFiLlama-adjusted TVL fails to accurately reflect the underlying value of DeFi.

H Token Classification Automation

This paper acknowledges the absence of token classification automation. One possible method to automate this process and avoid reliance on third-party data is to check the opcodes of smart contracts for those tokens. For a DeFi token, one can first fetch its smart contract code to examine its `mint` functions. If the token is a derivative token, its minting requirement should depend on the availability of its underlying tokens. We provide the following three examples:

1. WETH Smart Contract: To wrap ETH into WETH, the smart contract deposits ETH into its own address to mint WETH (see line 3), as shown below:

```
1 function deposit() public payable {
2     balanceOf[msg.sender] += msg.value;
3     Deposit(msg.sender, msg.value);
4 }
```

2. stETH in Lido: To wrap ETH into stETH, the Lido smart contract first checks whether deposits (ETH) are available before proceeding (see line 14). The relevant code snippet is shown below:

```
 1 function deposit(uint256 _maxDepositsCount, uint256
       _stakingModuleId, bytes _depositCalldata) external {
 2     ILidoLocator locator = getLidoLocator();
 3 
 4     require(msg.sender == locator.depositSecurityModule(),
           "APP_AUTH_DSM_FAILED");
 5     require(canDeposit(), "CAN_NOT_DEPOSIT");
 6 
 7     IStakingRouter stakingRouter = _stakingRouter();
 8     uint256 depositsCount = Math256.min(
 9         _maxDepositsCount,
10         stakingRouter.getStakingModuleMaxDepositsCount(
               _stakingModuleId, getDepositableEther())
11     );
12 
13     uint256 depositsValue;
14     if (depositsCount > 0) {
15         depositsValue = depositsCount.mul(DEPOSIT_SIZE);
16         /// @dev firstly update the local state of the
               contract to prevent a reentrancy attack,
17         ///     even if the StakingRouter is a trusted
               contract.
18         BUFFERED_ETHER_POSITION.setStorageUint256(
               _getBufferedEther().sub(depositsValue));
19         emit Unbuffered(depositsValue);
20 
21         uint256 newDepositedValidators =
               DEPOSITED_VALIDATORS_POSITION.getStorageUint256
               ().add(depositsCount);
22         DEPOSITED_VALIDATORS_POSITION.setStorageUint256(
               newDepositedValidators);
23         emit DepositedValidatorsChanged(
               newDepositedValidators);
24     }
25 
26     /// @dev transfer ether to StakingRouter and make a
           deposit at the same time. All the ether
27     ///     sent to StakingRouter is counted as deposited.
             If StakingRouter can't deposit all
28     ///     passed ether it MUST revert the whole
           transaction (never happens in normal circumstances)
29     stakingRouter.deposit.value(depositsValue)(
           depositsCount, _stakingModuleId, _depositCalldata);
30 }
```

3. aTokens in Aave V2: To wrap plain tokens into aTokens on Aave V2, the reserve token is transferred from the user's wallet to the liquidity pool (see line 19). The relevant smart contract logic is as follows:

```
1  function deposit(address _reserve, uint256 _amount, uint16 _referralCode)
2      external
3      payable
4      nonReentrant
5      onlyActiveReserve(_reserve)
6      onlyUnfreezedReserve(_reserve)
7      onlyAmountGreaterThanZero(_amount)
8  {
9      AToken aToken = AToken(core.getReserveATokenAddress(_reserve));
10 
11     bool isFirstDeposit = aToken.balanceOf(msg.sender) == 0;
12 
13     core.updateStateOnDeposit(_reserve, msg.sender, _amount, isFirstDeposit);
14 
15     //minting AToken to user 1:1 with the specific exchange rate
16     aToken.mintOnDeposit(msg.sender, _amount);
17 
18     //transfer to the core contract
19     core.transferToReserve.value(msg.value)(_reserve, msg.sender, _amount);
20 
21     //solium-disable-next-line
22     emit Deposit(_reserve, msg.sender, _amount, _referralCode, block.timestamp);
23 }
```

Therefore, we then check whether the `mint` function of this token is based on the existence of other tokens. If it is not, it should be a plain token. In the Ethereum opcode level, the smart contracts of derivative tokens without ETH as underlying always involve the operation of calling the `transferFrom` function of other ERC-20 tokens. These operations are associated with the opcodes `CALL`, `PUSH4 0x23b872dd`. `CALL` is the opcode to call a method in another contract, while `PUSH4 0x23b872dd` is the function selector `transferFrom`. On the other hand, the smart contracts of derivative tokens with ETH as underlying always involve the operation of transferring the ETH. This operation is associated with the opcode `CALLVALUE`. By identifying those opcodes, we can effectively distinguish the derivative tokens and plain tokens. Future research could explore automation techniques for distinguishing plain and derivative tokens.

The automation methods mentioned above still face several challenges and limitations. Different blockchains have distinct sets of opcodes, requiring tailored

Table 9: The comparison of calculation processes between the DeFi space ecosystem-wide DeFiLlama-adjusted TVL and TVR. The TVR contains only a single column because it is calculated by aggregating the value of all eligible tokens. In contrast, the DeFiLlama-adjusted TVL includes protocol-specific columns, as it is calculated by first aggregating the TVL of eligible protocols within a blockchain and then summing the TVL across all blockchains (see §4.2).

Tokens	**TVR**	**DeFiLlama-adjusted TVL**					
		Lido	**MakerDAO**	**Aave V2**	**Uniswap V2**	**Curve**	**Convex**
ETH	●	●	○	●	●	●	-
WETH	○	●	○	●	●	●	-
wstETH	●	-	○	-	●	●	-
USDT	●	-	○	●	●	●	-
USDC	●	-	○	●	●	●	-
WBTC	○	-	○	●	●	●	-
DAI	○	-	○	●	●	●	-
a3CRV	○	-	-	-	●	-	○
USDP	●	-	○	●	●	●	-
AAVE	●	-	-	●	●	●	-

●: The token value is included in the metric calculation.
○: The token value is not included in the metric calculation.
−: The absence of an asset-specific liquidity pool in the respective protocol.

automation methods for each blockchain. Additionally, some smart contracts are upgradable, meaning their rules can change over time. Consequently, automation methods must also be updated to remain effective. Also note that not all token smart contracts follow standard implementations and some have custom designs, making it difficult for automation methods to cover every possible contract.

I Environment Settings for Sensitivity Tests

Table 10 shows the environment settings for sensitivity tests.

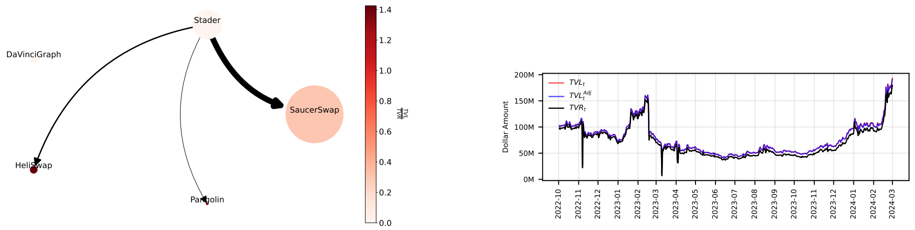
J Altchain Analyses

To gain a broader understanding of the double-counting issue, we analyze two niche Altchains: Hedera ranked 42nd in TVL and Ultron ranked 21st in TVL.

Table 10: Environment settings for sensitivity tests, including parameter details and PLF position information parsed from on-chain data.

Parameters	Related Equation	Value		
		Maximum TVL (2021-12-02)	LUNA collapse (2022-05-09)	FTX collapse (2022-11-08)
p_{ETH} [10]	Eq. 2, Eq. 3	$4,075.03	$2,249.89	$1,334.29
δ_{AAVE} [1]	Eq. 3	0.5	0.5	0.5
δ_{MKR} [22]	Eq. 3	1	1	1
$gasPrice$ [10]	Eq. 3	$\$4.85 \times 10^{-4}$	$\$1.50 \times 10^{-4}$	$\$7.60 \times 10^{-5}$
$gasLimit$ [36]	Eq. 3	$500,000$	$500,000$	$500,000$

PLF	Related Equation	Number of accounts		
		Maximum TVL (2021-12-02)	LUNA collapse (2022-05-09)	FTX collapse (2022-11-08)
MakerDAO	Eq. 3	27,051	28,220	29,711
Aave	Eq. 3	21,336	30,859	47,957



(a) Token wrapping network of Hedera on 2024-03-01. Node size corresponds to the TVL, edge width represents the dollar amount of tokens, and node color reflects the ratio between TVL and TVR.

(b) TVL and TVR of Hedera over time, where the red, blue, and black lines represent the DeFiLlama TVL subjected to double counting, DeFillama-adjusted TVL, and TVR.

Fig. 11: Hedera double counting analysis.

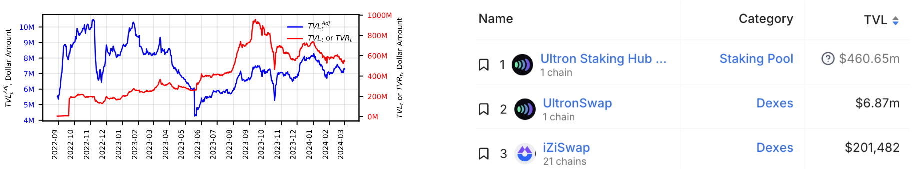
Our findings indicate that blockchains with limited infrastructure feature simpler token-wrapping networks, which leads to less double counting. Additionally, we observe that the DeFiLlama framework addressing the double counting might deflate the true value redeemable of an altchain.

J.1 Hedera

Hedera is a public hashgraph blockchain and governing body tailored to meet the requirements of mainstream markets [5]. As shown in Fig. 11a, the token wrapping network of Hedera is relatively simple. Hedera has only eight DeFi protocols, three of which have zero TVL and have been shut down. Among the other six protocols, only one liquidity staking protocol named Stader can generate receipt tokens that can be subsequently deposited into other protocols. Compared to the networks in Ethereum mentioned in §5, Hedera has a simpler token-wrapping network, thus experiencing less double counting under the TVL framework, as shown in Fig. 11b. We can also partially attribute hedera's low TVL-TVR ratio to the fact that its native coin HBAR also has token-like functions, rendering wrapping of HBAR unnecessary [14].

J.2 Ultron

Ultron is a layer-one blockchain [37] with three DeFi protocols in its ecosystem. The Ultron Staking Hub NFT, created by the Ultron Foundation, serves as a digital asset growth instrument allowing users to earn daily annual percentage rate (APR) returns in Ultron native tokens. Each user can mint non-fungible tokens (NFTs) and stake them on the protocol for 5 years with a vesting schedule. All liquidity is securely locked within a staking smart contract and can be claimed at specific timelines. UltronSwap and iZiSwap are two decentralized exchanges (DEXs) on Ultron. Ultron does not involve wrapping or leverage. NFTs



Name	Category	TVL
1 Ultron Staking Hub ... 1 chain	Staking Pool	$460.65m
2 UltronSwap 1 chain	Dexes	$6.87m
3 iZiSwap 21 chains	Dexes	$201,482

(a) TVL and TVR of Ultron over time. The left-hand-side y-axis denotes the dollar amount of DeFillama-adjusted TVL, while the right-hand-side y-axis represents the DeFiLlama TVL subjected to double counting.

(b) DeFiLlama removes the TVL of the Ultron Staking Hub NFT protocol from Ultron's TVL excluding double counting, as this protocol falls under the category of protocols that deposit into another protocol.

Fig. 12: Ultron double counting analysis.

minted by Ultron Staking Hub NFT and liquidity provider (LP) tokens generated by two DEXs cannot be further deposited into other protocols. Therefore, Ultron is not subject to the double counting problem under the TVR framework. However, DeFiLlama removes the Ultron Staking Hub NFT protocol from its adjusted TVL, falsefully suggesting this protocol deposits into another protocol. The inaccuracy of the methodology (see §2.1) makes the DeFillama-adjusted TVL of Ultron significantly lower than its TVR as shown in Fig. 12a.

K Robustness tests for Correlation Coefficients

As a robustness test for Table 4, we also calculate Spearman's rank correlation coefficients [34] between the natural logarithmic return of these indicators to make variables stationary, which is shown in Table 11.

Table 11: Spearman's rank correlation coefficients [34] between the natural logarithmic returns of macroeconomic indicators, cryptocurrency market indicators, and DeFi money multiplier computed from TVL and TVR.

	Macroeconomic / TradFi indicators			Cryptocurrency / DeFi indicators		
	$\ln \frac{CPI_t}{CPI_{t-1}}$	$\ln \frac{VIX_t}{VIX_{t-1}}$	$\ln \frac{M_t^{\text{TradFi}}}{M_{t-1}^{\text{TradFi}}}$	$\ln \frac{ETH_t}{ETH_{t-1}}$	$\ln \frac{S\&P_t}{S\&P_{t-1}}$	$\ln \frac{M_t^{\text{DeFi}}}{M_{t-1}^{\text{DeFi}}}$
$\ln \frac{CPI_t}{CPI_{t-1}}$	1.00***	-0.11	0.40**	0.06	0.04	-0.01
$\ln \frac{VIX_t}{VIX_{t-1}}$	-0.11	1.00***	-0.25	-0.17	-0.25	0.02
$\ln \frac{M_t^{\text{TradFi}}}{M_{t-1}^{\text{TradFi}}}$	0.40**	-0.25	1.00***	-0.04	-0.06	-0.08
$\ln \frac{ETH_t}{ETH_{t-1}}$	0.06	-0.17	-0.05	1.00***	0.88***	0.17
$\ln \frac{S\&P_t}{S\&P_{t-1}}$	0.04	-0.25	-0.06	0.88***	1.00***	0.33*
$\ln \frac{M_t^{\text{DeFi}}}{M_{t-1}^{\text{DeFi}}}$	-0.01	0.02	-0.08	0.17	0.33*	1.00***

***, **, and * denote the 1%, 5%, and 10% significance levels, respectively.