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). Our measurements reveal 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 among leading protocols via asset value depreciation and 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.

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, TVL is a similar measure of assets pooled for yield generation (see Definition 1) [4,21]. According to DeFiLlama, the entire DeFi TVL stands at over $200 billion as of November 22, 2025. While

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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. ◐: Partial Disclosure. ○: No disclosure.

blockchain systems were designed to enable automatic reconciliation and a coherent accounting whole without discrepancies [8,9], DeFi protocols and liquidity pools have fragmented shared ledgers into accounting "islands" where double counting thrives. Particularly, highly incentivized practices such as token wrapping and redepositing of borrowed tokens [4,21] can trigger double counting, artificially inflating TVL 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.[1] Moreover, the culprit for double counting, the "derivative tokens" (see Definition 3), also serves as channels for financial contagion, making TVL highly sensitive during market downturns. Unfortunately, the methods for different DeFi tracing platforms to calculate TVL are yet 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 [11,12,18,19] but overlook the issue of double counting within TVL. While some existing studies document the complexity and interconnections within DeFi at the token level [16], protocol level [20] and sector level [3], 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 [3], 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

[1] Value inflation in the blockchain space has also been observed in other metrics, such as throughput [14].

CoinMarketCap. We employ the token category data fetched from CoinMarketCap to identify "plain tokens", i.e. tokens that do not entail any underlying token. 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 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, up to $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 [7]. These protocols are decentralized applications inspired by traditional centralized finance systems [23].

2.1 TVL

Based on definitions and descriptions from existing literature [6,25], we define TVL as follows:

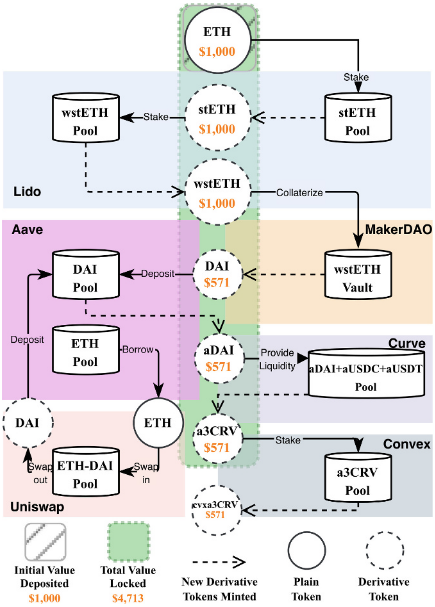


Fig. 1. An example of actions a DeFi user can take to maximize yield, enabled by the DeFi composability.

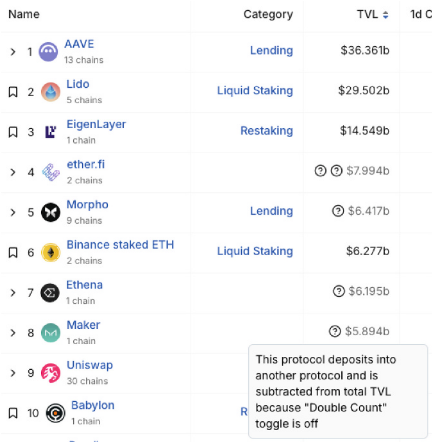


Fig. 2. DeFiLlama's TVL dashboard after deactivating the "Include in TVL: Double Count" toggle. When a user deactivates this toggle, protocols that deposit into another protocol will be excluded from the total TVL calculation, and their TVL numbers will be grayed out.

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, usually for yield generation purposes.*

TVL of the DeFi system can be expressed as

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

where $\mathbf{1}$ is a column 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 column 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 respective category, collectively accounting for approximately 68% of the total TVL. In the illustrative example in Fig. 1, the TVL of these protocols totals $4,713—equivalent to 4.713 times the initial ETH value deposited of $1,000.

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. The "Include in TVL: Double Count" toggle

(a) Wrapping in DeFi. (b) Rehypothecation in TradFi.

Fig. 3. Wrapping and its corresponding TradFi analogy. 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.

allows 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 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 [13], 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 [4,21,24]. 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. Figure 3a depicts a scenario where an investor initially supplies $1,000 worth of stETH to Lido (step ❶), which is then converted into $1,000 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)[2]. The wrapping in DeFi is similar to the 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) [1].

To illustrate the TVL double counting during wrapping, we use a balance-sheet approach to consolidate double-entry bookkeeping (see e.g. [15]) and

[2] 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.

Table 2. Protocol-perspective balance sheets of the wrapping scenario. We **boldface** the components included in the TVL calculation.

(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

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 [22]. 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) [17], 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. Immediately after step ❷, the value of the DeFi system is $1,000. However, if we deposit the receipt token wstETH from Lido into MakerDAO to issue another receipt token DAI, the TVL will be $2,000 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 $1,000 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 token.*

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 some 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 $\boldsymbol{\tau} = [\tau_i]_{m\times1}$, where m is the number of unique tokens and $\tau_i = 1$ if token i is a plain token and 0 otherwise. 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 $TVL = (\mathbf{p} \odot \boldsymbol{\tau})^T\mathbf{Q1} + [\mathbf{p} \odot (\mathbf{1} - \boldsymbol{\tau})]^T\mathbf{Q1}$, 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 Sect. 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

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

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. $\mathbf{p}_u = [p_i]_{m\times1}$ and $\mathbf{q}_u = [q_i]_{m\times1}$ 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. Appendix §D explains in detail the derivative token pegging mechanism that supports Eq. 2. For CDP stablecoins, the deviation of their price, i.e. "depegging", from the predetermined reference point due to the undercollateralization, is denoted as $\Gamma < c_d$.

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 a derivative token of stETH, which itself is a derivative token of ETH). We can derive the derivative token price function in terms of its ultimate underlying plain token prices and quantities: $p_d(\mathbf{p}_u, \mathbf{q}_u) = \left[p_{d_1} \circ p_{d_2} \ldots \circ p_{d_j}\right](\mathbf{p}_u, \mathbf{q}_u)$, 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. $[p_{d_1} \circ p_{d_2} \ldots \circ p_{d_j}]$ 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 affected by its token price due to the liquidation mechanism [2,22,24]. Detailed definitions of PLF and its liquidation mechanism are provided in Appendix §C. According to Appendix §C, a change in collateral j's price $p_{j,t} \rightarrow p_{j,t+1}$ will lead to the change of the account i's health factor $h_{i,t+1}(p_{j,t+1})$, a ratio between liquidation threshold-adjusted collateral value to debt value, and the liquidation profit $\Pi_{i,t+1}(p_{j,t+1})$, 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.

When $h_{i,t+1}(p_{j,t+1}) \geq 1$, the account is deemed safe and the quantity of collateral j in the account remains unchanged, represented by $q_{i,j,t+1}$. When $h_{i,t+1}(p_{j,t+1}) < 1$ and the liquidation profit $\Pi_{i,t+1}(p_{j,t+1}) \leq 0$, the liquidation is considered unprofitable for liquidators, rendering the liquidation unviable and the quantity of collateral in the account also unchanged, represented by $q_{i,j,t+1}$.

When $h_{i,t+1}(p_{j,t+1}) < 1$, 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 $\Pi_{i,t+1}(p_{j,t+1}) > 0$, 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 $t \rightarrow t+1$:

$$q_{i,j,t+1}(p_{i,j,t+1}) = \begin{cases} q_{i,j,t} + \Delta_{i,j,t+1} & \text{if } h_{i,t+1} < 1 \text{ and } \Pi_{i,t+1} > 0 \\ q_{i,j,t} & \text{otherwise} \end{cases}. \tag{3}$$

Δ and Π 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:

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

Table 3. Δ and Π in different scenarios, where $V_{\text{liq}} = \min\{\frac{V_c}{1+b}, \delta \cdot V_d\}$ 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 $V_d = \mathbf{d}^T\mathbf{p}_d$, where $\mathbf{c}$ and $\mathbf{d}$ are vectors of collateral and debt token quantities, represent 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) Quantity increase Δ_{t+1} for token in a CDP or a lending protocol.

	Δ of Repaid Token	**Δ of Collateral Token**
CDP	0	$-q$
Lending Protocol	$\frac{V_{\text{liq}} \cdot q}{V_d}$	$-\frac{(1+b)V_{\text{liq}} \cdot q}{V_c}$

(b) Liquidation profit Π_{t+1} in a CDP or a lending protocol.

	Π
CDP	$V_c - V_d - gasFees$
Lending Protocol	$V_{\text{liq}} \cdot b - gasFees$

where $\boldsymbol{\omega} = [\omega_i]_{n\times 1}$, $\omega_i = 1$ if protocol i is a PLF and 0 otherwise. The derivative token price depends on its underlying token's price $\mathbf{p}_u$ and quantity (see Eq. 2). In addition, the tokens quantity staked within a PLF is affected by their own price (see Eq. 3). 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, 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:

$$TVR = (\mathbf{p} \odot \boldsymbol{\tau})^T \mathbf{Q}\mathbf{1} = \underbrace{(\mathbf{p} \odot \boldsymbol{\tau})^T \mathbf{Q}(\mathbf{1} - \boldsymbol{\omega})}_{\substack{\text{plain tokens held by} \\ \text{smart contracts in non-PLFs}}} + \underbrace{(\mathbf{p} \odot \boldsymbol{\tau})^T \mathbf{Q}\boldsymbol{\omega}}_{\substack{\text{plain tokens held by} \\ \text{smart contracts in PLFs}}}, \quad (5)$$

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 Sect. 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 DeFi platform. Subsequently, we update the token price vector $\mathbf{p}$ from Eq. 2, quantity matrix $\mathbf{Q}$ from Eq. 3 and 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 adjusted TVL (TVL^{Adj}) from January 1, 2021 to March 1, 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^{Adj} is DeFiLlama's improved metric aimed at mitigating the double counting problem and is flawed as discussed in Sect. 2.1. We then break down the TVL of each protocol to obtain the unadjusted TVL per protocol per day (TVL_i). 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). We also retrieve the blockchain states from an Ethereum archive node for three key dates: December 2, 2021, marking the peak of DeFiLlama-unadjusted TVL; May 9, 2022, denoting the end of the Luna collapse; and November 8, 2022, representing the end of the FTX collapse.

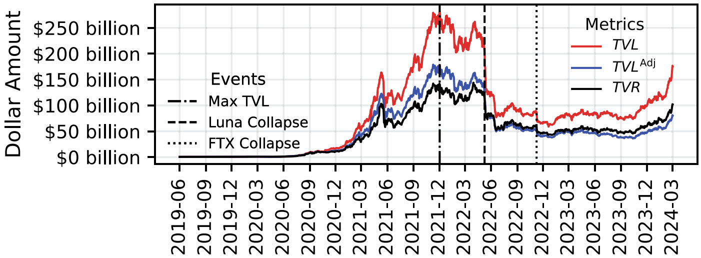


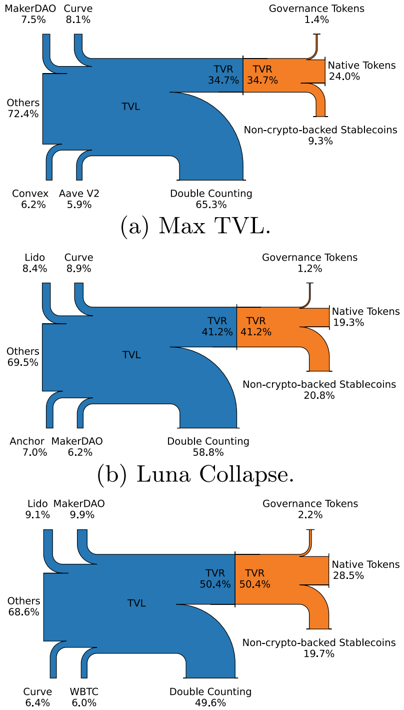
Fig. 4. TVL and TVR over time, where the red, blue, and black lines represent the TVL, TVL^{Adj}, and TVR. (Color figure online)

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 Sect. 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. Figure 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 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

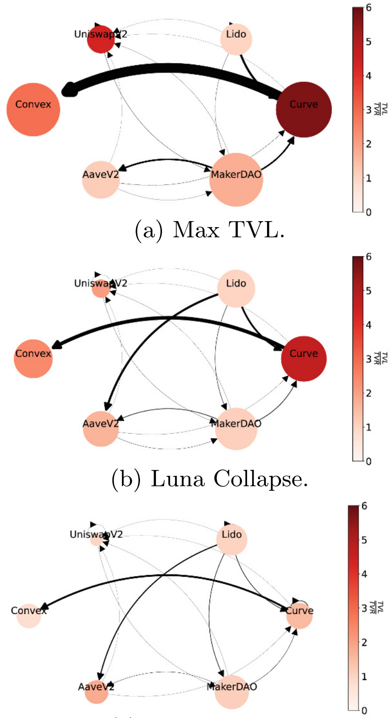


(a) Max TVL.

(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.

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 Sect. 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. Figure 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 TVR remains small. The proportion of native tokens decreases after the Luna

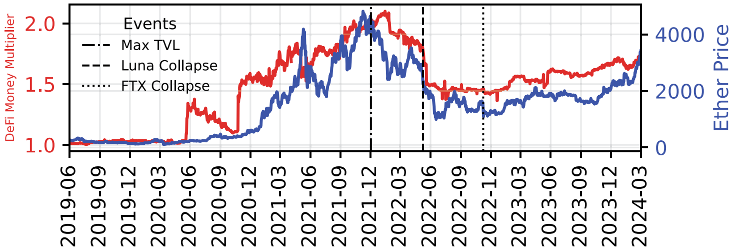


Fig. 7. DeFi money multiplier (red line) and ETH price (blue line). (Color figure online)

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. 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. Figure 7 plots the DeFi money multiplier.

Table 4 lists the Spearman's rank correlation coefficients 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 between the natural logarithmic return of these indicators to make variables stationary, which is shown in Appendix §K.

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 con-

Table 4. Spearman's rank correlation coefficients 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.

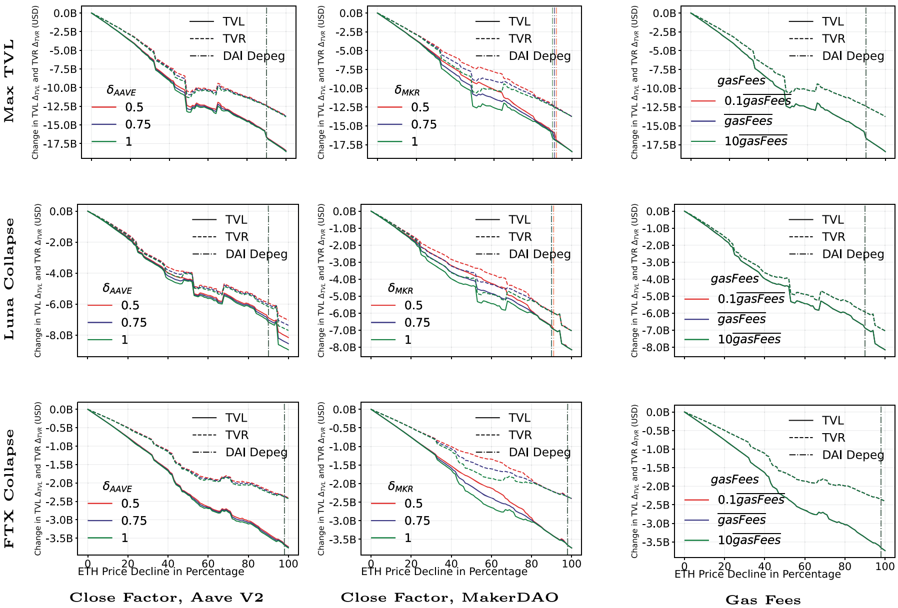


Fig. 8. Change in TVL Δ_{TVL} and TVR Δ_{TVR} as a function of ETH price decline in percentage d_{ETH} on three representative point with different parameter values. Subfigures within a row represent sensitivity tests conducted under the same snapshot, whereas subfigures within a column display sensitivity 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.

ducted 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 $\frac{TVL}{TVR}$ 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.

Figure 8 shows how ΔTVL and ΔTVR vary with ETH price decline 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 Sect. 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 and the close factor is 0.8; the maximum amount that can be liquidated is then \$80 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 MakerDAO has greater exposure to a decline of ETH price compared to Aave V2.
2. Gas fees ($\overline{gasFees}$). We first calculate the average gas fee across daily transactions using $\overline{gasFees} = \overline{gasLimit \times gasPrice}$, and then adjust it by scaling with factors of 0.1, 1, and 10. As shown in Fig. 8, the variations in $\overline{gasFees}$ 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.

6 Related Work

Several studies explore the role of TVL in DeFi valuation and risk monitoring. Metelski et al. [11] and Xu et al. [26] investigate the causal relationship between key DeFi performance metrics, such as TVL, protocol revenues, and the DeFi protocol valuations. Stepanova et al. [19] conduct preliminary descriptive and comparison work on TVL of 12 most popular DeFi protocols. Maouchi et al. [12] show 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. [18] use TVL divided by market capitalization for DeFi valuation and examine whether this metric drives the DeFi returns.

Some studies examine the DeFi composability and TVL double counting problem in a limited scope. Kitzler et al. [10] measure the composition of DeFi protocols. Saengchote [16] 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. Chiu et al. [3] use a standard theoretical production-network model to assess the value added and service outputs across various DeFi sectors on Ethereum.

7 Conclusion

This paper presents a novel yet effective measurement framework, TVR, to thoroughly address the double counting problem in DeFi. 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.

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