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REVIEW ARTICLE

How Do Decentralized Finance Protocols Compare to Traditional Financial Products? A Taxonomic Approach

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Abstract. This paper creates a new taxonomy of Decentralized Finance (DeFi) protocols following the methodology specifically tailored to information systems set out by Nickerson *et al.* (2013).[1] This taxonomy provides a tool to classify DeFi protocols, allowing for a structured comparison with traditional financial mechanisms in the present-day (as included in this paper), as well as providing a repeatable procedure in order to track development of the space in the future. Further, the clustering of classified protocols facilitates the rapid identification of similar protocols beyond the mere identification of functions. The dimensions and characteristics of the taxonomy are discussed, as well as qualitative observations concerning the current DeFi landscape. Comparisons with traditional financial mechanisms highlight not only instances of one-to-one replacement of centralized instruments with decentralized alternatives, but also new innovations and products better suited to DeFi environments. Risks and opportunities around these inventions are also discussed.

1. Introduction

1.1. Blockchain-based Financial Ecosystems—The blockchain-based Decentralized Finance (DeFi) ecosystem consists of multiple openly accessible networks with high transparency: smart contracts allow for the creation of trustworthy applications without the need to trust centralized institutions and promise a fast-evolving, more efficient financial infrastructure.[2] In the summer of 2023, the total value locked (TVL) in DeFi protocols was relatively stable at around 40 billion USD. While this accrues to less than 20% of its peak value in December 2021,[3,4] the interest in the space has led to a rapid development of a variety of DeFi protocols in recent years. Applications are expanding the number and types of services they offer, adding to their portfolios in order to become integrated platforms that provide a better user experience. These services are not just replicating their traditional counterparts: DeFi applications have created new products

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and services that cannot be found in traditional finance. Flash loans and Automated Market Makers (AMMs) are only two examples of such products.

Some implications for the traditional financial system can already be seen. Several central banks including the European Central Bank and the Swiss National Bank are exploring Central Bank Digital Currencies (CBDCs), where they also consider blockchain technology as a possible solution. CBDCs aim to create a more efficient financial system with better accessibility and interoperability for the involved central banks. They could, for example, reduce costs and settlement times for cross-border payments.[5] Blockchain-based ecosystems already allow sending money across borders with much lower fees than sending money via regular banks, with remittances being one of the markets most affected by the DeFi innovations.[6]

Swiss banks themselves are also exploring the possibilities of a blockchain-issued "Swisscoin", a token that would represent the Swiss franc. However, there are still some open concerns that need to be resolved. In addition to technological concerns, there are different regulatory aspects to be resolved, such as anti-money-laundering (AML) regulations and privacy concerns.[7]

While these are just some examples that have evolved out of the blockchain/DeFi ecosystem, the space is still developing rapidly. Traditional financial mechanisms are questioned and new concepts are created. A structured framework of current developments in the DeFi ecosystem can enhance a better understanding and therefore facilitate future research in the space. In this paper, we develop a taxonomy of DeFi assets and protocols, with the ultimate goal of identifying trends and characteristics that may innovate or complement the traditional financial ecosystem. After the description of the research method, Section 2 explains the dimensions and characteristics of the resulting taxonomy. Section 3 contains qualitative observations concerning the current DeFi landscape. The last section discusses the parallels and differences between DeFi protocols and their traditional counterparts. This section further derives possible implications for the traditional financial ecosystem.

1.2. Motivation & Research Method—Taxonomies are used in different forms and various fields, such as social science,[8] knowledge management,[9] and biology,[10] to classify and organize complex information into a structured hierarchy that allows for better retrieval of information.[1,11] Several DeFi-related taxonomies have been created already. Some of them are categorizing the start-ups behind DeFi protocols, looking at technical aspects like underlying blockchain, token type, and integration, as well as the business development itself.[12,13] Others are more specific, like Rossi which provides an in-depth classification of stablecoins.[14] Additionally, there are good overviews of DeFi business models, like Jensen *et al.*[15] Qin *et al.* provide a comparison of these business models to centralized finance.[16] This taxonomy of DeFi protocols aims to enable a more conceptual comparison to traditional financial mechanism. For that reason, the focus lies on the economic concepts of DeFi protocols, rather than their technical implementation.

Nickerson *et al.* developed a process to create a taxonomy specifically for information systems: their iterative method fulfills the goal of creating a more reliable and validated taxonomy, and it is the method we apply in this work.[1]

The resulting taxonomy should consist of multiple dimensions and characteristics: every dimension consists of at least two mutually-exclusive and collectively-exhaustive characteristics, such that every object will have exactly one characteristic in every dimension. To give a simple example, in the case of blockchains, one dimension would be "consensus mechanism". This dimension would contain the characteristics "Proof-of-Work", "Proof-of-Stake" and others. A

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classified blockchain would need to be matched to exactly one characteristic. If there was a blockchain that used Proof-of-Work and Proof-of-Stake consensus mechanisms simultaneously, the characteristics would have to be adjusted.

To create the initial version of the taxonomy, the *Conceptual-to-Empirical* step was applied. During a literature analysis, dimensions and characteristics were conceptualized. In the second step, a set of protocols was classified according to the current taxonomy. While classifying the protocols, the *Empirical-to-Conceptual* step of the taxonomy development process was applied with the goal of further refining the taxonomy.[1]

The set of protocols to be analyzed was defined by the top 100 projects listed under "DeFi" on `https://coinmarketcap.com/` on November 12th, 2023. The projects were additionally distinguished according to their listed tokens. For this reason, MakerDAO has two entries in the taxonomy, one for its lending and borrowing application with the token MKR and one for its stablecoin DAI. As the focus of this taxonomy was on the economic properties, Layer 1 (L1) blockchains as well as Layer 2 (L2) scaling solutions were excluded from it, resulting in 69 reviewed protocols.

Some special projects were examined even if they were not listed in this defined set of protocols. One of these special protocols was *inSure DeFi* as there was only one other insurance protocol within the top 100. Other special projects were *CreDA* and *Spectral* because of their innovative approach to credit rating.

2. Characteristics of Decentralized Finance Products

The resulting taxonomy of decentralized finance protocols consists of eight *dimensions*, each encompassing multiple, mutually exclusive *characteristics*. The upcoming subsections describe the dimensions of the taxonomy and explain their characteristics. The taxonomic names used for various dimensions and characteristics have been italicized for reader clarity, and Table 1 (below, Section 3) summarizes the taxonomy.

2.1. DeFi Stack—Like other technical infrastructure, the DeFi ecosystem is designed in a multi-layered architecture. The layers are built on top of each other and are therefore highly dependent. On the other hand, higher layers are making use of preferred parts of the stack. While doing so, they are abstracting and facilitating the use of the lower layers. This creates a composable and open infrastructure.[17]

The first dimension of this taxonomy refers to the DeFi stack. This taxonomy applies a simplified version of the DeFi stack by Schär,[17] which consists of five layers. The lowest layer is the settlement layer (L1), consisting of with the blockchain itself and its native protocol asset. The asset layer (L2) consists of all the tokens issued on the blockchain (including the native protocol asset, which is placed on L1 and L2). The third layer is represented by the protocol layer (L3), where smart contracts are placed. The application layer (L4) abstracts these smart contracts with user-oriented applications. On the aggregation level (L5), several applications are combined in order to create highly interoperable platforms.

As the focus of this review lies on the economic aspects of DeFi protocols, the settlement layer is excluded from this taxonomy and L1 blockchains are not considered. From an economic perspective, there is no clear distinction between protocols and applications. Therefore, they are combined into one layer in this paper. The resulting characteristics in the DeFi stack layer

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dimension are *Asset*, *Protocol*, and *Aggregation*. In this context, Assets refer to tradable tokens. Protocols refer to a set of smart contracts that might be extended by a user-friendly front end. Aggregations access several protocols to provide additional benefits to their users, for example by finding the pool with the highest yield.

2.2. Purpose—This dimension refers to the purpose a protocol is designed to fulfill. *Monetary Assets* aim to have at least one of the three functions of money, serving either as (i) a unit of account, (ii) a means of exchange, or (iii) a store of value, or some combination thereof. Stablecoins are the most prominent example of this characteristic.[14] *Decentralized Exchanges* allow users to trade one cryptocurrency for a different one. There are different designs for exchanges which are covered in the following dimensions.

Users can get access to additional funds by using *Borrowing* and *Lending* applications. Some of these applications allow lenders to deposit funds into a smart contract in order to get a reward from interest payments. Another form of borrowing that is only seen in blockchain-based markets is the flash loan. Flash loans enable more efficient liquidations and arbitrage transactions. In that way, they are increasing the stability of the DeFi ecosystem. However, there are still many problems around flash loans to be resolved; in particular, flash loans are often used in exploits, as they provide access to large amounts of capital to perform complex trade patterns with close to no risk for the lender and borrower.[18]

Many protocols offer some form of reward to users willing to provide liquidity to the protocol. To maximize such rewards, some protocols offer automated *Asset Management*.

On blockchains that use Proof-of-Stake as a consensus mechanism, users have to lock in their funds to participate in this process and to be rewarded for their stake. Liquid *Staking* protocols aim to facilitate staking for individual users and make the positions tradable. Usually, the funds are pooled together and rewards from validations are shared among the users. Mostly, a token is minted that marks a claim on the pool and therefore enables trading the staked positions.[19,20]

Asset-based *Derivatives* are financial contracts whose value is dependent on an underlying asset, group of assets, or benchmark. Many applications of decentralized derivatives aim to create synthetic assets that replicate off-chain assets on-chain. They also allow leveraged trading and short selling.[21] Perpetual swaps are a form of derivative that is only seen in blockchain-based markets. Traditional forms of derivatives, like options and futures, are rarely seen in DeFi applications. Perpetuals are mostly used to create leveraged long or short positions and there are exchanges like *dYdX* that specifically focus on the trading of such perpetual swaps instead of regular tokens.[22]

An *Oracle* is a third-party service that collects off-chain data and makes it available on-chain. It enables smart contracts to interact with data from outside the blockchain on which they operate.

Due to the pseudonymous nature of DeFi applications, loans usually require collateral. However, there are some approaches to offer *Credit*-based loans in DeFi.[23,24] It is possible to insure funds against unexpected losses due to scams or technical flaws. Similar to traditional *Insurance*, users have to pay a premium in order to insure their assets.[25–27]

Payment protocols aim to facilitate payments between users on the blockchain. They provide additional services like invoicing or prepared reports.[28]

2.3. Price Mechanism—DeFi protocols derive prices with different approaches. Some protocols rely on price feeds from a third party, an *Oracle Input*.[21,29] Other protocols let their prices be set by *Supply and Demand* from the market.

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Some exchanges are replicating the traditional design by using a limit order book. They either maintain an *On-Chain Order Book*, or they use an *Off-Chain Order Book*, where the order book is a distinct entity.[15] Even if the order book is maintained off-chain, this type of exchange faces scalability issues in blockchain-based environments. For that reason, several DeFi exchanges follow the design of an *Automated Market Maker (AMM)*. The basic form of an AMM follows the constant product approach $x \times y = k$.[17]

The basic design of an AMM does not allow users to place limit orders. However, several decentralized exchanges are offering order book functionalities. 1INCH for instance offers a separate limit order book protocol, next to its aggregation of AMMs.[30] Uniswap V3 is offering similar functionalities with its "Range Orders". While Uniswap operates on Ethereum, Pancake Swap introduced the same functionality on its Exchange V3 on Binance Smart Chain.[31]

Biswap also introduced its V3 Version: they are using a similar approach to Uniswap V3, where they split the liquidity reserves into a finite number of "ticks". These "ticks" are located on the same $x \times y = k$ formula used by other AMMs, but the price moves incrementally between them. This eliminates price slippage, as long as the price remains within one tick.[32] On Uniswap V3, it is possible to mimic a limit order by providing liquidity to a very small price range. As soon as the price crosses the defined range, all the provided liquidity is swapped. However, if the price returns to the old level and recrosses the price range, the liquidity is swapped back, meaning the order becomes unfilled again.[33] Biswap V3 uses a different approach for its orders. A trader that places a limit order provides liquidity only to one specific tick, and as soon as the price crosses the tick, all orders placed to that specific tick get swapped. After an order is swapped, its liquidity becomes inactive and can no longer be used by the pool. Unlike on Uniswap V3, the tokens can not get swapped back to the initial tokens and users can claim their tokens anytime.[32] Some protocols are *Asset Based,* designed to derive their price from another asset.[21] In prediction markets, like betting applications, the price is derived from an event or the likelihood of an event to occur,[17] so we have termed these protocols *Event Based*.

In other cases, the price of an asset depends on the *Yield* a protocol generates for the user. If the price is negotiated off-chain between users directly, the price mechanism is characterized as *P2P Negotiation*.

2.4. Liquidity Storage—This dimension refers to the smart contract a user interacts with and how it manages its liquidity. To facilitate transactions and eliminate any matching process, protocols make use of a liquidity *Pool*. Hereby all users interact with the same smart contract.[23] Other applications lock funds into a smart contract, a *Vault*, usually as collateral for something in exchange. The locked funds remain dedicated to one user. Only this user has access to the *Vault*. Other DeFi applications are just enabling the atomic transfer of funds from one party to another without storing them in a smart contract. They are called *Over The Counter (OTC)* protocols.[17]

2.5. Collateral—DeFi protocols that issue an asset often rely on collateral to secure transactions. It is mostly seen in borrowing and lending protocols that allow users to borrow tokens while posting an equal or larger value of collateral asset as a guarantee. If the user fails to repay the debt, the collateral can be sold to protect the protocol from losses. To borrow DAI tokens from the MakerDAO protocol, for example, the user needs to lock a higher value of another *Cryptoasset* as collateral into the smart contract. In this case, if the value of the collateral drops below a certain threshold, the collateral is automatically sold to fully cover the user's debt.[34–36] Other assets are secured by *Fiat* or a *Commodity* that is locked in a bank account with the goal of

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ensuring a stable value of the protocol's token.[37]

All the borrowing and lending applications in the sample rely on overcollateralization for issuing loans, except for flash loans which need to be paid back within the same transaction. Users are interacting with a pool or with a user-specific vault.[23] Maple and TrueFi are the only protocols of the sample offering uncollateralized loans, but in both cases, a human entity is responsible for assessing a user's creditworthiness. Additionally, they both address institutional clients.[38,39] However, these properties do not align with the goal of open access to the DeFi ecosystem.

Regular users have access to uncollateralized loans in traditional finance. Overall credit card debt reached 1 trillion USD in the US in 2022. The average credit card holder carried a debt of more than 5000 USD.[40] The borrowable amount is calculated by the issuer itself or a third party, often with the use of a credit score. Some protocols try to create a similar credit score on-chain. Two examples of such protocols are Spectral Finance and CreDA.[24,41] Both protocols scan a user's past transactions on the blockchain, as well as loans that were taken out, in order to calculate a credit score. They then issue a non-fungible token, an ERC721 token, that determines the user's credit score. This token can be used to get credit-based loans, without the need for collateral. However, both protocols are still in their beta-test phase and they did not list any real applications by the time of writing.[24,41] For that reason, both applications were not in the original sample, but were added because of their distinctive approach.

2.6. Governance Process—Governance refers to the structures and processes that control the decision-making, and therefore the evolution and integrity, of a protocol. However, governance is not the focus of this taxonomy. Therefore, this taxonomy distinguishes between protocols that issue a specific *Governance Token*, and protocols that assign *Equity-Based* voting power to holders of their utility token. Third are protocols that are governed by a *Centralized* entity.[42]

2.7. Token Supply—This dimension refers to a protocol's token, rather than to its service. Let us consider the example of a decentralized exchange that lets users swap ETH to USDC, but issues a distinct utility token: in this case, the dimension *Token Supply* would refer to the utility token. This taxonomy distinguishes between *Capped*, *Inflationary*, *Deflationary*, and *Dynamic* token supply. A capped supply refers to a fixed total amount of tokens, even if not all tokens are immediately released. An inflationary or deflationary supply means that the amount of tokens in circulation is increasing, respectively decreasing, over time. A dynamic token supply does not follow a predetermined scheme, but changes according to external factors. Ampleforth, for example, adjusts its token supply to converge the price towards the predefined peg.[43]

2.8. Integration—This taxonomy differentiates between *Single-Chain* and *Cross-Chain* applications. Some applications like *Chainlink* are specifically designed to operate across multiple chains.[44] Single-chain protocols can still have distinct implementations on different blockchains that do not interact with each other.

2.9. Additional Findings from Taxonomy Development—Concepts that prove to be working often get replicated by other protocols or on other networks. One example is the stablecoin DAI from MakerDAO. It plays an important role in the Ethereum network. On other networks, there are many similar implementations of this stablecoin. VAI and Acala Dollar are just two examples of similar stablecoins but on different networks.[45,46]

All of the observed Lending / Borrowing applications are following similar approaches to MakerDAO or Aave. They all provide overcollateralized loans, either with the use of a vault or a

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liquidity pool. There are similar observations around decentralized exchanges, especially AMMs.

DeFi applications are trying to diversify their portfolios by offering more services to users. Pancake Swap, for example, originally was an AMM similar to Uniswap, but now offers perpetual swaps, yield farming and staking pools, and a prediction market feature next to the DEX.[31] Another example is FRAX, originally an algorithmic stablecoin that is partially backed by USDC. FRAX is additionally offering an exchange, borrowing and lending, and staking opportunities.[47] Other examples of platforms are 1INCH or Flamingo Finance.[30,48]

Alpaca Finance is originally an application designed for yield farming, but they are introducing their own stablecoin on their website.[49]

3. Taxonomy for Decentralized Finance Protocols

The resulting taxonomy is displayed in Table 1, while the list of all classified protocols can be found in Appendix B. Here we comment on the main insights we obtain from our classification.

Table 1. Taxonomy of Decentralized Finance Protocols

Dimension	Characteristics			
DeFi Stack Layer	Asset	Protocol	Aggregation	
Purpose	Decentralized Exchange	Lending / Borrowing	Monetary Asset	Asset Management
	Staking	Derivative	Oracle	Credit
	Insurance	Payment		
Price Mechanism	Oracle Input	Supply / Demand	AMM	On-Chain Order Book
	Off-Chain Order Book	Asset Based	Event Based	Yield
	P2P Negotiation			
Liquidity Storage	Pool	Vault	OTC	
Collateral	Fiat / Commodity	Cryptoasset	No Collateral	
Governance	Equity Based	Governance Token	Centralized	
Token Supply	Capped	Inflationary	Deflationary	Dynamic
Integration	Single-Chain	Cross-Chain		

3.1. Distribution of Decentralized Finance Protocols—We find that 64% of the observed applications operate on the protocol layer. In terms of purposes, decentralized exchanges make up 33% of the population, and monetary assets make up 19%. This seems to be a large proportion, given that both of these purposes are mostly redundant. This means there is more competition compared to their traditional peers. However, further explanation would require additional research, like analyzing trading volumes and network-specific properties.

AMMs account for 17 out of 23 decentralized exchanges. This design seems to be the most beneficial in the DeFi space.

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If a protocol requires liquidity storage, the pool architecture is used in 67% of the cases. They are used by most purposes of applications. The use case of vaults seems to be specifically used for applications similar to MakerDAO.

Of protocols that require collateral, 43% use cryptoassets. In comparison, the “connection” to traditional finance of protocols that use fiat or commodities as collateral is rather small, at 3%.

There is no example for an *On-Chain Order Book* in this list of classified protocols. However, there were examples in an earlier version and the taxonomy should also allow for future classifications to this characteristic.

More than half of the protocols are making use of a governance token, and 75% of the populations are operating as single-chain applications. This suggests that most of the activity is happening within a network. However, cross-chain trading volumes would have to be analyzed for more insights.

If the design of a protocol does not require a dynamic token supply, most protocols issue a capped supply of their tokens. The full distribution of classified protocols can be found in Table 2 in Appendix A.

3.2. Clustering of Classified Protocols—From the list of classified protocols, we created a similarity matrix between the observed protocols. Each entry of the matrix is given by a similarity score defined as the fraction of dimensions where the two protocols have the same characteristic.

We can then define a complementary dissimilarity matrix (1 - similarity matrix), which we can use to cluster the observed protocols using a hierarchical clustering algorithm. The resulting dendrogram is shown in Figure 1.

This representation of the taxonomically measured similarity of protocols can be seen as a plausibility control of the taxonomy, while also providing a structured visualization of the landscape of existing DeFi protocols. It can be observed the stablecoins appear in the red cluster while borrowing and lending applications appear to be more distributed. However, Aave and Compound appear next to each other in the blue cluster. MakerDAO, JUST, and Liquidity appear closely in the purple cluster. Even if they share the same purpose, they differ in most other dimensions. Decentralized exchanges are distributed as well. Most AMMs on a protocol level are grouped in the blue cluster, order book exchanges appear in the purple cluster, and exchanges that are operating cross-chain can be found in the green cluster.

Other examples are very similar, despite their differing purpose. Acala Swap and Chainlink have a different purpose, but are similar in the other dimensions. Therefore they are listed closely in Figure 1. Both credit applications form the yellow cluster, they show a low similarity to the rest of the observed protocols.

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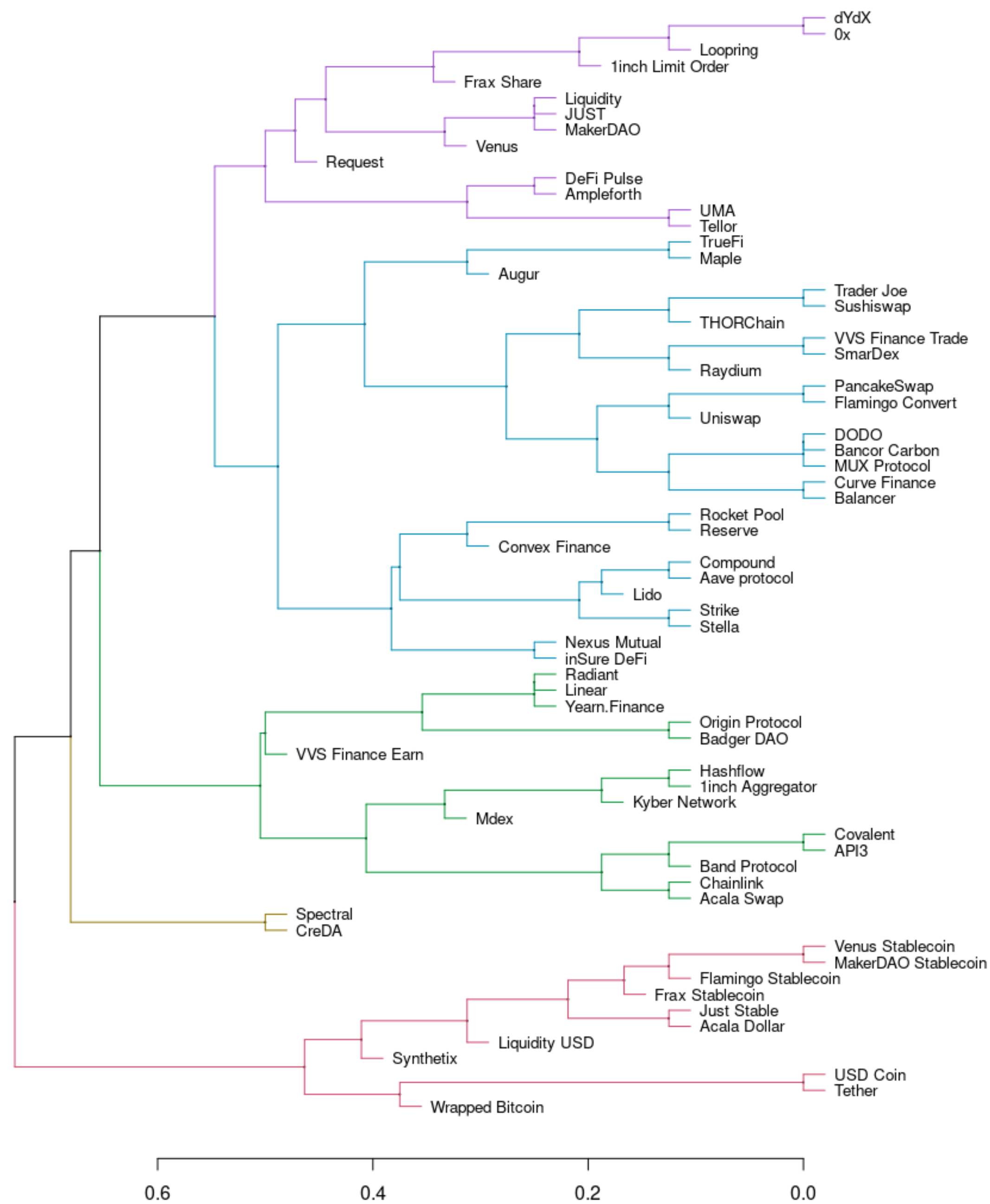

Fig. 1. Cluster Dendrogram highlighting the similarities between different families of protocols. The dendrogram is obtained by hierarchical clustering using a dissimilarity matrix to define distances between protocols.

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4. Defi vs the Traditional Financial Ecosystem

In this section, we compare the taxonomy of DeFi protocols to their traditional counterparts. We look at several traditional financial applications and make a comparison based on the dimensions and characteristics of the taxonomy. As in Section 2, the taxonomic names used for various dimensions and characteristics have been italicized for reader clarity.

Traditional financial institutions do not issue their own "tokens", therefore the dimension *Token Supply* will not be discussed further. The dimension *Integration* will be neglected for similar reasons.

4.1. Exchanges—The *Purpose* dimension of exchanges is similar in DeFi and traditional finance. However, there are significant differences in *Price Mechanism*. Users of traditional exchanges who would like to buy or sell an asset need to submit a limit order containing a maximum (or minimum) price they are willing to accept. These orders are maintained in a central limit order book. When a buying order and a selling order match in terms of their price, the order gets settled, and the funds are exchanged.[16] Decentralized order-book exchanges are very limited in scalability in blockchain networks. Therefore AMMs are more common DeFi.

The two designs also differ in *Liquidity Storage*, AMMs require a liquidity pool while order book exchanges only enable transactions (*OTC*) between users without storing any liquidity. Basic AMMs (see section 2.3) do not offer order book functionalities; however, DeFi protocols have found ways to replicate traditional order book functionalities on-chain. With the introduction of Uniswap V3 and the new version of Biswap, AMMs made a large step in catching up to central limit order book exchanges in terms of functionality. Uniswap is already working on V4.[50] Lehar and Parlour compared the AMM Uniswap with Binance, a centralized order book exchange.[51] They concluded that AMMs can be beneficial over order book exchanges under certain circumstances, with regard to variables such as pool size and gas fees.

4.2. Lending, Borrowing, and Credit—For traditional loans, the *Collateral* can be a car, a house, or any other valuable asset. The issuer of the loan, the lender, can seize or sell the collateral if the borrower fails to repay the loan. As borrowers can be held accountable in traditional finance, uncollateralized loans (i.e., *Credit*) are possible. The *Price Mechanisms* in both worlds show some similarities, the lender typically judges the borrower's financial ability to repay the loan and sets the amount and interest rate accordingly.[52] Unlike in traditional finance, borrowers cannot be held accountable for their missed payments in DeFi. Therefore, a safe overcollateralization needs to be maintained at all times. Most DeFi lending protocols rely on *Oracle Input* to assess the collateral's value at all times. Additionally, protocols need to make liquidation events lucrative for liquidators, meaning to allow them to make a profit. This ensures that "bad" loans are removed from the system before they become a systemic risk.[53]

Concerning *Liquidity Storage*, the lending pools use a similar business model to banks in their basic form. They collect liquidity from lenders and give them a small yield in exchange. On the other side, they issue loans to borrowers and collect interest rates. A share of the interests goes to the bank, or the pool, itself, while the rest is returned to the lenders.[23]

4.3. Securities Market and Credit Rating—In traditional finance, it is possible to reuse collateral or to sell entire loans to another institution. This creates a market for asset-backed securities (ABS). There are no such markets in DeFi. However, looking just at borrowers and investors in Figure 2, the traditional and the DeFi markets appear to be very similar. A borrower

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needs to provide collateral and pay interest in order to receive a loan.

In traditional ABS markets, investors can buy a part of an ABS tranche. This allows them to claim some or all of the interest yet to be paid by the initial borrower. The intermediating institutions claim a share as well. As this claim is tradeable, the investor is also able to sell it anytime. In DeFi lending protocols like Aave, the lender provides liquidity to a pool and receives an *aToken* which represents a claim on a share of the interest rates collected by the pool. These *aTokens* are also tradeable, similar to traditional ABS.

The rating of an ABS is typically conducted by third-party rating agencies. The price of an ABS is determined by its rating. However, as rating agencies are only able to analyze a sample of an ABS' underlying assets, there is some uncertainty in ABS pricing. An additional factor is that trading prices for ABS are not transparent, as they are mostly traded over the counter.[54]

Chen *et al.* analyzed the issuance of ABS in China.[54] Some ABSs were issued using blockchain technology and others were issued in the traditional way. They found a significantly smaller yield spread on blockchain-issued ABSs compared to the traditional ones. This means that the uncertainty that is calculated in the rating of an ABS deal is smaller with the use of blockchain technology. They also noted that the effect was stronger on ABS deals that were rated by less reputable rating agencies. The research suggests that blockchain technology might be well suited for the rating of a user's creditworthiness, as the entire transaction history of a user is stored on the blockchain and can be analyzed automatically to calculate a rating.

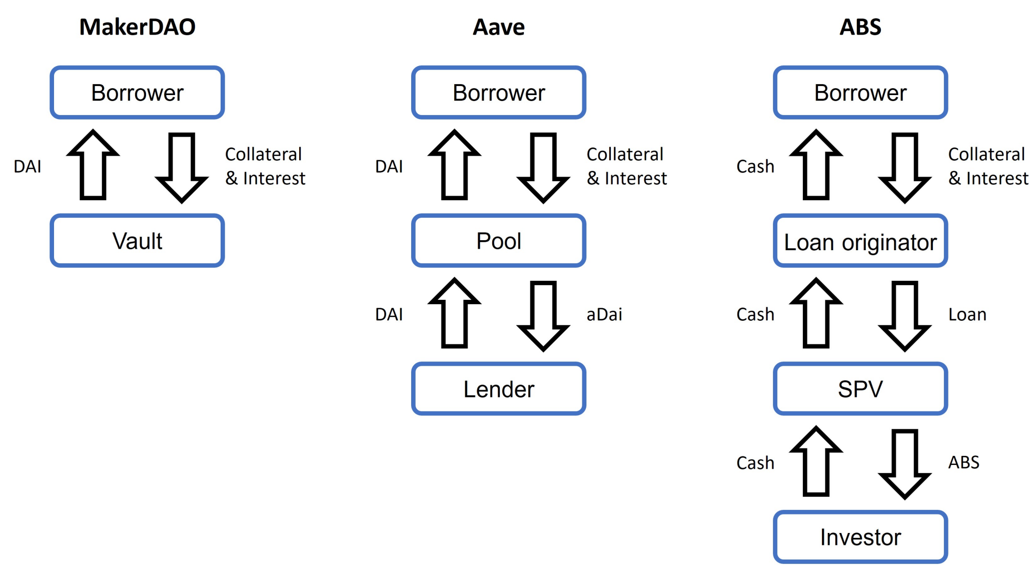

Fig. 2. DeFi Lending compared to ABS.[55]

4.4. Derivatives—The most common types of derivatives in traditional finance are options and futures (or forwards). They are agreements to trade a defined amount of an asset to a defined price at a specified time in the future, or the option to execute such a trade.[56] In DeFi, perpetual swaps are more common.[21] Regarding the *Price Mechanism*, all forms of derivatives are either *Asset Based* or occasionally *Event Based*. Traditional derivatives can be traded *OTC* and do not require any *Collateral*. As users cannot be held accountable in DeFi, replicating traditional derivatives requires locking the assets of both parties involved as collateral into a *Vault*. This

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makes them highly capital-ineffective.

4.5. Asset Management—Traditional investment funds, like hedge funds or exchange-traded funds (ETFs), collect liquidity from investors and invest it according to their strategy. The business model is similar to yield aggregators in DeFi concerning *Price Mechanism*, *Liquidity Storage*, and *Collateral*.

Intending to maximize profit for its users in an automated way, yield aggregators also come with certain risks. The funds are usually provided to liquidity pools of AMMs or lending pools, whatever promises high returns. However, this means that the investment faces the risks of the underlying protocol as well. Transaction volumes on AMMs, and therefore the expected transaction fees, may be difficult to predict. The same is true for the utilization of lending pools and their interest rates.[25]

A pool might generate a high yield as long as it is small. As soon as the pool becomes larger, the generated yield might become significantly lower. Therefore, the yield of a pool does not remain constant and positions need to be managed for optimal returns. With large amounts of funds invested via yield farming, different pool strategies are competing against each other. The more funds following a specific strategy, the less effective it becomes.[57]

Augustin *et al.* analyzed the transaction history of yield farming pools on Pancake Swap.[58] They concluded that small investments into yield farms may be less profitable. This comes from the fact that fixed transaction costs have a larger impact and would reduce profits significantly. On the other hand, too large investments into farming pools may cause price slippage on every trade, which would also have negative effects on profitability. This means that there is an optimum investment size into a pool somewhere in the middle. Additionally, they analyzed the incoming and outgoing flows of the pools. They found a negative correlation between past incoming flows and future returns, which would imply that chasing high-yield pools is not an optimal strategy for investors.

4.6. Insurance—The basic operating model of insurers is relatively similar in DeFi and traditional finance. Users pay a fee to get coverage in case of a loss. The price is determined by the risk of a loss event, *i.e.* the *Demand* for coverage. In both cases, the funds from all users are collected in a *Pool* which is used to pay upcoming claims, no additional *collateral* is required.

4.7. Composability Risk—In the dimension of *DeFi Stack Layer*, it is difficult to make a comparison to the traditional financial system. However, there are large differences in the interoperability of traditional financial entities. Banks and financial service providers need to be connected to one another to enable a functioning financial ecosystem. The interoperability of different entities and countries is a concern of governments and businesses around the world that requires coordinated efforts. Countries are tackling this topic with different approaches.[59]

The DeFi ecosystem claims to ensure this interoperability and provide open access. However, within the DeFi ecosystem, some other concerns are yet to be addressed. Even if a single protocol works fine, there are many interacting protocols in the DeFi ecosystem. Of the observed protocols, 35% rely on external oracle feeds. These combinations can open new possibilities but also pose additional systemic risks. A failure of a single protocol might cause a chain reaction and disrupt the entire DeFi ecosystem. In 2020, a false oracle price feed triggered liquidations worth around $100M on Compound. The protocol itself was working as designed and assumed that the loans were undercollateralized, just because the external reference price feed was corrupted.[60]

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4.8. Governance—Unlike traditional financial entities, DeFi protocols are less regulated. Many DeFi protocols apply a democratic governance approach, like MakerDAO, where token holders can vote on changes to the protocol.[34] Nadler and Schär found that in many cases, the majority of tokens are held only by a small group of users.[61] This gives them exceptional governance power over the protocol and therefore poses a possible source of risk.

A similar problem occurs if users gather their liquidity at yield aggregator protocols. If a yield aggregator moves funds to a relatively small protocol due to good yield expectations, and at the same time this protocol's utility token is its Governance Token, the yield aggregator might gain significant power over the smaller protocol. This could result in a more centralized distribution of power in the DeFi ecosystem, as the holders of yield aggregator Governance Tokens would essentially gain voting power over the smaller protocol for free.[17]

5. Conclusion

Blockchain-based markets have different properties from traditional markets, such as their expanded accessibility and statutory transparency. Additionally, DeFi protocols are highly composable and interoperable. This taxonomy provides a tool to classify DeFi protocols and allows a structured comparison with traditional financial mechanisms. Our classification proposes a structured mapping of the current DeFi space, which can be repeated in the future to track its development. As there seems to be some ongoing competition among protocols that operate similar functions, replicating this exercise would highlight changes in the DeFi space. Furthermore, our clustering of classified protocols facilitates the rapid identification of similar protocols beyond the mere identification of functions.

Traditional financial systems are facing concerns about interoperability and composability, something that is at the core of the ethos of the DeFi space. The lack of regulation and rapid development of DeFi protocols however led to fragile dependencies, which enabled several exploits in the past.

Our classification highlights some of the main differences that can be found between traditional and decentralised systems, particularly around the mechanics of exchanges. Traditional order book exchanges show different characteristics than AMMs in DeFi. While AMMs provide fewer functionalities, they are rapidly developing to incorporate order-book-like functions.

Borrowing and lending applications show similar characteristics in DeFi and the traditional world, however traditional lending schemes typically require less collateral coverage. This enables greater possibilities for a secondary securities market which is currently not possible in DeFi. However, blockchain technology still could offer benefits for credit ratings in this space.

DeFi derivatives show similar characteristics to their traditional peers. However, significant differences in the underlying mechanics can be found. Innovative products like perpetual swaps were created to adopt derivative functionalities to DeFi ecosystems.

Yield aggregators also show similar characteristics in DeFi compared to traditional investment funds. In DeFi they provide easy access and a high degree of automation. However, users should be aware of the risks that arise from the automatic movement of large funds.

In conclusion, we find that DeFi protocols generally leverage blockchain technology's benefits to create a wide range of applications, striving for efficiency and accessibility. In particular, they are not just replicating traditional financial mechanisms - instead, there have been significant

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innovations that led to the creation of new products, better suited for DeFi environments.

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Appendix A: Distribution of Decentralized Finance Protocols

Table 2. Distribution of Decentralized Finance Protocols

Dimension	Characteristics			
DeFi Stack Layer	Asset 14%	Protocol 64%	Aggregation 22%	
Purpose	Decentralized Exchange 33%	Lending / Borrowing 13%	Monetary Asset 19%	Asset Management 6%
	Staking 4%	Derivative 6%	Oracle 9%	Credit 6%
	Insurance 3%	Payment 2%		
Price Mechanism	Oracle Input 35%	Supply / Demand 9%	AMM 25%	On-Chain Order Book 0%
	Off-Chain Order Book 7%	Asset Based 15%	Event Based 2%	Yield 3%
	P2P Negotiation 4%			
Liquidity Storage	Pool 67%	Vault 8%	OTC 25%	
Collateral	Fiat / Commodity 3%	Cryptoasset 43%	No Collateral 54%	
Governance	Equity Based 28%	Governance Token 53%	Centralized 19%	
Token supply	Capped 61%	Inflationary 6%	Deflationary 6%	Dynamic 27%
Integration	Single-Chain 75%	Cross-Chain 25%		

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Appendix B: Classification of DeFi Protocols

Protocol	Coin	DeFi Stack Layer	Purpose	Price Mechanism	Liquidity Storage	Collateral	Governance Process	Token Supply	Integration	Source
0x	ZRX	Protocol	Decentralized Exchange (DEX)	Off-Chain Order book	OTC	No Collateral	Governance Token	Capped	Single-Chain	[64]
1inch Aggregator	1INCH Aggregate	Aggregation	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Equity Based	Capped	Cross-Chain	[30]
1inch Limit Order Protocol	1INCH Limit Order	Protocol	Decentralized Exchange (DEX)	Off-Chain Order Book	OTC	No Collateral	Equity Based	Capped	Cross-Chain	[30]
Aave protocol	AAVE	Protocol	Lending / Borrowing	Oracle Input	Pool	Cryptoasset	Governance Token	Dynamic	Single-Chain	[63]
Acala Dollar	aUSD	Asset	Monetary Asset	Oracle Input	Pool	Cryptoasset	Centralized	Dynamic	Single-Chain	[46]
Acala Swap	ACA	Aggregation	Decentralized Exchange (DEX)	Oracle Input	Pool	No Collateral	Centralized	Capped	Cross-Chain	[46]
Ampleforth	AMPL	Protocol	Monetary Asset	Oracle Input	OTC	No Collateral	Governance Token	Dynamic	Single-Chain	[43]
API3	API3	Aggregation	Oracle	Oracle Input	Pool	No Collateral	Equity Based	Capped	Cross-Chain	[65]
Augur	REP	Protocol	Derivative	Event Based	Pool	No Collateral	Governance Token	Capped	Single-Chain	[66]
Badger DAO	BADGER	Aggregation	Asset Management	Asset Based	Pool	Cryptoasset	Governance Token	Capped	Cross-Chain	[67]
Balancer	BAL	Protocol	Decentralized Exchange (DEX)	AMM	Pool	Cryptoasset	Governance Token	Capped	Single-Chain	[68]
Bancor Carbon	BNT	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Governance Token	Capped	Single-Chain	[69]
Band Protocol	BAND	Aggregation	Oracle	Oracle Input	Pool	No Collateral	Governance Token	Capped	Cross-Chain	[70]
Chainlink	LINK	Aggregation	Oracle	Oracle Input	Pool	No Collateral	Centralized	Capped	Cross-Chain	[44]
Compound	COMP	Protocol	Lending / Borrowing	Oracle Input	Pool	Cryptoasset	Governance Token	Capped	Single-Chain	[71]
Convex Finance	CVX	Protocol	Staking	Asset Based	Pool	Cryptoasset	Equity Based	Capped	Single-Chain	[72]
Covalent	CQT	Aggregation	Oracle	Oracle Input	Pool	No Collateral	Equity Based	Capped	Cross-Chain	[73]
CreDA	CREDA	Protocol	Credit	Oracle Input	Vault	No Collateral	Centralized	Capped	Single-Chain	[41]
Curve Finance	CRV	Protocol	Decentralized Exchange (DEX)	AMM	Pool	Cryptoasset	Governance Token	Capped	Single-Chain	[74, 75]
DeFi Pulse	DPI	Protocol	Derivative	Oracle Input	OTC	Cryptoasset	Governance Token	Dynamic	Single-Chain	[76]
DODO	DODO	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Governance Token	Capped	Single-Chain	[77]
dYdX	DYDX	Protocol	Decentralized Exchange (DEX)	Off-Chain Order Book	OTC	No Collateral	Governance Token	Capped	Single-Chain	[22, 78]
Flamingo Convert	FLM	Protocol	Decentralized Exchange (DEX)	AMM	Pool	Cryptoasset	Governance Token	Inflationary	Single-Chain	[48]
Flamingo Stablecoin	FUSD	Asset	Monetary Asset	Asset Based	Vault	Cryptoasset	Governance Token	Dynamic	Single-Chain	[48]
Frax Share	FXS	Protocol	Monetary Asset	Oracle Input	OTC	No Collateral	Equity Based	Capped	Single-Chain	[47]
Frax Stablecoin	FRAX	Asset	Monetary Asset	Oracle Input	OTC	Cryptoasset	Governance Token	Dynamic	Single-Chain	[47]

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Hashflow	HFT	Aggregation	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Governance Token	Capped	Cross-Chain	79
inSure DeFi	SURE	Protocol	Insurance	Supply / Demand	Pool	No Collateral	Governance Token	Capped	Single-Chain	26
JUST	JST	Protocol	Lending / Borrowing	Supply / Demand	Pool	No Collateral	Equity Based	Capped	Single-Chain	80
Just Stable	USDJ	Asset	Monetary Asset	Oracle Input	Pool	Cryptoasset	Governance Token	Dynamic	Single-Chain	80
Kyber Network	KNC	Aggregation	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Equity Based	Dynamic	Cross-Chain	81
Lido	LDO	Protocol	Staking	Oracle Input	Pool	Cryptoasset	Governance Token	Capped	Single-Chain	82
Linear	LINA	Aggregation	Derivative	Asset Based	Pool	Cryptoasset	Equity Based	Capped	Cross-Chain	83
Liquidity	LQTY	Protocol	Lending / Borrowing	Supply / Demand	OTC	No Collateral	Centralized	Capped	Single-Chain	84
Liquidity USD	LUSD	Asset	Monetary Asset	Oracle Input	Vault	Cryptoasset	Centralized	Capped	Single-Chain	84
Loopring	LRC	Protocol	Decentralized Exchange (DEX)	Off-Chain Order Book	OTC	No Collateral	Equity Based	Capped	Single-Chain	85
MakerDAO	MKR	Protocol	Lending / Borrowing	Supply / Demand	OTC	No Collateral	Equity Based	Dynamic	Single-Chain	34
MakerDAO Stablecoin	DAI	Asset	Monetary Asset	Oracle Input	Vault	Cryptoasset	Governance Token	Dynamic	Single-Chain	34
Maple	MPL	Protocol	Credit	P2P Negotiation	Pool	No Collateral	Governance Token	Capped	Single-Chain	39
Mdex	MDX	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Governance Token	Deflationary	Cross-Chain	86
MUX Protocol	MCB	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Governance Token	Capped	Single-Chain	87
Nexus Mutual	NXM	Protocol	Insurance	Supply / Demand	Pool	No Collateral	Equity Based	Dynamic	Single-Chain	27
Origin Protocol	OGN	Aggregation	Asset Management	Asset Based	Pool	Cryptoasset	Governance Token	Capped	Single-Chain	88
PancakeSwap	CAKE	Protocol	Decentralized Exchange (DEX)	AMM	Pool	Cryptoasset	Governance Token	Inflationary	Single-Chain	31
Radiant	RDNT	Aggregation	Lending / Borrowing	Oracle Input	Pool	Cryptoasset	Equity Based	Capped	Cross-Chain	89
Raydium	RAY	Protocol	Decentralized Exchange (DEX)	Off-Chain Order Book	Pool	No Collateral	Centralized	Capped	Single-Chain	90
Request	REQ	Protocol	Payment	P2P Negotiation	OTC	No Collateral	Equity Based	Deflationary	Single-Chain	28
Reserve	RSV	Protocol	Monetary Asset	Asset Based	Pool	Cryptoasset	Governance Token	Dynamic	Single-Chain	91
Rocket Pool	RPL	Protocol	Staking	Asset Based	Pool	Cryptoasset	Governance Token	Dynamic	Single-Chain	92
SmarDex	SDEX	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Centralized	Capped	Single-Chain	93
Spectral	-	Protocol	Credit	-	-	No Collateral	Centralized	-	Cross-Chain	24
Stella	ALPHA	Protocol	Lending / Borrowing	Oracle Input	Pool	Cryptoasset	Centralized	Capped	Single-Chain	94
Strike	STRK	Protocol	Lending / Borrowing	Oracle Input	Pool	Cryptoasset	Equity Based	Capped	Single-Chain	95
Sushiswap	SUSHI	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Equity Based	Capped	Single-Chain	96

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Synthetix	SNX	Aggregation	Derivative	Oracle Input	Pool	Cryptoasset	Governance Token	Dynamic	Single-Chain	[97]
Tellor	TRB	Protocol	Oracle	Oracle Input	OTC	No Collateral	Governance Token	Deflationary	Single-Chain	[98]
Tether	USDT	Asset	Monetary Asset	Asset Based	OTC	Fiat / Commodity	Centralized	Dynamic	Single-Chain	[99]
THORChain	RUNE	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Equity Based	Capped	Cross-Chain	[100]
Trader Joe	JOE	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Equity Based	Capped	Single-Chain	[101]
TrueFi	TRU	Protocol	Credit	P2P Negotiation	Pool	No Collateral	Governance Token	Deflationary	Single-Chain	[38]
UMA	UMA	Protocol	Oracle	Oracle Input	OTC	No Collateral	Governance Token	Inflationary	Single-Chain	[102]
Uniswap	UNI	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Governance Token	Inflationary	Single-Chain	[103]
USD Coin	USDC	Asset	Monetary Asset	Asset Based	OTC	Fiat / Commodity	Centralized	Dynamic	Single-Chain	[104]
Venus	XVS	Protocol	Lending / Borrowing	Supply / Demand	OTC	Cryptoasset	Governance Token	Capped	Single-Chain	[45]
Venus Stablecoin	VAI	Asset	Monetary Asset	Oracle Input	Vault	Cryptoasset	Governance Token	Dynamic	Single-Chain	[45]
VVS Finance Earn	VVS Earn	Aggregation	Asset Management	Yield	Pool	No Collateral	Centralized	Capped	Single-Chain	[105]
VVS Finance Trade	VVS Trade	Protocol	Decentralized Exchange (DEX)	AMM	Pool	No Collateral	Centralized	Capped	Single-Chain	[105]
Wrapped Bitcoin	WBTC	Asset	Monetary Asset	Asset Based	OTC	Cryptoasset	Governance Token	Dynamic	Cross-Chain	[106]
Yearn.Finance	YFI	Aggregation	Asset Management	Yield	Pool	Cryptoasset	Equity Based	Capped	Cross-Chain	[107]

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