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Opportunities and Risks in Decentralized Finance (Pandl/Rosenberg)

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- Decentralized finance (DeFi) is an experimental and unregulated alternative financial system, grounded in cryptocurrency technology. The DeFi ecosystem includes many of the same products and services found in the traditional financial system—including credit and lending, trading and exchange, derivatives, and insurance—but no centralized intermediaries. It can be considered both a suite of financial technology with the potential to disrupt existing market structures, as well as a compelling use case of blockchains that is helping drive value for crypto assets.
- The DeFi marketplace has expanded dramatically since the middle of 2020—roughly 10x on the most common summary measure. Part of this growth very likely reflects yield: stablecoin yields are typically around 5% on established platforms, much higher than yields on insured bank deposits. Speculative activity likely also plays a role. But user adoption may also relate to longer-running trends including digitization, globalization, and declining trust in centralized institutions.
- Compared to traditional finance DeFi may offer certain advantages, including easier access for underbanked populations and faster settlement times. But despite its promise, DeFi is still very much a work-in-progress—with plenty of hacks, bugs, and outright scams—and will pose a challenge for policymakers concerned about consumer protection and other social goals.
- The structure and activities of two key protocols, Aave and Uniswap, demonstrate the main applications of DeFi—lending and trading/exchange. Aave connects lenders and borrowers through a pooled structure and algorithmically-determined interest rates. Uniswap uses an automated market maker structure and is the dominant decentralized exchange.
- DeFi activity generates value for crypto assets both directly and indirectly. Users pay various fees and spreads when using DeFi protocols, similar to the traditional financial system, and a portion of this revenue can be directed to the protocol "owners"—typically the token holders of decentralized autonomous organizations (DAOs). Network transaction fees also create demand for the blockchain's native asset or "currency", like Ethereum's Ether.

Opportunities and Risks in Decentralized Finance

Alongside the traditional financial system there exists an experimental and unregulated alternative financial system, grounded in cryptocurrency technology, known as Decentralized Finance or DeFi. The DeFi ecosystem includes many of the same products and services found in the traditional financial system—including credit and lending, trading and exchange, derivatives, and insurance—as well as its own unique elements. The main difference is that the marketplace is almost entirely decentralized: there are no banks, brokers, or insurers, only open source software connected to a blockchain. By almost any measure DeFi has gone through a period of rapid growth over the past year, and debates are now less focused on whether these products work than on how they can achieve greater scale. For investors, DeFi should be considered a suite of financial technology that has the potential to disrupt aspects of the existing market structure, as well as one of the most compelling use cases of blockchains and cryptocurrencies that is helping drive value for these assets. Despite its promise, DeFi is still a work-in-progress—with plenty of hacks, bugs, and outright scams—and will pose a challenge for policymakers concerned about consumer protection.

DeFi Foundations[1]

DeFi is built on a foundation of blockchains and smart contracts. Blockchains like Bitcoin and Ethereum allow value to be transferred between parties without the need for a trusted third party. In the traditional financial system, institutions like banks and brokers typically stand between parties in a transaction to ensure that funds are transferred and received, and to maintain a record of asset ownership. On a blockchain, transactions are conducted peer-to-peer, verified through the platform's consensus mechanism and its miners or stakers, and stored on the nodes of a distributed network. In a financial markets setting, the blockchain can be thought of as a sequential database of transactions, which can potentially replace the traditional double-entry bookkeeping maintained by centralized institutions.

But if blockchains were only useful as an alternative ledger or bookkeeping technology their applications would be fairly limited—they might replace certain back office functions in financial services, or could be used to create new money systems and "stores of value", but they would not be able to perform more complex operations. However, the block-by-block updating of a smart contract blockchain can be used to document more than just peer-to-peer transactions: it can record any arbitrary change in state of a complex system. This allows smart contract blockchains to run software, including the applications powering DeFi. Smart contract blockchains are therefore more akin to distributed computers than an accounting ledger. In the case of the Ethereum blockchain—the home of about two-thirds[2] of DeFi—this computing system is known as

[1] For more comprehensive background on the technologies underpinning DeFi, we recommend as a starting point: (i) *The Basics of Bitcoins and Blockchains*, Antony Lewis, Mango Publishing, 2018; (ii) *Mastering Ethereum*, Andreas Antonopoulos and Gavin Wood, O'Reilly Media, 2019; and (iii) *Blockchain and the Law*, Primavera De Filippi and Aaron Wright, Harvard University Press, 2018.

[2] Source: Defi Llama.

the Ethereum Virtual Machine (EVM).

Smart contracts are pieces of software or code that execute commands in a deterministic way. They are commonly compared to a vending machine: you insert a coin and a product comes out. The vending machine contains an implicit contract to exchange one thing for another—a quid pro quo. Smart contracts are a digital version of the same basic concept: a binding commercial agreement between two parties, memorialized in autonomous code rather than a traditional business contract. In DeFi, smart contracts are incorporated into more complex decentralized applications (Dapps) which can execute many types of commands. From the standpoint of the user experience the vending machine analogy still holds: users "lock" a token into a protocol and the software performs an expected function (e.g. borrows funds, swaps tokens).

These features make up DeFi: decentralized applications, based on smart contracts, layered onto a blockchain (Exhibit 1). With this underlying structure the DeFi ecosystem is able to replicate many of the elements of traditional finance without centralized intermediaries.

Exhibit 1: A Decentralized Financial System Built on the Blockchain

Source: Goldman Sachs Global Investment Research

The DeFi marketplace includes many types of traded assets—literally tens of thousands—and interacting with the protocols requires some understanding of these tokens. We will focus on Ethereum but other smart contract blockchains share a similar structure. The Ethereum blockchain has its own native asset or "currency", Ether or ETH. Most of the other assets in DeFi are ERC-20 tokens, which is a fungible[3] token standard that can interact with smart contracts. All of the DeFi protocol governance tokens discussed below are ERC-20 assets. In addition, virtually any other asset can be "tokenized" and represented as an ERC-20 token on the Ethereum blockchain. This includes other cryptocurrencies like Bitcoin, which is used heavily in DeFi, most commonly in wrapped format and expressed as WBTC. Ethereum itself is also frequently wrapped to function as an ERC-20 token and expressed as WETH. Lastly, claims to assets "locked" in protocols are often tokenized. For example, in exchange for lending the stablecoin USDC on the Compound protocol a user will receive a cUSDC token representing the position.

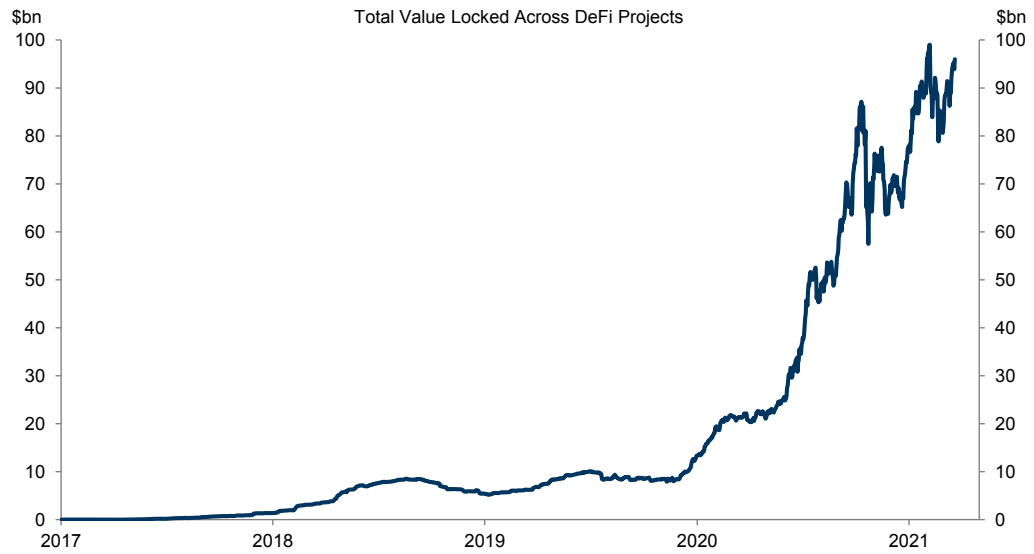
You say you want a revolution

DeFi protocols have been around for a number of years, but usage began to accelerate in the middle of the 2020. Growth in the market preceded last year's surge in the price of Bitcoin, and probably contributed to renewed interest in cryptocurrencies generally. Since then the DeFi ecosystem has expanded dramatically. Total Value Locked (TVL)—a measure of the market value of crypto assets deposited in DeFi protocols—has increased from less than $10bn in the first half of 2020 to nearly $100bn today (Exhibit 2). While this measure has a number of flaws and involves substantial double counting, it seems representative of growth in protocol usage and complexity of the market. Estimates suggest that roughly 3.5 million unique addresses have interacted with DeFi protocols, while the decentralized exchange Uniswap currently sees approximately 300,000 active users per month.[4] Monthly active users of Metamask, a wallet used for DeFi and other crypto applications, reportedly reached 10 million this year.

[3] Each token of the type is the same, in contrast to non-fungible tokens (NFTs), which use the ERC-721 standard.

[4] Source: Dune Analytics.

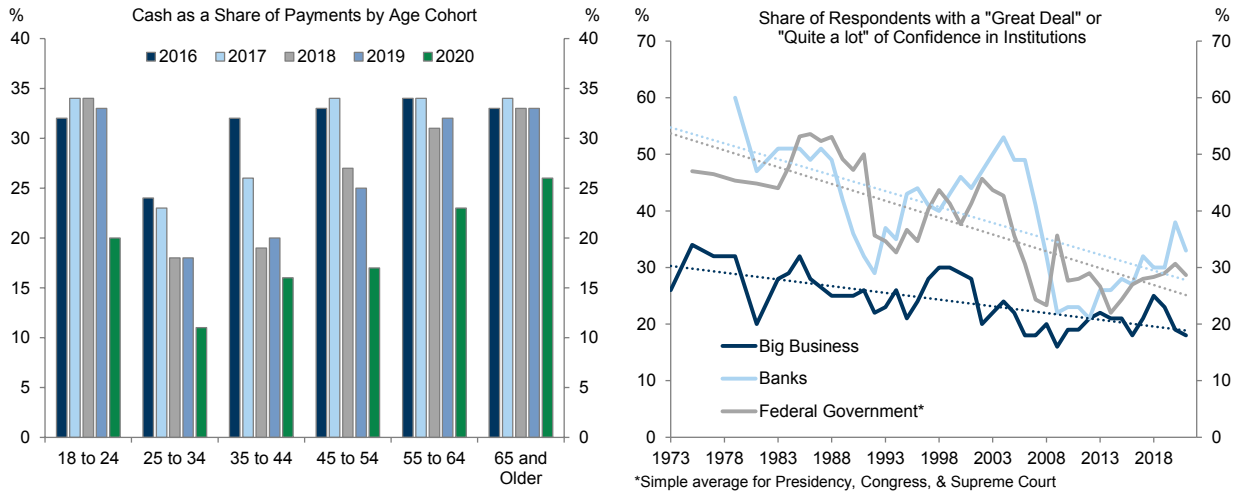
Exhibit 2: Rapid Growth of DeFi Marketplace Over Last Year



Source: DeFi Pulse, Goldman Sachs Global Investment Research

What is driving adoption of this technology? Part of the explanation, undoubtedly, is yield. As we discuss further below, stablecoin yields on established platforms are typically around 5%—about ten times the yields available on insured bank deposits—and these yields can be enhanced in a variety of ways (including with leverage). Speculative trading activity of cryptocurrencies has also likely supported demand for decentralized exchanges. But DeFi adoption, like crypto more broadly, may also reflect other social and generational trends, including rising digitization of commerce. For example, surveys by the Federal Reserve show that cash use declined across all age groups during the pandemic, and that the 25-34yr age group used cash for only 10% of payments last year (Exhibit 3, left panel). This may be contributing to adoption of digital payment technologies generally (e.g. Venmo), including crypto-based stablecoins (e.g. Nasdaq-listed Coinbase recently issued a debit card where balances are held in USDC and rewards can be received in DAI, both popular stablecoins). Other drivers of DeFi adoption may include globalization—DeFi is essentially borderless—as well as declining trust in centralized institutions (Exhibit 3, right panel). Certain market participants may also be drawn to DeFi by the lack of "know your customer" and anti-money laundering (KYC/AML) rules that govern the traditional financial system.

Exhibit 3: Possible Drivers Include Digitization, Globalization, & Declining Trust in Institutions



Source: Federal Reserve, Gallup, Goldman Sachs Global Investment Research

DeFi is an alternative financial system built from the ground up, and its structure therefore differs from the traditional financial system in many ways (Exhibit 4).[5] A few key differences account for DeFi's unique structure. First, assets are typically not held in custody by a third party, but instead are held in users' own digital wallets. Second, DeFi is open and permissionless: all the code underpinning lending and trading platforms is available for anyone to see and copy, and any developer can launch new protocols to the blockchain or connect protocols together. Third, because users' identities are generally unknown, there is (currently) no credit scoring and very little uncollateralized lending—almost all borrowing is over-collateralized, and the limited uncollateralized lending (known as "flash loans") must be borrowed and repaid within the same transaction block.

[5] For another comparison, see "DeFi Beyond the Hype: The Emerging World of Decentralized Finance", University of Pennsylvania Wharton Blockchain and Digital Asset Project.

Exhibit 4: Unique Structure Built from the Ground Up

	Traditional Finance (TradFi)	Decentralized Finance (DeFi)
Intermediaries	Banks, brokers, insurers, & other institutions	None; transactions intermediated through smart contract code
Custody	Regulated custodian	Self-custody (user wallet)
Loan types	Secured, unsecured, generally fixed maturity	Primarily secured, no maturity
Interest rates	Determined by central bank, as well as supply, demand & risk	Determined algorithmically, based on supply, demand & risk
Risk	Counterparty risk, market risk	Protocol risk, market risk
Risk management	Collateral, credit scoring	Collateral, auto-liquidation
Collateral types	Virtually any asset	Crypto assets
Regulatory oversight	Governments, self-regulatory bodies	None
Intellectual property for lending/trading systems	Held by private firms	Open source code
User identification	KYC/AML process	Pseudonymous
Record keeping	Intermediary accounts	Public blockchain

Source: Goldman Sachs Global Investment Research

DeFi's structural differences allow the marketplace to offer certain advantages relative to the traditional financial system, which may include:

1. **Easier access for the underbanked:** Anyone with an internet connection can participate in DeFi; there is no need for a bank or exchange to be present in the local market.
2. **Unique products:** DeFi protocols are open and interoperable[6], which means developers can create certain products which do not exist in traditional finance (e.g. automated yield harvesting strategies and user-created algorithmic portfolio benchmarks).
3. **Faster pace of innovation:** Open source code and permissionless networks allow developers to copy and tweak existing protocols and quickly launch competitors.
4. **Higher transparency:** All DeFi transactions are observable on the blockchain, and much of the protocol-specific data is available through free and open APIs.
5. **More efficiency:** Protocols have relatively little operating expenses once deployed, so may provide more value to users in certain circumstances (although protocols do generate revenue which can be distributed to "owners", as discussed below).
6. **Lower cost cross-border payments:** Blockchains provide a mechanism for secure

[6] However, interoperability also creates dependencies and a type of "interconnectedness risk" also present in the existing financial system.

and low-cost cross-border payments, which should help lower transaction fees for remittances.

7. **Faster trade settlement:** Final trade settlement typically occurs in seconds or minutes rather than days.

At the same time, DeFi still has many drawbacks. Some of these, like frequent protocol bugs and losses from hacking, are typical features of new technology and reflect the immaturity of the industry. Other weaknesses may be more structural. For example, it remains unclear how DeFi can achieve the scale needed to compete head-to-head with traditional financial services technology. The industry has begun to experiment with a variety of solutions, including alternative blockchains and methods to expand Ethereum's own scale (e.g. sidechains and layer 2 protocols), but transaction costs remain fairly high, such that low-dollar-value transactions are essentially priced out. This highlights another important drawback: cost. Although the traditional financial system has its own flaws, retail investors are able to execute many securities transactions at remarkably low cost. This seems very likely to be a barrier to broader DeFi adoption for the time being. In addition, because there are no centralized intermediaries, DeFi puts more personal responsibility on individual users: for the most part there is no recourse for lost passwords or errant transactions. Lastly, although many in DeFi would consider it a positive, the lack of KYC/AML standards means that the marketplace can potentially help facilitate the work of bad actors with socially harmful goals. There are regular scams in DeFi in which promotors walk away with users' funds but remain protected by the blockchain's anonymity. The International Monetary Fund (IMF) has also raised concerns around terrorism finance in its work on crypto assets and central bank digital currencies (CBDCs). For these reasons there is likely a role for more regulatory oversight of DeFi.

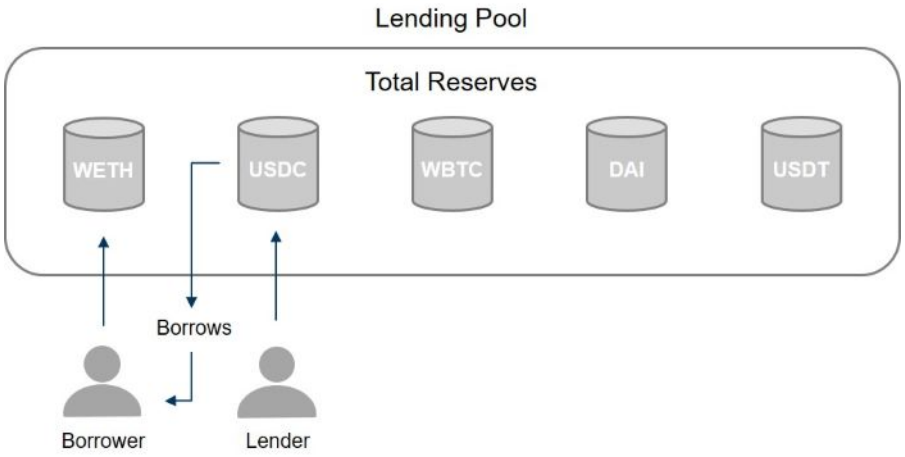
Sources and uses of funds: Aave & Uniswap

The structure and activities of two key protocols, Aave and Uniswap, demonstrate the main applications of DeFi—lending and trading/exchange. Aave began life as ETHLend, a decentralized peer-to-peer lending protocol founded by Stani Kulechov in 2017. ETHLend enabled users to borrow ETH and various stablecoins against ERC-20 tokens as collateral on a peer-to-peer basis. In 2018 the team launched a new parent company, Aave, named for the Finnish word for "ghost". Once the company recognized that collateral on Ethereum was gaining market cap, and that liquidity and risks could be pooled, they built and later launched the Aave Protocol on the Ethereum Mainnet in 2020. The new protocol deviated from the peer-to-peer model of ETHLend, and instead used a decentralized liquidity pool model that allows lenders and borrowers to access a pooled fund of tokens, rather than directly matching borrowers and lenders for individual loans. Aave currently has about $28bn in TVL across multiple chains, including Polygon and Avalanche, and this year the company will launch an institutional product, Aave Arc.

Users have a choice of lending tokens or borrowing against crypto collateral. Lenders deposit tokens in lending pool smart contracts that hold reserves in a variety of tokens. Borrowers are able to remove funds from the pool, provided that they lock in a greater value of tokens as collateral (Exhibit 5). If the value of deposited collateral falls below a

certain threshold the protocol automatically liquidates the collateral and considers the loan settled. Effectively, lenders and borrowers interact only with the lending pool, eliminating the need to directly match individuals in order to execute a loan. The structure virtually eliminates counterparty risk; however, participating in the platform still involves significant exposure to risks, such as smart contract risk (e.g. bugs in the code) and liquidation risk.

Exhibit 5: Aave Uses Pool-based Structure

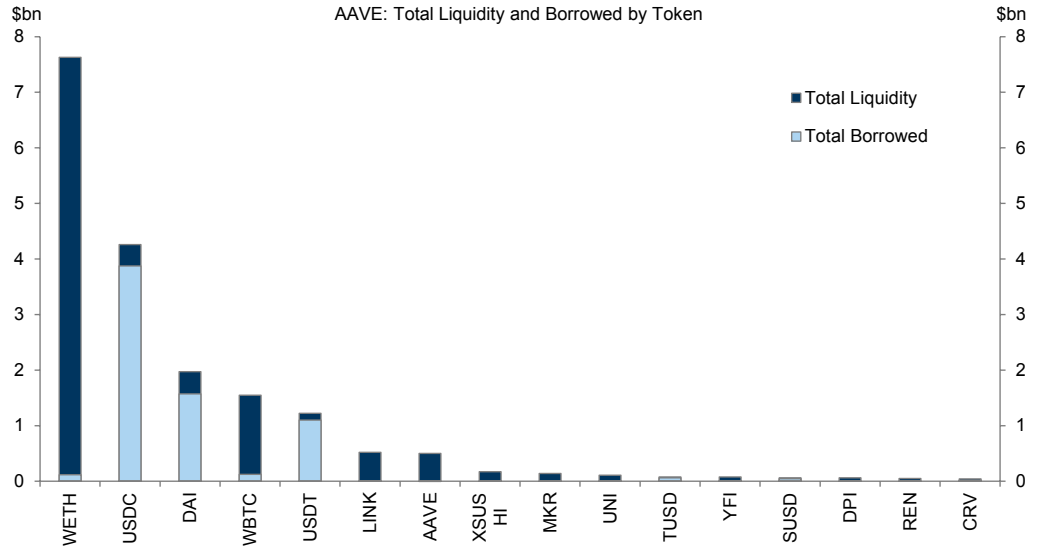


Source: Aave, Goldman Sachs Global Investment Research

The Aave v2 protocol currently hosts 31 tokens[7], with the greatest amount of total value locked in Wrapped Ether (WETH). Users tend to post collateral in a wide range of assets, but tend to borrow primarily in stablecoins, including USDC, DAI, and Tether (USDT) (Exhibit 6). Why might someone borrow from a platform like Aave? Likely for the same reasons that an investor might borrow against her collateral in traditional finance: for speculative purposes, because an asset sale might generate a capital gains tax liability, or for short-term working capital. Aave provides a mechanism for efficient collateralized lending against crypto assets, similar to collateralized lending against securities in traditional finance. Over time protocols like Aave may begin accepting non-crypto collateral, competing more directly with established lenders. Lending protocol MakerDAO has experimented with non-crypto-backed loans, and French bank Societe Generale recently applied for a Maker loan backed by tokenized bonds.

[7] Excluding AMM liquidity provider tokens.

Exhibit 6: Range of Assets Used as Collateral, Borrowing Mostly in Stablecoins

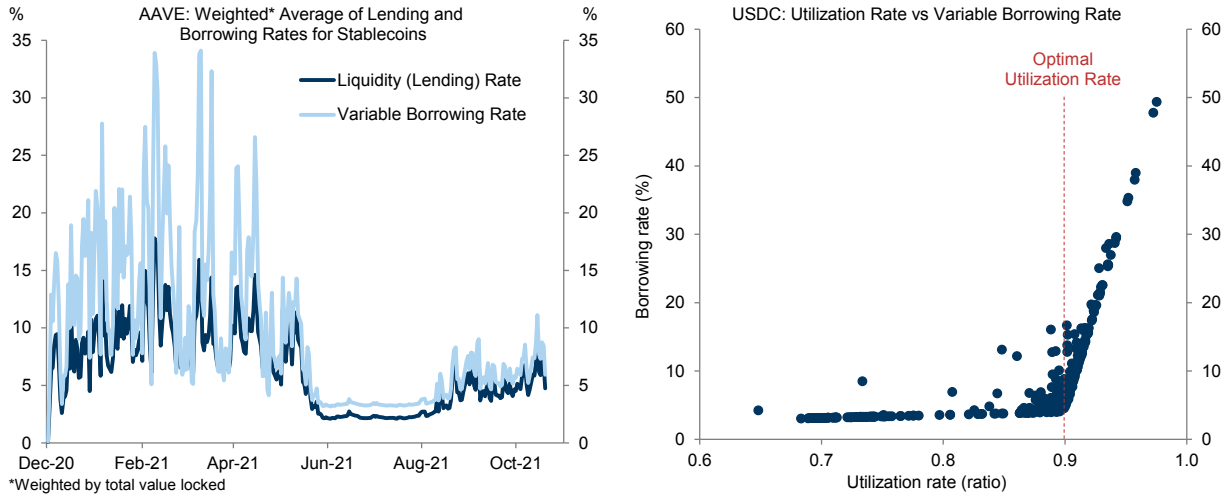


Source: Aave, The Graph, Goldman Sachs Global Investment Research

Interest rates on the Aave platform are determined programmatically and can vary wildly based on supply and demand conditions (Exhibit 7, left panel). Each pool begins with a variable loan base rate of 0%, which then rises gradually as users begin to borrow funds, up to a pool-specific optimal utilization rate. As utilization moves beyond the optimal level rates begin to rise more sharply in order to curtail loan demand and encourage repayment (Exhibit 7, right panel). Deposit interest rates are equal to borrowing rates less a spread that is allocated to the protocol itself.[8] Aave interest rates are only a function of the model parameters and supply/demand conditions, and do not take into account macroeconomic developments.

[8] Aave also provides fixed-rate loans, which operate slightly differently. The spread captured by the protocol is a function of both fixed and variable borrowing rates and their respective shares of borrowers.

Exhibit 7: Programmatically Determined Interest Rates Can be Volatile



Source: Aave, The Graph, Goldman Sachs Global Investment Research

Uniswap is a non-custodial decentralized exchange (DEX) that launched publicly on the Ethereum Mainnet in 2018. Hayden Adams, the creator of Uniswap, modeled the initial concept after an idea proposed by Ethereum co-founder Vitalik Buterin. Reflecting the unique aspects of a marketplace built on open source software, in 2020 SushiSwap launched a fork of Uniswap (essentially a copy) which offered some additional features. Currently, Uniswap and SushiSwap constitute more than 80% of DEX market share.[9]

Uniswap differs materially from the traditional broker-dealer market maker model. Uniswap does not trade its own portfolio of assets or match individual buyers and sellers. Instead Uniswap is structured as a simple automated market maker (AMM), which algorithmically determines prices and quantities of pooled assets to facilitate trading. The pooled assets are provided by the asset owners themselves, rather than a third party. In traditional finance, this would be equivalent to an asset manager offering a portion of its portfolio assets into a trading pool for market making. On Uniswap (although not all DEXs) pools include only two assets. Any user can swap one token for another via an existing pool or create a new liquidity pool. This model may have advantages over traditional market making for more obscure or illiquid assets; for more liquid assets, price discovery likely occurs on centralized exchanges (e.g. Coinbase) and arbitrageurs maintain consistency with Uniswap.

Trading protocols use various types of AMMs. Uniswap uses a constant product formula, where the product of the Dollar value of the assets in a liquidity pool ("x" and "y") always equals a constant, "k":

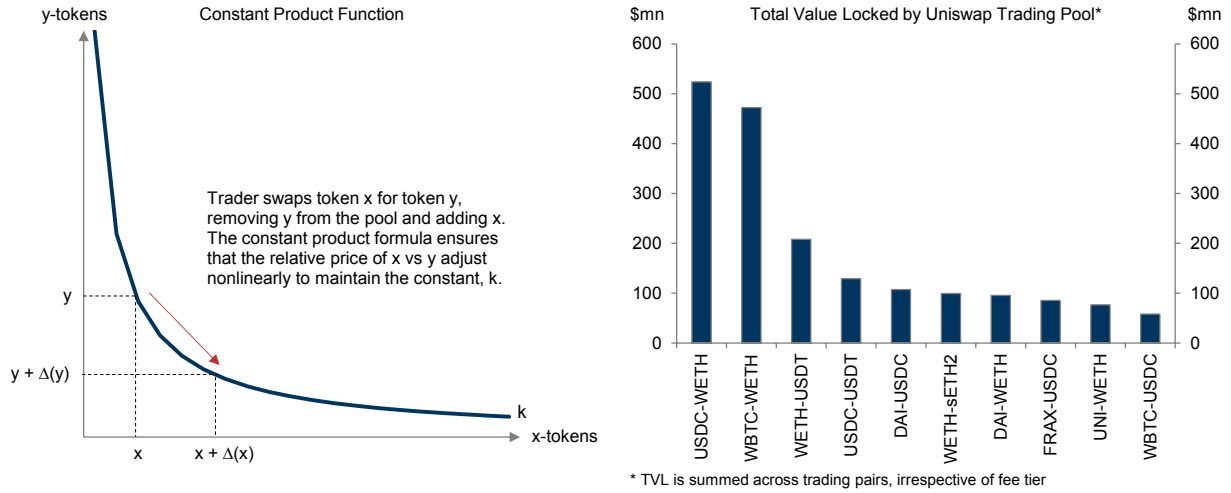
$$x * y = k$$

This function jointly determines the relative price and quantity of the two assets in the pool: a greater amount of y token lowers its price relative value to x token (Exhibit 8, left panel). The largest pools on the Uniswap v3 platform currently are between Wrapped

[9] Source: Dune Analytics.

Ether and certain stablecoins (Exhibit 8, right panel).

Exhibit 8: Uniswap's Structure Simultaneously Determines Quantity and Price

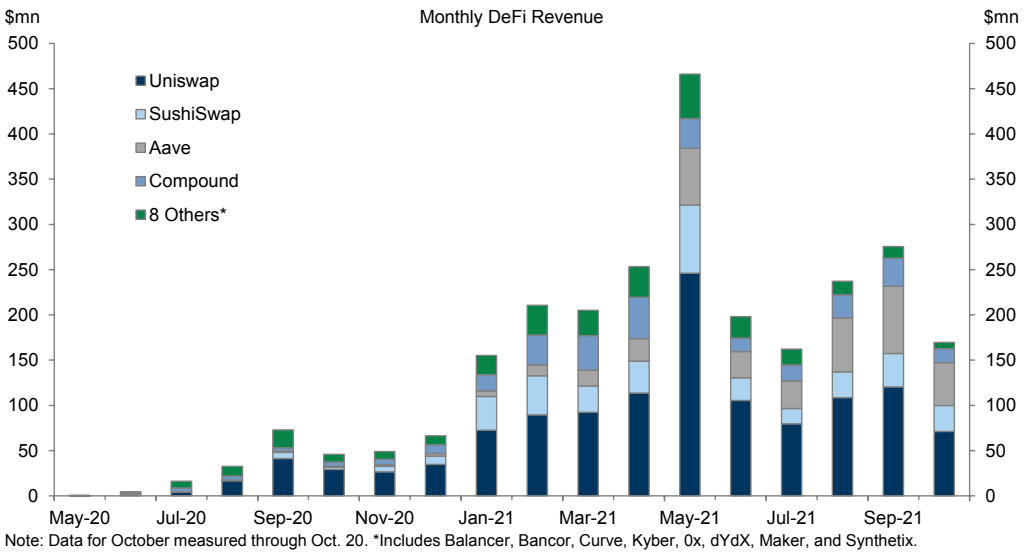


Source: Federal Reserve Bank of St. Louis, Uniswap, The Graph, Goldman Sachs Global Investment Research

Value creation: direct and indirect

User activity in DeFi generates value for cryptocurrency assets both directly and indirectly. Users pay various fees and spreads when using DeFi protocols, similar to the traditional financial system. The vast majority of this revenue (>95%) accrues to the "supply side"—the lenders on platforms like Aave and liquidity providers on Uniswap—but a portion is directed to the protocol itself. According to The Block Research, the 12 largest Defi protocols generated revenue of $2.3bn year-to-date, led by Aave and Uniswap (Exhibit 9).

Exhibit 9: Substantial Growth in Protocol Revenue

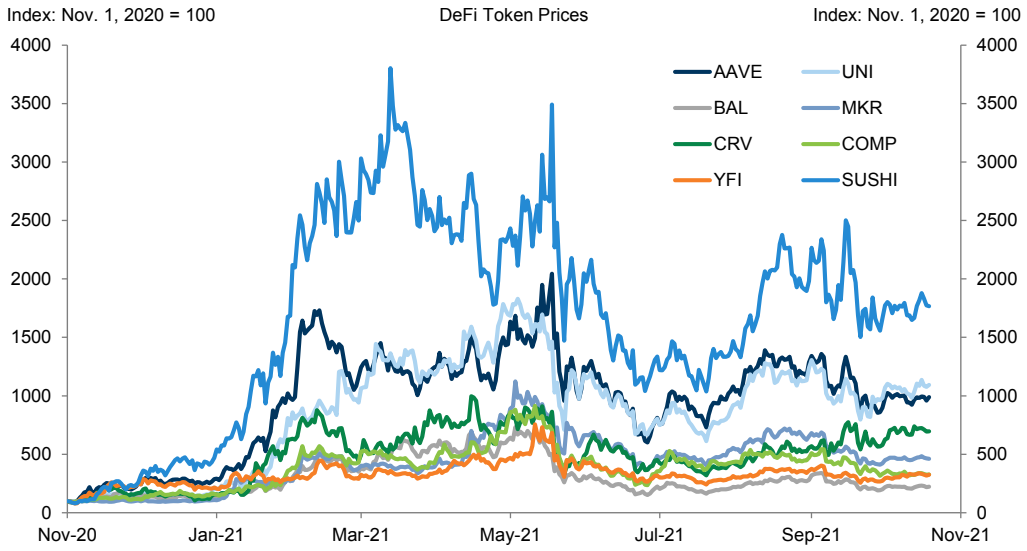


Source: The Block, Goldman Sachs Global Investment Research

In line with the decentralized ethos of the marketplace, most protocols are structured as

decentralized autonomous organizations or DAOs.[10] These are internet-native voting-based organizations that provide the governance for DeFi protocols. When raising funds DeFi projects often issue tokens, and token ownership then determines how voting rights are distributed. Owners of these governance tokens can propose changes to protocols and vote on community proposals. Governance tokens can also serve as a claim to a portion of protocol revenue, and in that way are akin to shares in a joint stock company. The mechanism through which protocol revenue is directed to governance token holders differs significantly by project. In some cases, protocols pay a "staking yield" which resembles an equity dividend, and in other cases tokens are "burned" in order to reduce circulating supply, thereby raising the value of outstanding tokens much like equity share buybacks. Uniswap's UNI token does not pay any type of dividend at this time, but nonetheless commands a high market value, presumably on the expectation that protocol revenues will be directed to token holders at some point in the future (Exhibit 10).

Exhibit 10: Protocol Revenue Can Accrue to DAO Token Holders



Source: Coin Metrics, Goldman Sachs Global Investment Research

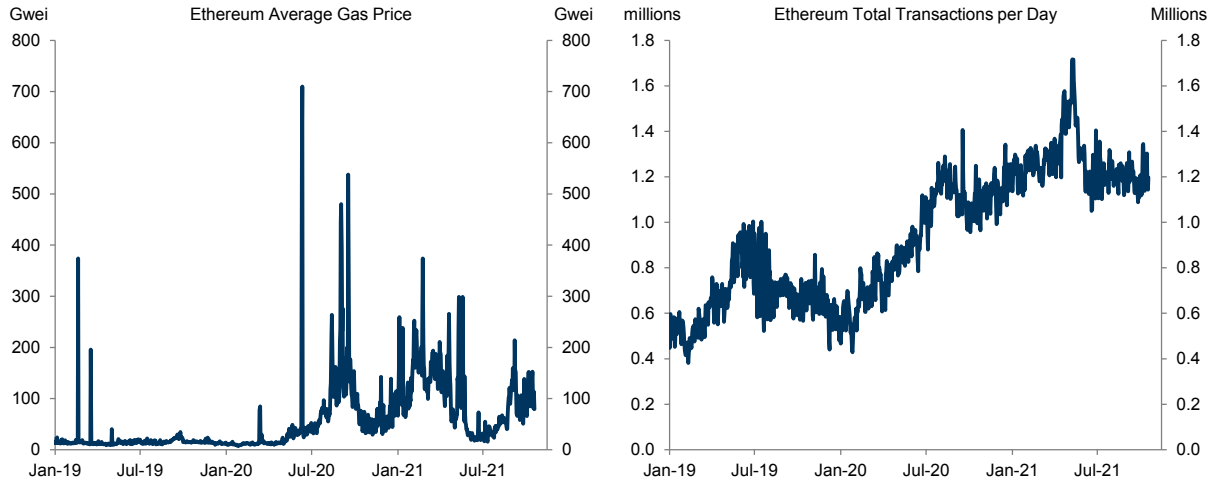
DeFi activity can also indirectly create value for the native asset of the smart contract blockchain due to network effects and transaction fees—the same goes for other blockchain activity like gaming or purchases of NFTs. Every blockchain transaction requires a fee which compensates miners or stakers for securing the network (in addition to block rewards). These fees are paid in the blockchain's native asset: ETH for Ethereum, SOL for Solana, AVAX for Avalanche, etc. In the case of Ethereum, transaction costs are known as "gas" and are denominated in gwei, which is a small fractional unit of ETH.[11] There is also a distinct gas price, denominated in gwei, which fluctuates based on network activity and therefore regulates network congestion (Exhibit 11, left panel). Each blockchain operation—sending ETH between addresses,

[10] Not all DeFi protocols are structured as DAOs, and in practice the degree of decentralization differs.

[11] Specifically, 10^{-9} ETH.

borrowing from Aave, etc—taxes the network by a certain amount and has an associated gas cost which rises with complexity. The cost of any transaction is equal to the product of the operation-specific gas cost and the network price of gas at the time.[12] Therefore, rising DeFi activity will tend to drive up the price of gas, generating more demand for ETH to pay transaction costs (Exhibit 11, right panel). In this way, the native asset of a smart contract blockchain will tend to benefit when network activity rises.

Exhibit 11: DeFi Activity Indirectly Affects Blockchain's Native Token through Transaction Fees



Source: Etherscan, Coin Metrics, Goldman Sachs Global Investment Research

TradFi 2.0

Innovation in the DeFi ecosystem moves extremely fast, and market focus has recently moved beyond established protocols like Aave and Uniswap to newer projects such as Olympus DAO and Alchemix Finance—a set of protocols dubbed "DeFi 2.0". But from the standpoint of the broader financial system DeFi is still a relatively small market segment and a suite of very new technologies. In light of risks from hacking and protocol bugs, and the need for users to secure custody of their own assets, broader public adoption is likely still some way off. Developers may need to create new mechanisms for unsecured lending in order to make inroads into more areas of traditional finance, and greater regulatory oversight seems inevitable, which could slow the industry's development. Nonetheless, the many innovations in decentralized finance point to avenues through which related technology might disrupt or be adopted by the existing financial system. They also demonstrate a compelling use case for blockchains and cryptocurrency technology that should help support market valuations for these assets over time.

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[12] Technically the product of the gas units and a base fee plus a "tip" which serves to prioritize transactions.

Disclosure Appendix

Reg AC

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