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PERSPECTIVE

International business and decentralized finance

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Abstract
Over the last decade, the green shoots of a new economic order have emerged as decentralized technologies challenge traditional financial systems. Decentralized finance (DeFi) holds the potential to transform international business (IB) by offering accessible financial services across borders, disrupting traditional intermediaries, and promoting financial inclusion. While traditional fintech has challenged banks, DeFi operates outside legacy systems, leveraging blockchain technology and smart contracting to introduce a new range of products and services that provide first-movers with an upper hand to both expand their business across the globe as well realize cost savings on existing business. Despite offering advantages like efficiency, transparency, and security, DeFi faces regulatory uncertainties and scalability, adoption, and stability concerns. Our study explores how DeFi can seamlessly integrate into the IB space while addressing these challenges. In addition to offering insights for investors, multinational firms, and regulators, we also lay the groundwork for future IB research in the fintech domain. As the DeFi innovation unfolds, understanding and harnessing its potential can empower stakeholders to engage responsibly and effectively in this transformative landscape.

Keywords International business · DeFi · Fintech · Smart contracts · Blockchain · Financial innovation · Regulation

> *"I believe that DeFi will create a new, easy-to-use and globally accessible financial system for the world."*
>
> – Vitalik Buterin (Ethereum Founder).[1]

Introduction

Decentralized finance (DeFi) stands poised to disrupt international business (IB) by providing accessible and efficient financial services across borders whose far-reaching institutional implications should be analyzed. DeFi platforms offer the potential for financial inclusion by eliminating traditional intermediaries, enabling individuals in underserved regions to participate in global economic activities. Additionally, decentralized exchanges, smart contracts, and novel funding avenues may empower businesses' and entrepreneurs' ability to strategically compete globally. However, regulatory uncertainties and the need for robust security and compliance measures present challenges. Our study lays the groundwork for a deeper understanding of how DeFi can seamlessly integrate into the international business landscape in harmony with the growing need for IB research on current technological developments (Buckley et al. 2017; Meyer et al. 2023; Tung, 2023).

New financial technologies have provided some nascent competition to our global banking system (John et al. 2022; Makarov & Schoar, 2022b). Fintech takes many forms, including electronic banking, domestic and cross-border payment mechanisms, and peer-to-peer lending. For example, within two and a half years of its introduction, over 140 million individuals (roughly 80% of the adult population) and 13 million businesses have utilized the Pix system in Brazil (IMF, 2023). Fintech innovations have reduced costs and increased efficiency, which is good for consumers and for economic growth. Further, they have forced traditional banks to innovate. However, these new financial

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[1] Excerpt from the preface of *DeFi and the Future of Finance* by (e.g., Harvey, Ramachandran, and Santoro (2021)).

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technologies have one commonality: they use the traditional financial infrastructure. As such, there is a limit as to how much costs can be reduced, and the limitation is directly related to the legacy infrastructure.

While fintech companies are disrupting traditional banks, another wave of disruption is on the horizon: decentralized finance or just DeFi. In contrast to most fintech, DeFi does not use legacy infrastructure. All transactions appear in a shared ledger called a blockchain. Thousands of identical copies of this immutable ledger reside on computers worldwide, providing a fully automatic back office. DeFi offers unprecedented efficiency, financial inclusion (you do not need a bank account), and heightened security. It presents a new frontier for international business.

In its simplest form, DeFi is a peer-to-peer method of exchange often enabled by algorithms. For example, suppose you hold asset A – which might be in a U.S. dollar pegged stablecoin – and want to purchase asset B. In a decentralized exchange (DEX), an algorithm will facilitate trade (e.g., Lehar & Parlour, 2022a). The algorithm is open-source, and anyone can see the liquidity and the expected transaction price. No one controls the algorithm. The algorithm does not care if you are a buyer or seller and is available 24/7. This algorithm is called a smart contract in the parlance of DeFi. The transaction record is written to an immutable ledger called a blockchain. This type of transaction contrasts sharply with the current system of brokers, execution brokers, market makers, Depository Trust and Clearing Corporation, and so on. DeFi has no middle layer, human market maker, or centralized exchange.

The potential for cost reduction within the legacy centralized financial infrastructure is limited. While traditional financial institutions currently face challenges from fintech firms, they will eventually face competition from DeFi.

Many misperceptions exist about DeFi. Importantly, DeFi is not just about trading cryptocurrencies. DeFi has many dimensions, including the enablement of web3 applications. For example, think of renting out your CPU overnight and being paid in a token or using a token to purchase computing time in a decentralized network. Web3 innovation poses a threat to most of today's most valuable companies. The impact of DeFi goes well beyond finance.

The integration of financial markets across national boundaries, regionally and globally, carries significant implications. For instance, the African Continental Free Trade Area (AfCFTA) is a significant step toward economic integration in developing economies. To this end, the emergence of DeFi represents a promising frontier in international financial market integration that extends its benefits beyond advanced economies to include low-income countries. Considering the reliance on centralized systems, exploring DeFi's role in this context becomes essential. By leveraging DeFi's decentralized nature, cross-border activities can be facilitated with increased accessibility, efficiency, and cost-effectiveness while decreasing exposure to centralized financial and political risks (see Kobrin, 1979 for a discussion on political risks). This transformation may lead to more diverse firm choices and foster entrepreneurial opportunities across borders, ultimately contributing to broader economic growth and financial inclusion worldwide (e.g., Allen et al. 2021).

In this study, we aim to examine the implications for international business posed by the emergence of DeFi, focusing on its advantages, challenges, and risks. We analyze the DeFi landscape to provide potential investors, multinational firms, entrepreneurs, regulators, and other stakeholders' valuable insights to navigate this dynamic new field. The revolution of fintech has begun, and through this study, we hope to equip you with the knowledge necessary to interact in this new frontier responsibly and effectively.

The DeFi market

Evolution

The DeFi market gained significant traction in 2018, with the launch of the decentralized exchange Uniswap and the subsequent rise of other decentralized applications built on Ethereum, such as lending platforms and yield farming. This phase was characterized by innovation, as developers experimented with new financial primitives and sought to replicate traditional financial services using blockchain technology.

Through early 2021, the DeFi market experienced exponential growth. As depicted in Fig. 1, the total value locked (TVL) in DeFi protocols skyrocketed, reaching almost $200 billion by the end of 2021.[2] The introduction of automated market makers such as Uniswap and decentralized lending platforms such as Compound significantly expanded the market. Yield farming, when users provide liquidity and earn fees and governance tokens as rewards, became popular, attracting investors and speculators (Augustin et al. 2022).

The DeFi market also faced periods of high volatility and market corrections. In mid-2020, a series of exploits highlighted the vulnerabilities of early DeFi protocols. These incidents, such as the bZx attack, exposed weaknesses in smart contracts and liquidity pools, leading to significant

[2] Total value locked (TVL) refers to the cumulative value of all assets deposited in a decentralized finance protocol that contributes to its economic activity. This activity encompasses a range of operations, including lending, borrowing, economic provision, asset management, and insurance. Essentially, TVL constitutes the aggregate of all DeFi protocol assets that accrue rewards, interest, new coins and tokens, fixed income, and so forth.

Fig. 1 Total market liquidity: This figure depicts the evolution of total market liquidity expressed in billions of US dollars of total value locked. Data source: https://defillama.com/

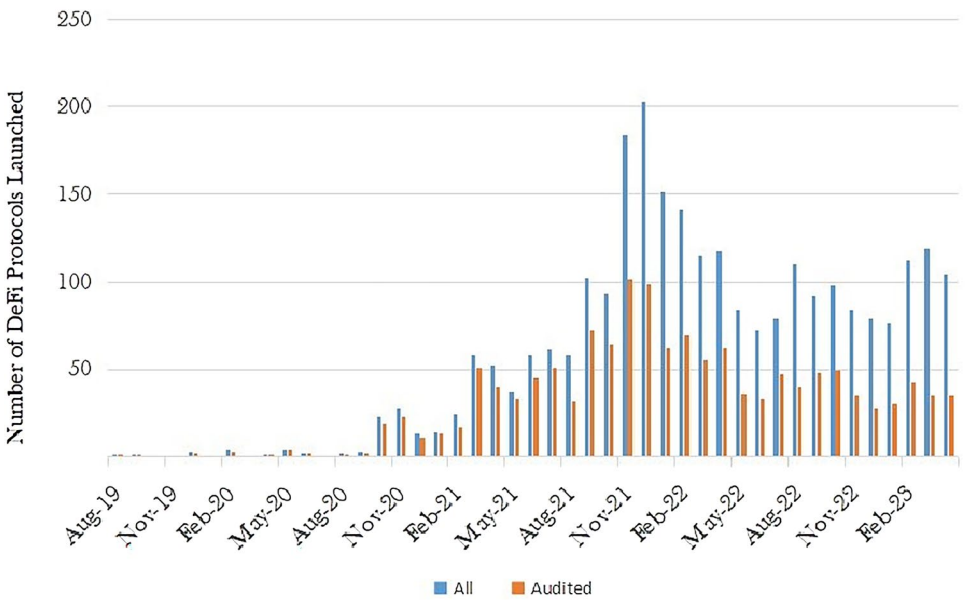

Fig. 2 Evolution of audited protocols: This figure depicts the launch of DeFi protocols over time. *Blue bars* represent the number of DeFi protocols launched per month. *Orange bars* represent the proportion of audited protocols (e.g., with code revisions). Courtesy: Landsman et al. (2024)

user losses. These events prompted developers to improve security measures and implement audits.

Auditing in decentralized finance involves a process in which specialized firms, such as Haken, TrailBits, and Certik, examine smart contract code to identify potential weaknesses, bugs, or security vulnerabilities that malicious actors could exploit. By conducting these audits, these firms can suggest code revisions and improvements to fix the identified vulnerabilities and enhance the overall security of the DeFi applications.[3]

Figure 2 illustrates the evolution of DeFi protocols and the proportion of audited protocols over time. The blue bars indicate the number of DeFi protocols launched, offering insights into the growth and adoption of DeFi over time.

[3] See "Smart contract risk" section for a detailed description of auditing services.

The orange bars represent the proportion of audited protocols, highlighting the subset of DeFi protocols that have undergone code revisions – protocols less likely to have vulnerabilities.

Another important driver of DeFi market growth is the increasing use of decentralized exchanges (DEXs). DEXs emerged as a key component of the DeFi market, allowing users to trade cryptocurrencies directly from their wallets without relying on centralized intermediaries. DEXs such as Uniswap, SushiSwap, and PancakeSwap gained significant popularity, attracting large trading volumes and liquidity. For example, to date, Uniswap has traded over $2 trillion in value. The rise of DEXs contributed to the growth of decentralized trading and the concept of permissionless financial transactions.

As the popularity of DeFi increased, scalability and high transaction fees on the Ethereum network became pressing issues. Various Layer 2 solutions, such as Optimistic Rollups and Zero-Knowledge Rollups, emerged to address these challenges. These Layer 2 solutions aimed to enhance scalability, reduce transaction costs, and improve user experience, enabling DeFi protocols to handle more transactions. With the growth of different blockchain networks, efforts to achieve crosschain interoperability gained momentum. Projects such as Wormhole and Layer Zero aimed to establish bridges between different blockchain ecosystems, enabling seamless transfer of assets and data across networks. Crosschain interoperability is expected to enhance DeFi's scalability and expand its reach to other blockchain networks.

As DeFi gained prominence, regulators worldwide started paying closer attention to the sector. Regulators sought to ensure compliance with existing financial regulations, particularly regarding know-your-customer and anti-money-laundering requirements.

While regulators can target centralized exchanges such as Coinbase, Kraken, Binance, and FTX with regulatory enforcement actions, dealing with decentralized protocols is much more challenging. These protocols are just algorithms. How does a regulator serve an algorithm with, for example, a Wells Notice, given that the algorithm exists on thousands of computers worldwide.[4] Nevertheless, regulators are actively investigating how they can regulate decentralized protocols.

Summary statistics

We now describe the market by providing an overall anatomy of its current state. Table 1 depicts updated summary statistics of 2793 DeFi protocols spanning 32 DeFi categories as of May 2023.[5] DEXs make up 31% of the DeFi sector and are among the most significant contributors to its growth. They represent a new type of cryptocurrency exchange, allowing direct peer-to-pool trading without an intermediary. Unlike traditional exchanges that require users to deposit funds into a broker account, users can simply connect their wallets and trade instantly.

Yield farming protocols, Finance, account for 15% of the DeFi industry. Yield farming is an investment strategy in which users "farm" tokens by lending or staking cryptocurrencies in a DeFi market to earn high returns or rewards, often in additional cryptocurrency. Yield farmers typically hop between different protocols to maximize their returns, making it an active investment strategy.

Lending platforms, such as Aave, Compound, and MakerDAO, make up 9% of the DeFi space. These platforms operate similarly to banks, providing loans to users who provide crypto assets as collateral. However, unlike traditional banks, these platforms operate decentralized, without intermediaries, and all loans are overcollateralized. They also often offer higher interest rates than traditional financial institutions.

Regarding market capitalization (i.e., total tokens in circulation times their price), DEXs lead with $9.4 billion, followed by bridge ($5.6 billion) and liquid staking ($3.2 billion) protocols. Bridge protocols in DeFi facilitate the transfer of assets between different blockchain networks.[6] Liquid staking protocols enable users to earn staking rewards while maintaining the liquidity of their staked assets.[7]

While market capitalization offers a comprehensive overview of the total value of tokens across various sectors, it is not widely utilized to assess the intrinsic value of DeFi protocols due to its limited scope, primarily focusing on protocols with listed tokens – constituting less than 30% of the market. As an alternative, market participants often turn to

[4] In April 2024, the SEC served a Wells Notice to Uniswap Labs. This had no impact on the functionality of any of the Uniswap decentralized exchanges. Uniswap Labs is funded by the Uniswap DAO and conducts research and offers enhancements to the DEX trading algorithms.

[5] See "Appendix" for a detailed description of each DeFi category.

[6] They enable interoperability by creating a bridge that connects isolated blockchains, allowing users to transfer tokens and assets across different networks. Bridge protocols enhance liquidity and expand the range of assets utilized within the DeFi ecosystem.

[7] Liquid staking protocols generate derivative tokens (often referred to as staked tokens) representing the staked assets – staking an asset means funds are escrowed in a smart contract to ensure users do not deviate from expected behavior. These derivative tokens can be freely traded and utilized within the DeFi ecosystem, enabling users to benefit from staking rewards while retaining the flexibility of using their assets for other purposes, such as lending or trading.

Table 1 DEFI categories: This table depicts the summary statistics of DeFi protocols bucketed into industries retrieved on May 2023

DeFi category	Protocols	Mcap ($ billions)	TVL ($ billions)	Governance (%)	Staking (%)	Chains (#)	Oracle (%)	Audits (#)
DEX	858	9.40	17.26	45	28	1.47	10	0.53
Yield	428	2.61	5.19	59	54	1.57	13	0.74
Lending	245	2.80	14.27	67	18	1.66	65	0.81
Reserve currency	120	0.29	0.01	14	93	1.09	6	0.15
Services	114	2.34	2.41	37	47	1.44	9	0.54
Derivatives	108	1.50	1.42	56	31	1.40	57	0.70
Algo-stables	106	0.57	0.27	35	82	1.26	32	0.39
Yield aggregator	99	0.54	1.24	59	39	2.30	25	0.69
Liquid staking	91	3.24	19.02	59	13	1.48	7	0.76
CDP	89	1.08	9.88	61	20	1.49	53	0.71
Farm	69	0.01	0.02	33	84	1.13	4	0.36
Indexes	46	0.09	0.60	63	30	1.43	37	0.78
Bridge	43	5.57	10.86	56	9	8.84	12	0.79
Options	39	0.14	0.13	72	23	1.90	54	0.87
Launchpad	35	0.56	0.65	66	60	2.66	14	0.74
Gaming	34	1.39	0.00	47	71	1.41	6	0.65
Synthetics	33	0.83	0.64	67	27	1.42	55	0.73
Prediction market	28	0.08	0.02	54	32	1.57	39	0.71
NFT marketplace	25	0.35	0.18	32	24	1.24	0	0.44
Cross chain	24	0.28	0.67	63	25	6.13	7	0.88
Insurance	24	0.37	0.34	88	38	2.17	33	1.33
NFT lending	21	0.04	0.33	52	29	1.29	43	0.76
Liquidity manager	20	0.04	0.38	70	35	3.10	25	0.85
Real World Assets (RWA)	16	0.01	0.36	56	19	1.31	19	0.75
Options vault	15	0.01	0.08	60	13	1.87	60	0.53
Leveraged farming	13	0.04	0.26	77	23	1.23	31	1.38
Payments	13	0.27	0.22	54	15	3.46	8	0.62
Privacy	12	0.04	0.32	42	25	2.00	8	0.50
Staking pool	10	0.04	0.07	30	10	1.40	0	0.30
Uncollateralized lending	7	0.11	0.01	86	43	1.57	0	1.00
Oracle	5	3.46	0.00	40	60	1.80	20	0.40
RWA lending	3	0.10	0.00	67	0	1.00	0	0.67
Total	2793	38.19	87.07	55	35	2.03	24	0.69

Protocols report the number of DeFi protocols per category. *Mcap* reports the average market capitalization (total tokens in circulation times their price) in a given category expressed in billions of USD. *TVL* reports the average total value locked in a given category expressed in billions of USD. It proxies for economic activity, measuring the value of all assets passing through a smart contract in dollars. *Governance* reports the average number of DeFi protocols with open governance through DAO (decentralized autonomous organization) in a given category. *Staking* reports the average number of DeFi protocols with active staking in a given category. Staking occurs when users can lock up their digital assets in a staking contract to receive staking rewards (passive income). *Chains* reports the average number of listed chains per DeFi protocol in a given category. *Oracle* reports the average number of DeFi protocols integrated with an oracle in a given category. Oracles act as bridges, facilitating connections between on-chain and off-chain data sources. For instance, retrieving real-time data from various sources, such as price feeds, to enable DeFi lending applications. *Audits* reports the average number of audits per DeFi protocol in a given category. Data source: https://defillama.com/.

the metric of total value locked (TVL), encompassing all assets currently held within a protocol. The highest TVL is observed in the liquid staking category at $19.0 billion, followed by decentralized exchanges (DEXs) at $17.3 billion, lending at $14.3 billion, and bridges at $10.9 billion. The total market averaged about $90 billion this year.[8]

[8] All data as of May 2023

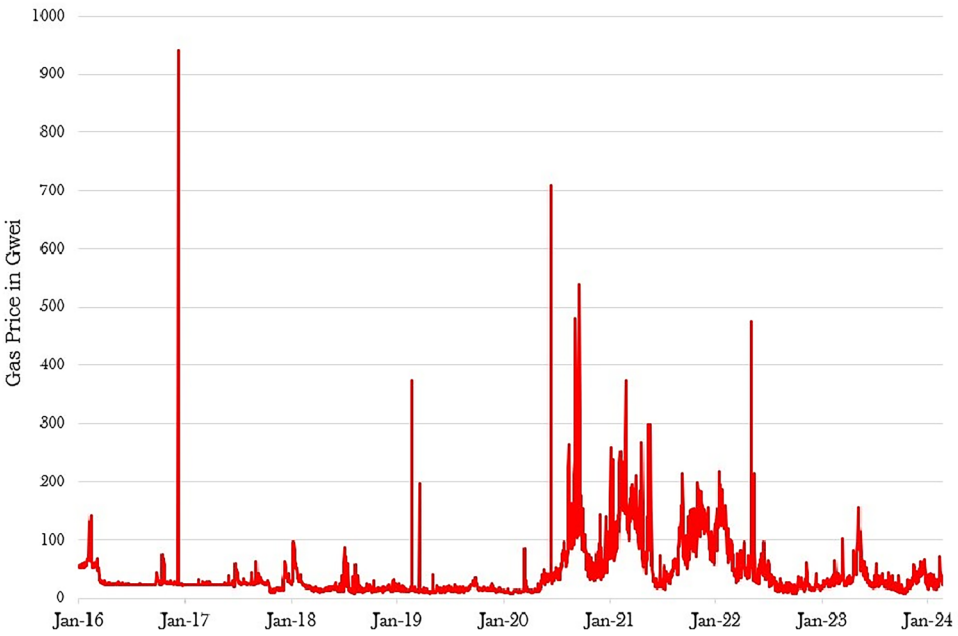

Fig. 3 ETH gas cost: This figure depicts the evolution of Ethereum's gas cost (transaction fees) expressed in Gwei (1 Gwei is equal to 1 billionth of Ether). If, for example, you pay 0.000000100 ETH as a transaction fee, you would say the cost was 100 Gwei. Data source: https://etherscan.io/chart/gasprice

The advantages of DeFi

DeFi is gradually gaining momentum in the financial sector, introducing several possibilities for consumers and businesses. This innovative space is characterized by numerous notable advantages that promise to redefine how we interact with financial systems. In the following sections, we explore eight key benefits that set DeFi apart from traditional financial systems: facilitation of peer-to-peer transactions, interoperability, transparency, public accessibility, potential for financial inclusion, programmability, integration capabilities, and unrestricted access to markets that operate around the clock. These elements contribute to DeFi's transformative potential in the international business landscape.

Lower fees

High fees have always been a persistent pain point in traditional financial services (Beck et al. 2008). The traditional banking system and financial services industry involve many intermediaries. Every time a transaction occurs, several entities, such as the bank, payment processors, and sometimes even third-party financial institutions, must approve it, each taking its cut in the form of fees or commissions. Additionally, these institutions incur significant operational costs related to personnel, real estate, regulatory compliance, and other administrative expenditures. These costs are ultimately passed on to consumers through fees, which are a heavy burden to international businesses.

DeFi is set to disrupt this aspect by drastically reducing transaction costs (Harvey et al. 2021; Makarov & Schoar, 2022b). Instead of relying on intermediaries, DeFi operates based on pre-programmed algorithms, or smart contracts, which execute transactions automatically once certain conditions are met. This characteristic makes the process faster and significantly reduces costs because an intermediary is unnecessary.

In DeFi, transactions are made directly between peers (peer-to-pool), thereby eliminating the need for intermediaries and their associated costs (Capponi et al. 2023). A good example is a DeFi exchange, also known as a DEX. In a DEX, such as Uniswap or SushiSwap, traders transact directly with each other guided by smart contracts, without a broker or a human market maker. The fees involved are usually the DEX transaction fee and the network transaction fee (known as "gas" on Ethereum), which are typically much lower than the commission charged by a traditional exchange.

Figure 3 shows the evolution of gas fees. In DeFi, you must pay a fee to run an algorithm in the Ethereum blockchain, analogous to paying to run a computer program in a popular cloud computing platform. Each program has a certain number of operations denoted as gas.

This direct, peer-to-peer interaction leads to greater efficiency and lower fees, which is one of the key advantages of DeFi over traditional financial systems. Notably, lower fees make financial services more accessible to a wider range of people, especially those in developing regions where traditional banking fees can be prohibitive. Thus, DeFi can potentially foster financial inclusion on a global scale (e.g.,

Harvey et al. 2021; Popescu, 2022). For businesses, the benefits are obvious. Value can be transferred nearly instantly anywhere in the world at a low cost without the fees associated with the current banking system.

One area in which the benefits of DeFi on international business are visible is cross-border transactions. By operating on blockchain networks and smart contracts, DeFi platforms provide greater transparency, immutability, and real-time transaction settlement, reducing the risks of fraud, manipulation, and counterparty default on cross-border transactions. Additionally, DeFi enables borderless access to financial services, allowing users from different countries to participate in a global financial ecosystem without facing the same level of regulatory hurdles and restrictions typically encountered in traditional cross-border transactions. This aspect of DeFi can foster greater financial inclusion and participation, especially in regions with limited access to traditional banking services. More research examining the implications of innovation in this space is necessary to evaluate the effectiveness of DeFi in addressing cross-border transaction issues.

Currency risk exposure

International businesses face various challenges in managing currency risk and hedging strategies within traditional financial systems (e.g., Demirag, 1988; Pantzalis & Laux, 2001; Batra et al. 2017). The volatility of exchange rates and the complexity of existing hedging instruments can create friction in cross-border transactions. In exploring the potential impact of decentralized finance (DeFi) on these challenges, it becomes essential to evaluate how DeFi may offer innovative solutions in the realms of currency risk exposure and hedging.

Traditional hedging against currency risk often involves using complex financial instruments, such as futures and options, traded on traditional markets. These instruments may require engagement with financial institutions, adding layers of complexity to the hedging process. DeFi introduces the potential for decentralized financial instruments and protocols that streamline and democratize the hedging process. Smart contracts on DeFi platforms can enable businesses to create and execute programmable, automated hedging strategies directly on a blockchain. This reduces reliance on intermediaries and enhances accessibility, allowing a broader range of businesses to engage in effective currency risk management within the decentralized financial ecosystem. Moreover, pricing output in tokens may provide firms with a first-mover advantage, potentially raising its equilibrium profit (e.g., Chod & Lyandres, 2023; Shakhnov And Zaccaria, 2023).

As international businesses navigate the challenges of currency risk and hedging, the emergence of DeFi offers promising solutions. For instance, by leveraging decentralized stablecoins and innovative smart contract capabilities, businesses can potentially enhance the predictability and efficiency of cross-border transactions. We encourage IB researchers to evaluate the pros and cons of employing a single currency or a form of cryptocurrency for international business transactions and its potential impact on exchange rate expenses and exposure to exchange rate risks.

Transparency

A significant advantage of DeFi is its inherent transparency, a trait it derives from its foundation, blockchain technology (Nakamoto, 2008). In traditional finance, operations are often opaque and rely heavily on government regulators to monitor and detect potential discrepancies or illicit activities. This system has proven flawed at times when regulators have failed to adequately supervise financial activities, leading to the failure of financial institutions, financial fraud, or market manipulation.

In contrast, DeFi's transparency helps rectify this problem and accelerates innovation. DeFi protocols are built on open-source code that anyone can inspect and audit, which fosters a level of trust and transparency unparalleled in traditional financial systems, revealing the quality of the platform (Lyandres et al. 2022) and helping firms overcome contractual incompleteness (Chen et al. 2023). Moreover, if someone has an idea to improve a particular protocol, they can freely access and build upon the existing code, leading to rapid enhancements and iterations. This open-source ethos accelerates the development cycle, and a new protocol or an enhancement to an existing one could be launched within days.

Blockchain's transparent nature also enables forensic analysis of transactions (Cong et al. 2022; Foley et al. 2019). This feature, known as blockchain forensics, allows analysts to track and study transaction patterns, identify anomalous behavior, and investigate potential illicit activities (Amiram et al. 2022; Griffin & Shams, 2020; Makarov & Schoar, 2022a; Sokolov, 2021). This capability has proven invaluable when tracing transactions and funds is crucial, such as detecting money laundering or tracking stolen funds (Cong et al., 2023).

Figure 4 illustrates an example of a case of blockchain forensics conducted by Chainlysis, a reputable blockchain data analytics firm, concerning the ransomware attack on the Colonial Pipeline (Cong et al., 2023). The figure provides a visual representation of how blockchain forensic analysts traced the path of 75 BTCs (equivalent to approximately $5 million) that was paid as ransom by Colonial Pipeline. Through meticulous tracking of the Bitcoin blockchain, the FBI successfully recovered approximately 60% of the ransom payments. Additionally, the figure depicts the payment

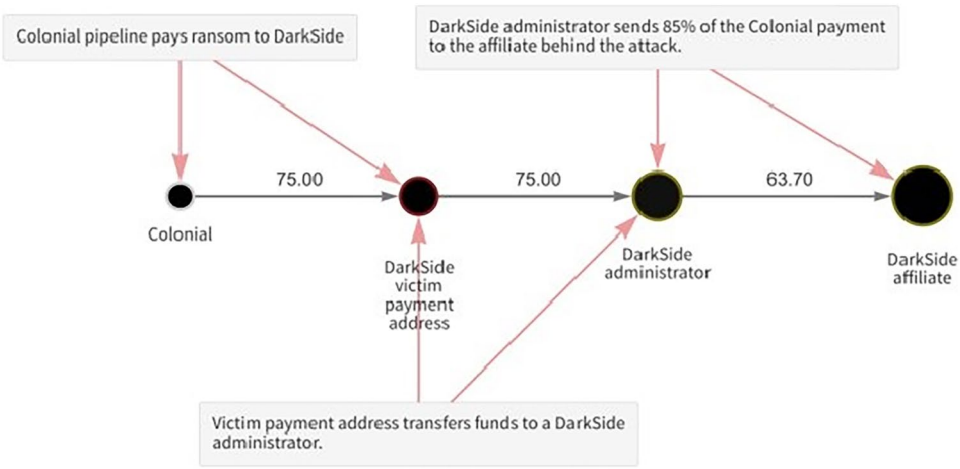

Fig. 4 Blockchain forensics analysis: This figure depicts Chainlysis's blockchain forensic analysis in the case of Colonial Pipeline's ransomware attack. The figure shows the trail of 75 BTCs paid as ransom. The diagram also shows how the Darkside, as Ransomware-as-a-Service (RaaS), malware provider cashes 15% of the payment, while the remaining 85% goes to an affiliate wallet (the entity responsible for the attack). Courtesy: Cong et al. (2023)

distribution, highlighting how a portion of it served as a fee for DarkSide, the malware provider responsible for offering Ransomware-as-a-Service, while the remaining payment went to the affiliate responsible for carrying out the attack.

Another advantage of blockchain transparency is that it can be harnessed to enhance regulatory compliance within DeFi. While the principle of anonymity is cherished in the crypto world, some protocols explore the enforcement of know-your-customer and anti-money laundering regulations. Enforcing these regulations could help build trust with regulators and open the door for the increased institutional adoption of DeFi.

Thus, the inherent transparency in DeFi not only fosters trust and accountability, but also enables innovation, facilitates forensic investigation, and could potentially enhance regulatory compliance. IB research has focused on multinationals' ability to improve operational efficiency (Benito et al. 2009), reduce costs (Akamah et al. 2017), and attract foreign investments (Cannizzaro & Weiner, 2018). In this context, future research could assess the impact of blockchain transparency on multinationals.

Public accessibility

DeFi applications are built on public blockchains, offering unrestricted, permissionless access to financial services. This feature alters the financial landscape by removing the need for approval from centralized authorities and by opening up global financial markets to anyone with Internet access. For example, an entrepreneur in a remote region of the world can now directly borrow funds from a DeFi lending platform such as Compound or Aave, circumventing the traditional, often restrictive banking system. Moreover, with limits to financial access and regulatory barriers to raising traditional capital, tokens may be able to finance a strictly larger set of ventures than traditional equity (Malinova & Park, 2023).

The public nature of the blockchain also allows external entities, such as regulatory agencies and researchers, to analyze the data. This transparency can be instrumental for regulatory bodies in monitoring the market, enforcing compliance, and detecting illicit activities. Similarly, researchers can study transaction patterns, investigate market dynamics, and gain insights into user behavior, all contributing to an improved understanding and further development of the DeFi ecosystem.

By operating on a public blockchain, DeFi democratizes access to financial services and opens up avenues for transparent analysis and inspection of financial transactions, paving the way for a new era in the financial industry characterized by inclusivity, transparency, efficiency, and innovation. IB research has dedicated significant resources to unraveling strategic competitiveness for private, public, and state-owned firms (e.g., Boellis et al., 2016; Choudhury & Khanna, 2014; Meyer et al. 2014).[9] Future research might explore the ramifications of public accessibility on blockchain-based applications for firms' competitiveness in the international arena.

Interoperability

Decentralized applications (dApps) in DeFi have the unique advantage of being interoperable, meaning they can operate seamlessly across different protocols. For example, imagine a scenario where you can buy a token on one DEX and sell it on another in the same transaction. In traditional finance, such an event could never happen because transferring funds between entities such as brokers and banks can be cumbersome and takes several days to complete. In the DeFi

[9] See also Birkinshaw and Morrison (1995), Filatotchev et al. (2008), Jackson and Deeg (2008), and Meyer et al. (2014).

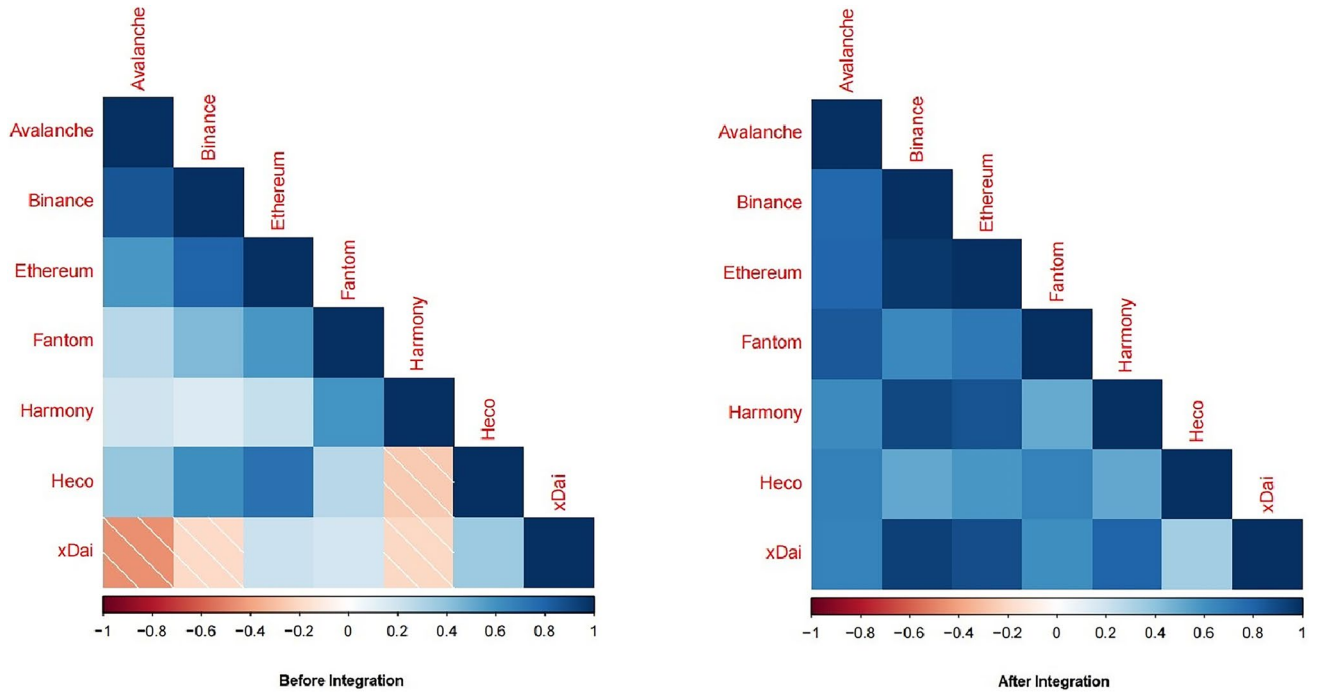

Fig. 5 Interoperability effects: This figure depicts interoperability effects (measured as TVL correlations) for the young chain Avalanche before and after enabling cross-chain capabilities (via oracle integration). Correlations range from -1 (*red*) to +1 (*blue*). Each *square* measures the TVL correlation between blockchains before (*left side*) and after (*right side*) Avalanche oracle integration. Courtesy: Cong et al. (2023)

ecosystem, transactions are processed instantaneously, often in seconds or minutes, promoting efficiency and ease of use.

Another aspect of interoperability is the emergence of cross-chain applications, which allow the transfer of assets and data across different blockchain networks (Schulte et al. (2019)). Traditionally, blockchain networks have operated in isolation, but cross-chain technology breaks down these barriers and allows seamless interactions. For example, a user might want to use a lending platform on the Ethereum blockchain while holding assets on the Binance Smart Chain. Crosschain solutions facilitate such preferences, ensuring users can interact with the full spectrum of DeFi applications, regardless of the blockchain they operate on.

On another front, oracles are crucial in enhancing interoperability within DeFi. Oracles provide smart contracts with data from outside the native blockchain. Doing so enables dApps to react to real-world events and conditions, enhancing their functionality and utility. For instance, a decentralized insurance platform might rely on an oracle to provide real-time weather data to settle claims related to weather events. Using oracles extends the interoperability of dApps, allowing them to interact with other applications in the DeFi space and the world of traditional finance.

In Fig. 5, the interoperability effects, measured as total value locked (TVL) correlations, are illustrated for the nascent Avalanche blockchain both before and after the implementation of cross-chain capabilities facilitated through oracle integration. The correlations between Avalanche's TVL and other blockchains exhibit a shift towards more positive values (indicated by dark blue hues) following the integration of oracles. This trend suggests that the incorporation of oracles fosters increased synergies among different chains, particularly as the mass of integrated decentralized finance (DeFi) protocols grows within a given blockchain (Cong, Prasad, et al. 2023).

Thus, through features such as cross-chain applications and oracles, the interoperability inherent to DeFi enhances its efficiency, flexibility, and usability, surpassing traditional financial systems' capabilities. It allows transactions to occur swiftly and seamlessly, enabling financial innovation and accessibility unprecedented in traditional finance.

Composability

The open-access and integrable nature of most DeFi applications sets them apart from their traditional finance counterparts. Traditional finance systems typically operate in silos, so that each bank or financial institution has a proprietary infrastructure, which often does not communicate well with other systems. This structure results in inefficient processes,

such as delayed bank transfers and limited ability to create innovative, cross-platform financial products. In contrast, DeFi applications typically follow standard protocols and are constructed using open-source software. Openness allows anyone to audit the underlying code, fostering trust through transparency. It also facilitates ease of integration or interoperability among different DeFi services, leading to an innovative concept known as "composability" or "money legos."

Composability is the ability to seamlessly connect different DeFi protocols to build new financial products or services and is akin to combining different Lego blocks to create a unique structure. This level of interoperability and integration is unprecedented in traditional finance. For example, consider the composability of two distinct DeFi protocols: Compound and MakerDAO. Users can put their tokens, like Circle's stablecoin USDC, into Compound, a lending platform, to earn interest. In return, they get an equity token called cToken, which can be deployed to another pool and earns interest. Now, these cTokens may also be used as collateral in MakerDAO to get a loan in the form of DAI, a decentralized stablecoin linked to the US dollar. This smooth connection between two protocols, creating a new financial service, shows the strength of composability and the creative possibilities in the DeFi world.

The main difference between interoperability and composability lies in their respective focus. Interoperability enables seamless interaction between existing protocols or platforms, facilitating the movement of assets and data across different networks. Composability combines and integrates different smart contracts or protocols to build novel financial applications or strategies.

Furthermore, this composable nature of DeFi not only enhances efficiency but fosters a highly competitive and innovative ecosystem, encouraging continuous improvement and development. As DeFi applications continue to be built and integrated, the possibilities for innovative financial products and services are seemingly endless, potentially transforming the entire financial sector.

Programmability

While composability refers to the seamless integration and combination of different decentralized applications (DApps)[10] and financial protocols, allowing developers to create more complex and interconnected financial products. Programmability relates to the capability of writing and executing custom code, typically in the form of smart contracts, to automate specific financial operations. A key facet of DeFi lies in its ability to harness the programmable nature of blockchain technology, which allows developers to code and create diverse financial instruments. This programmability has led to significant innovation and is one of the main factors setting DeFi apart from traditional finance.

Traditional finance tends to be rigid due to regulatory constraints and the limitations of physical, centralized systems. New financial products or services in traditional finance often need to go through complex processes of design, compliance checks, and regulatory approval before they can be launched, making innovation in traditional finance slower and more constrained compared to DeFi.

In contrast, DeFi opens up significant opportunities for financial innovation, limited only by developers' imaginations and technical expertise. One prime example is the creation of synthetic assets, which can be found on platforms such as Synthetix. Synthetic assets are tokens that mirror the price of other assets, such as stocks, commodities, or other cryptocurrencies. Users can gain exposure to various markets, such as gold or Apple stocks, without owning the underlying assets. This concept is novel and offers unprecedented access to global markets.

Another innovative DeFi instrument is a flash loan, an innovation unique to DeFi and unfeasible in traditional finance. A flash loan is a loan with zero collateral, no credit checks, no interest rate, and zero duration. Flash loans allow users to borrow and return funds within a single transaction and are often used for arbitrage opportunities or swapping collateral on loans. The flash loan structure is possible because of the atomic nature of blockchain transactions, in which several operations can be executed at once or not at all, eliminating default risk. That is, if the borrower has insufficient funds to repay the loan, the entire transaction fails and reverts to the state before the loan was taken out.

Such developments are just the tip of the iceberg, illustrating the potential of DeFi to disrupt finance. By combining the principles of finance with the capabilities of blockchain, DeFi is reshaping the way we interact with money, creating a more open and inclusive financial system.

24/7 access to markets

The last, but certainly not the least, distinguishing factor between DeFi and traditional finance is the unceasing operation of DeFi markets. Traditional financial markets, such as stock exchanges and banks, usually operate within specific business hours, often from Monday to Friday, and are closed during weekends and holidays. As a result, the ability to transact, particularly across borders, can be slow and often takes several business days due to time zone differences and banking hours. In contrast, DeFi markets are operational 24/7, all year round. They are not constrained by traditional working hours or geographical locations. Further, DeFi has no settlement delay, so execution and settlement

[10] A dApp is an application not centrally controlled by a corporation or government. An example is the popular MetaMask wallet.

are instantaneous. This constant availability permits real-time trading and transactions, drastically reducing the time needed for fund transfers and settlements.

Another example of constant access is a decentralized exchange, such as Uniswap or Sushiswap. Traders from anywhere in the world can trade digital assets at any time. A DEX has no "market close" hours, no holidays, and no restrictions based on the trader's location. This access revolutionizes the trading experience, offering unparalleled convenience and speed.

The round-the-clock operation particularly transforms the dynamics of cross-border transactions. For instance, a user in Asia can instantly send funds to a user in America, regardless of the time. Such a transaction would traditionally take a few business days due to differences in time zones and the slower processing times of conventional banking systems. With DeFi, however, the transaction happens in real-time, increasing international commerce's speed and making financial operations more efficient.

In conclusion, the ceaseless operation of DeFi markets is a significant move forward in global financial systems, enhancing the efficiency, speed, and convenience of transactions. It provides a compelling illustration of how DeFi can disrupt and potentially redefine our understanding of financial systems.

Potential for financial inclusion

The potential for financial inclusion is another profound advantage the DeFi sector brings. Traditional banking systems have historically failed to adequately serve individuals in rural areas and those with lower incomes. For instance, a recent report by the World Bank estimates that more than 1.4 billion people worldwide remain unbanked.[11] Almost 6 million US households have no bank account.[12] The main causes behind this problem are the absence of physical banking infrastructure and the perceived risks associated with extending services to these segments of society.

DeFi, however, has the potential to alter the status quo completely. With DeFi, only an Internet connection and a smartphone are required to access a myriad of financial services, making physical infrastructure irrelevant. This universal access democratizes the financial landscape, allowing anyone, anywhere, to participate in the Internet-enabled economy.

For instance, consider an individual without a bank account, a common scenario in many developing nations. Such a person can still save and grow their funds using DeFi protocols. A platform such as Yearn.Finance, for example, provides a simple way to automatically earn deposit yields, all managed by a decentralized algorithm. The individual can deposit their crypto assets into Yearn.Finance's smart contract and earn interest over time, without needing a traditional bank account.

Similarly, DeFi lending platforms, such as Aave and Compound, allow users to earn interest by providing liquidity or to borrow funds by providing collateral without needing a credit check or a physical bank. This level of accessibility opens up new opportunities for individuals who have been underserved by the traditional banking system, providing them with a way to enhance their economic prospects and financial stability.

DeFi plays a pivotal role in enhancing financial access and has the potential to significantly promote financial inclusion, particularly in low-income economies. A prominent example of how innovation spurs financial inclusion is "Equity Bank," based in Kenya, which has attracted considerable attention for its commitment to improving financial access in the region. According to the bank's CEO, the percentage of the Kenyan population with bank accounts has risen from a mere 4% in 1994 to an impressive 90% today, showcasing the remarkable progress in increasing financial inclusion.[13] DeFi's involvement could further advance this inclusion by expanding the array of financial products and services accessible to customers in these underserved regions.

Researching DeFi's potential for financial inclusion is very promising, especially focusing on evaluating initiatives that promote economic growth and prosperity in underserved areas of the world.[14]

Implications to monetary policy

DeFi has several implications for monetary policy. First, the existence of new tokenized value of both crypto and real-world assets provides a challenge to central bank monopolies over fiat. It gives companies an alternative way to pay for items or receive payments. Second, DeFi speeds up the transfer process, increases security, and allows for transparency as all transactions are visible in the decentralized ledger. Third, DeFi provides another channel for financing businesses.

However, there are challenges as with any new technology. The inherent volatility of DeFi crypto-assets, regulatory uncertainties, and potential risks associated with smart

[11] See https://www.worldbank.org/en/news/feature/2022/07/21/covid-19-boosted-theadoption-of-digital-financial-services.

[12] See https://www.fdic.gov/analysis/household-survey/index.html.

[13] See https://www.theceomagazine.com/executive-interviews/finance-banking/james-mwangi/.

[14] IB researchers have been increasingly interested in financial inclusion issues (e.g., Allen et al., 2021; Ault, 2016; Bowen & De Clercq, 2008; London & Hart, 2004).

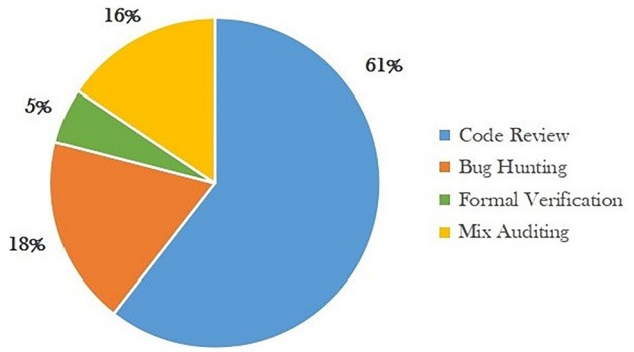

Fig. 6 Auditing: This figure depicts the distribution of auditing services including code reviews, formal verification, and bug hunting. Courtesy: Landsman et al. (2024)

contracts pose significant hurdles for governments seeking to integrate these systems into their economic strategies. Policymakers must carefully navigate these complexities to harness the benefits presented by DeFi while developing safeguards against potential risks.

Indeed, it is no surprise that many central banks have launched central bank digital currency (CBDC) initiatives. They likely had little choice because they needed to compete with blockchain technologies. It is likely that, in the future, cryptocurrencies and CBDCs (which are centralized currencies) will coexist (Chiu & Davoodalhosseini, 2023). Taxes will be paid in CBDC fiat and government employees will be paid in CBDC fiat. Other than that, consumers and businesses can choose a payment token.

DeFi risks

Naturally, any new technology involves risks and challenges. Complete elimination of risk is an unachievable goal – even the most secure investments, such as US Treasury bills, carry a certain degree of risk. DeFi, given its novel and complex nature, is not exempt from risk. This section explores several key risks associated with the adoption of DeFi in international business that require careful consideration.

Smart contract risk

Smart contracts, computer programs that execute transactions when pre-defined conditions are met, are susceptible to coding errors and bugs (Harvey et al., 2021). For example, errors in the business logic of a contract can lead to unintended consequences, such as in the infamous DAO hack in 2016, which led to the loss of about $60 million worth of ether due to a recursive-call vulnerability – also known as a reentrancy bug.

Risk mitigation strategies include rigorous testing, code reviews, audits, and automated tools to detect known vulnerabilities. Additionally, it is advisable to involve experienced developers or auditors who are well versed in smart contract development and its associated risks. Despite these precautions, the inherent complexity of smart contracts and their immutable nature, once deployed on the blockchain, pose significant challenges in ensuring flawless operation.

In response to the growing risks associated with smart contracts in DeFi, the need for auditing, formal verification, and bug hunting has significantly increased. These functions have become critical because smart contracts' autonomous and immutable nature requires that they operate flawlessly right from the deployment.

Figure 6 depicts the distribution of auditing methods across hundreds of audited DeFi protocols. The most popular auditing method is code review. Code review involves examining the smart contract code for potential vulnerabilities, security flaws, and logical errors. Auditors also assess the logic and implementation of the smart contracts to ensure they operate as intended and do not contain any hidden or malicious functionality. A code review aims to ensure the integrity and reliability of the DeFi protocol.

Formal verification is another crucial process gaining popularity in the DeFi space. It involves mathematically proving that a smart contract behaves as expected. Formal verification is a more rigorous process than regular auditing and can provide stronger guarantees about the correctness of a contract.

Finally, bug bounties have become common in the DeFi ecosystem (Landsman et al., 2024). A bug bounty usually involves the community detecting potential vulnerabilities in smart contracts. Many projects run bug bounty programs, rewarding individuals who find and report bugs in their code. Such programs have created a collaborative ecosystem in which developers and users work together to improve the security and reliability of DeFi protocols. An increasing portion of audited protocols uses a mix of these different methods, possibly resulting in a more complete auditing process.

Research in this space may investigate the relevance of auditing for market players, the presence of certification effects, the cross-section variation of auditing quality, and the economic impact of auditing on DeFi protocols' userbase and economic growth.

Governance risk

Decentralized governance is a fundamental aspect of DeFi, allowing participants to make decisions collectively and influence the direction of a protocol or platform, therefore having far-reaching implications for the corporate governance of multinational corporations (MNCs) implementing

Table 2 Governance proposals: This table depicts a sample of governance proposals across popular DeFi protocols as of February 2024

Name	Proposals	Successful proposals	Proposals in Jan 2024
1inch Network	55	44	3
Aave	538	498	36
Alchemix	126	119	4
Balancer	692	669	14
Curve Finance	203	12	0
Compound	175	134	6
Pancake Swap	3718	179	8
Uniswap	58	33	4
Venus Protocol	53	53	6

Data source: https://defillama.com/governance

DeFi technology to manage their operations efficiently (e.g., Benito et al., 2009). For MNCs, DeFi governance can reshape the landscape of global competitiveness (Aguilera et al. 2019), potentially diffusing decentralized governance practices across national borders (Cumming et al. 2017).

In the current form, DeFi's governance typically revolves around decentralized autonomous organizations (DAOs) or similar structures (Goldberg & Schar, 2023). Consistent with the conventional practice in traditional finance, a project's token holders possess voting rights commensurate with their token holdings, thereby participating in decision-making processes about the project's future (Kondova & Barba, 2019).

The risk of centralization could jeopardize the concept of decentralization (Ferreira et al. 2023). An example of this risk would be if a few significant token holders, known as "whales," exerted dominance over the decision-making process (Appel & Grennan, 2023; Han et al., 2023). Consequently, these whales might favor decisions that are advantageous to themselves but detrimental to smaller token holders or the wider community. Of course, this expropriation of stakeholders has a longstanding history in traditional finance.

Table 2 offers an overview of governance proposals across popular DeFi protocols. The table illustrates decentralized governance's inherent complexity and varying degrees of success. Interestingly, some protocols, such as *PancakeSwap*, *Curve*, and *ShibaSwap*, have the lowest success rates, perhaps reflecting the large degree of shareholder fragmentation among these DeFi applications.

Often, voter participation is low, with only a small percentage of token holders partaking in voting. Low participation can lead to decisions that do not necessarily reflect the majority's interests (Chohan, 2022). Several factors can contribute to low participation, such as a lack of incentives, complexity of the process, investors buying tokens for speculation and not caring about DAO, and sentiment among token holders that their vote will not make a significant impact.

Figure 7 illustrates the voting system of the decentralized lending protocol Compound. The process begins with the introduction of a proposal. Following its launch, the proposal undergoes a review by the community under Compound's governance guidelines. After the proposal is vetted, the voting phase commences. This stage can span several days or weeks until a quorum is achieved or the designated voting time frame elapses. Following the conclusion of the voting period, a decision is reached. If successful, the proposal then progresses to the implementation stage.

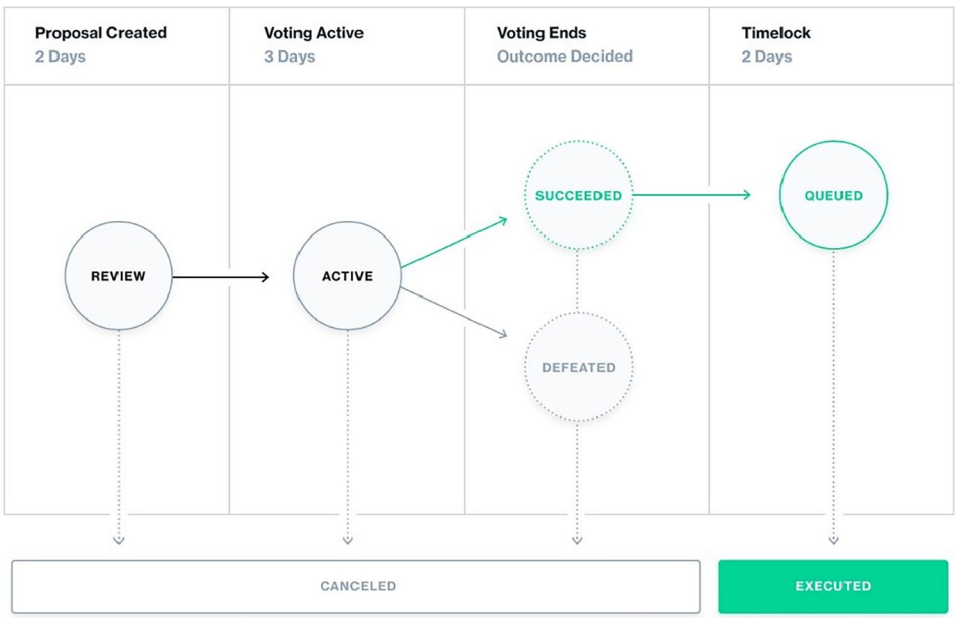

Fig. 7 Governance: This figure depicts the governance system of Compound. Data source: https://compound.finance/Governance

Another potential risk arises when a single actor creates multiple accounts to sway voting outcomes in their favor. Token-based voting systems attempt to curb this risk by linking influence to token holdings. The risk, however, cannot be entirely eradicated, especially when the token distribution is uneven. Many voters may have short-term interests because token holders can freely trade their tokens. A voter's short-term focus could lead to decisions that yield immediate benefits but compromise the project's long-term sustainability.

Furthermore, DeFi projects often incorporate intricate technical and economic concepts. Making informed decisions about such complex issues can be daunting for the average token holder, potentially leading to sub-optimal governance decisions.

Lastly, regulatory risk cannot be overlooked. Regulatory bodies could classify Certain governance tokens as securities due to the voting rights and potential profit they offer, posing legal complications for both the token holders and the project.

To mitigate these risks, projects can implement measures such as locking periods for tokens used in voting, quadratic voting (for which the cost of votes increases exponentially),[15] delegation of votes to expert representatives, and on-chain governance when all actions are transparent and auditable on the blockchain. Despite these measures, governance in DeFi remains a complex issue that necessitates further research.

Some obvious research questions arise. What is the optimal structure of a DAO? How do we think about the valuation of the governance tokens, given they only have voting rights and no obvious cash flow rights? Should there be a minimum token holding for voting? Should there be markets for vote buying? How do we think about the regulation of DAOs, given they are not domiciled in any particular country?

Oracle risk

Oracles serve as indispensable conduits in the DeFi ecosystem, bridging the gap between blockchains and real-world data (John, Kogan, et al., 2022). Smart contracts, encoded with the terms of the agreement, inherently lack the capacity to access off-chain or real-world data independently. This limitation necessitates the role of oracles, third-party services that infuse smart contracts with external information, ranging from cryptocurrency prices to weather data.

Table 3 Oracles: This table depicts an overview of the market for DeFi oracles as of February 2024

Oracle name	Protocols secured	Total value secured ($ billion)
Chainlink	369	20.53
Chronicle	3	9.13
WINkLink	2	8.12
Pyth	159	3.01
Switchboard	12	0.71
Others	289	3.34
Total	834	44.84

Data source: https://defillama.com/oracles

Oracles' essential role does not negate the risks they bring to the DeFi ecosystem. A notable risk is centralization, when reliance on a single oracle for data introduces a point of potential failure into the system. This risk can have severe repercussions if the oracle malfunctions or feeds inaccurate data (Adams, Wan, & Zinsmeister, 2022). Examples of such repercussions are faulty liquidations in a lending platform (Campello et al., 2023) or distorted pricing on a decentralized exchange (Capponi & Jia, 2024).

Additionally, the quality of data an oracle provides hinges upon the reliability of its sources. If these sources falter or offer stale data, the DeFi applications, depending on it, can be negatively affected. Furthermore, relying on a third-party oracle service brings risks, such as service downtime, hacking, or even discontinuation. If the oracle goes down, every transaction sent to the smart contract that uses it will fail.

Table 3 provides a snapshot of the market for DeFi oracles, showing the number of protocols each oracle secures and the total value secured by each in billions of US dollars.

Various strategies are available to counter these risks. Using data from multiple oracles can safeguard against the malfunction or manipulation of a single oracle. Decentralized oracle networks such as Chainlink are designed to diminish centralization risk by amalgamating data from several independent node operators. Some protocols also cross-verify the data provided by oracles by cross-referencing it against multiple data sources.

Despite these risk mitigation strategies, the threat of oracle risk remains a significant challenge in the DeFi space. Future research in this area could include (1) assessing the incentives that could ensure information integrity, (2) the economic implications of oracle adoption and interoperability effects among integrated protocols, and (3) the effects of increased competition among oracle providers.

[15] In quadratic voting, each participant is allocated a certain number of credits they can use to cast votes on an issue (Benhaim et al., 2023b). The cost of casting multiple votes for the same issue increases quadratically rather than linearly. As such, the marginal cost of each successive vote is significantly higher than the last.

Liquidation risk

Providing collateral has long been a standard practice for borrowers seeking a loan. For instance, you might offer your property as collateral to secure a substantial loan, thereby providing the lending institution with a reliable means of recovering their funds if you cannot repay the loan. In theory, the value of your house will always be at least equal to the loan amount.

The guarantee is contingent on the collateral maintaining a stable value. For example, in a traditional mortgage loan, the price of the house (the collateral) may plummet in value, so that the loan amount becomes greater than the value of the collateral. In this situation, a homeowner could choose not to make their mortgage payments, prompting the bank to foreclose or try to renegotiate the loan. Ultimately, the homeowner could simply walk away, and the bank would take a loss when it sells the house. The homeowner, of course, might not walk away and continue to pay the mortgage, hoping their home's price will recover.

Home prices are relatively stable. In contrast, cryptos are highly volatile. To preserve the overcollateralization (collateral worth more than a loan), loans are rapidly closed out if the collateral value drops below a certain level. There is no renegotiation. A third party known as a keeper will close out or liquidate an undercollateralized loan by selling the collateral, paying off the loan, taking a fee, and, in most cases, returning the residual, if any, to the borrower (Lehar & Parlour, 2022b). One risk is that the keeper liquidates the collateral at less than a favorable price.

In DeFi, obtaining a loan involves providing crypto collateral even though the value of cryptocurrencies is highly volatile: the value of the Ethereum or NFTs used as collateral last week could undergo significant changes this week. If the collateral loses value, it becomes worthless as a guarantee for the DeFi lender. This risk also exists in traditional finance because any asset can fluctuate in value. The risk is more prevalent and pronounced in DeFi, however, due to the inherent inconsistency in the value of cryptocurrencies.

We encourage further research on the interplay of liquidations and the value of cryptocurrencies, the economics of decentralized lending applications, and overall market stability.

Custodial risk

Custodial risk is an inherent part of managing cryptocurrencies, primarily due to their association with private keys. Losing these keys equates to losing access to the corresponding digital assets. Numerous instances in the cryptocurrency world underscore this risk when individuals have lost access to substantial holdings due to forgotten passwords or misplaced keys. While self-custody offers autonomy, it comes with the responsibility of key management.

There are four main approaches to custody. First, the user can hold the private keys and run the risk of losing them. There is no "password" recovery. Second, the user can use a service that "splits" the private key and, say, two of three pieces can constitute the original private key. The user keeps two pieces, and a custodian keeps the final third. Any attack on or a loss of one piece is immaterial. Third, the user may choose a professional custodian, like Fidelity, to keep their keys. These services are popular with investment managers who do not want to bear the risk of losing their private key. Finally, many delegate custody to the broker/exchange they are using.

However, there is a long list of exchange hacks (Mt. Gox, Bitfinex, Binance, etc.) and frauds (FTX). There are many choices from opaque offshore exchanges such as Binance to the U.S.-based exchange Coinbase, which has a high degree of transparency given it is listed on the Nasdaq stock exchange. Future research may assess the risks custodial of crypto assets imposed on multinationals and the costs associated with potential solutions in this space.

Environmental risk

While environmental risk was a concern in the past due to the energy-intensive Proof of Work (PoW) consensus mechanism, Ethereum transitioned to a different consensus mechanism in late 2022 called Proof of Stake. After this transition, the need for energy-intensive mining was eliminated. Although environmental risks remain significant for the Bitcoin blockchain, most decentralized finance protocols operate through Ethereum and Ethereum-compatible blockchains. Consequently, the environmental risk has been largely mitigated.

Scalability risk

Scaling is a critical challenge for DeFi applications, many built on the Ethereum blockchain (Benhaim et al., 2023). The current state of Ethereum's infrastructure can only process a limited number of transactions per second, creating a bottleneck that leads to slower transaction times and higher fees, especially during periods of high demand. This bottleneck is a significant obstacle, particularly when comparing Ethereum's capabilities to centralized systems such as Visa, which can handle tens of thousands of transactions per second.

Several strategies are being developed to address the scalability issue and increase the Ethereum network's transaction capacity. Ethereum and Defi need to be able to process thousands, if not millions, of transactions per second.

Table 4 Blockchains: This table reports the summary statistics for the main blockchains in the DeFi market.

Layer 1 networks	DeFi protocols	TVL (billion)	Volume (million)
Ethereum	968	39.31	1210.00
Tron	29	8.65	7.51
BSC	691	3.62	351.88
Arbitrum	541	2.82	299.90
Solana	127	1.86	516.87
Polygon	517	0.88	55.69
Avalanche	358	0.87	87.32

TVL and Volume reports the average daily values as of February 2024. Data source: https://defillama.com/chains.

Two initiatives are underway to achieve this goal. First, Ethereum will "shard" into 64 subchains coordinated by a master chain. Sharding will lead to increased transactions per second – but is only a modest improvement compared to traditional finance. A more promising approach for increasing speed is the Layer 2 solutions, such as Optimistic and ZkRollups, which are also being explored to improve Ethereum's scalability. These solutions process transactions off the main Ethereum chain (Layer 1), reducing the burden on the network. Once confirmed, the transactions are batched together and added to the main chain.

Moreover, alternative blockchain platforms, such as Binance Smart Chain (BSC), Polkadot, and Solana, have emerged to offer more scalable environments for DeFi applications. These networks offer higher throughput and lower transaction fees than Ethereum's current state, attracting developers and users.

Table 4 provides an overview of the current state of the blockchain market. Dominating the DeFi market, Ethereum boasts the highest number of protocols among the largest Layer 1 networks. It also leads in terms of total value locked, accounting for approximately 43.9% of the DeFi market, and commands the largest average daily trading volume, more than double that of its nearest competitor. Despite Ethereum's dominance, alternative blockchain platforms, such as BSC, Arbitrum, Polygon, Optimism, Avalanche, and Solana, are potential contenders for providing scalability solutions to the DeFi market. The numbers in the table represent a market snapshot as of February 2024. Given the rapid pace of innovation, the market is likely to change dramatically in the future.

While these efforts promise improvements, the transition is complex and poses risks, including potential technical issues or delays in the implementation timeline. Thus, while DeFi holds auspicious potential, it is vital to carefully manage these scaling risks to ensure the successful evolution and adoption of DeFi applications, especially on the wave of alternative blockchains.

Block building risk

Almost all DeFi uses the proof-of-stake (PoS) consensus mechanism. In this framework, the amount of crypto – say, ether – that you stake determines the probability that you will be designated to propose a block (a set of transactions to be added to a blockchain). That is, if you stake 10% of the ether, you have a 10% probability of being selected to propose a block. The technique is much more efficient than proof of work (PoW) from an energy point of view. Investing in specialized computer equipment is unnecessary; electricity consumption is no different from traditional payment networks. PoS works because if a proposer includes an invalid transaction, they are penalized, and it comes right out of their stake. Why would proposers include invalid transactions when they know they will lose money? PoS is incentive-compatible.

The technique, however, is not without risk. For example, suppose you are designated to propose a block. You have full access to the list of candidate transactions. As a proposer, you can pick and choose which ones to include. Suppose you see a large buy order for a token. You can insert your own transaction to buy the token before the large transaction. Doing so will almost guarantee that the price of your purchased token will rise after the large buy transaction. The practice is called front running. In contrast to front running in today's centralized securities markets, front running in crypto is not illegal, given that all candidate and final transactions are visible to anyone. The proposer makes money in three ways: (1) a reward for proposing the block; (2) individual transaction fees; and (3) front-running profits. These collective profits are known as the maximal extractable value in the industry.

The problem of front running also exists in PoW. In that model, the miners are proposers, and a miner would want to front-run, too. In PoW, the success of front running is not guaranteed because of the probabilistic nature of winning a block in the PoW model. In PoS, once designated, you know for sure you could front-run successfully. Indeed, several companies specialize in "building" blocks. When a proposer is chosen, they can either build the block independently or use a building service such as Flashbots. These services order transactions in such a way as to maximize profitability.

Regulatory and cross-border risk

Regulators are still developing frameworks for cryptocurrencies, grappling with finding the right balance between facilitating innovation and protecting consumers. If regulations are lax, then consumers may be exploited. If regulations are too harsh, innovation is driven offshore – and no country wants its best ideas offshore. The regulator faces at least five challenges. First, the technology is complex, requiring

a long learning curve. Second, technology is evolving rapidly, so even after investing in understanding the technology, acquired knowledge is quickly dated. Third, recruiting experts to join the regulatory team is challenging because they typically have other competitive, often more profitable, employment opportunities from both DeFi-oriented and traditional companies seeking to enter the space. Fourth, as a global technology, unfavorable regulation in one country leads to regulatory arbitrage, encouraging developers to move to another, more-friendly country. Fifth, decentralized finance is, by definition, decentralized. It is challenging to enforce, and there is no person to serve. The computer programs composing the DeFi space exist on thousands of computers worldwide.

The evolving and complex nature of technology and regulatory uncertainty pose challenges for regulators and the DeFi space. Finding the middle ground requires an investment in understanding the landscape, keeping up with evolving protocols, and attracting knowledgeable employees.

For example, in the United States, the Securities and Exchange Commission (SEC) and the Commodity Futures Trading Commission (CFTC) are working to classify cryptocurrencies and blockchain-based assets. The SEC's recent legal actions against Ripple Labs are a prominent example of its approach to classifying certain tokens as securities. Similarly, the CFTC's approval of ErisX's Ethereum futures contract suggests that certain tokens could be regulated as commodities.

Regulatory initiatives are also on the agenda of several countries across the globe. However, the variation in the treatment of local agencies to several cryptocurrency-related issues calls for international harmonization (Beale, 2023; Cong, Landsman, et al., 2023). For instance, the Organization for Economic Cooperation and Development (OECD, 2022) recently called for developing a framework to harmonize the taxation of cryptocurrencies. In Europe, the European Union (EU) has recently adopted the Market in Crypto Assets (MiCA) regulation – the bloc's first comprehensive set of crypto-related regulations designed to address existing EU financial services legislation gaps. MiCA aims to safeguard investors through enhanced transparency and implement a comprehensive framework for issuers and service providers, including compliance with anti-money laundering rules. In light of the global nature of crypto markets, introducing this harmonized regulatory system across the EU signifies an improvement over the current scenario of fragmented national legislation existing in only some member states.[16]

[16] The new regulations encompass issuers of utility tokens, asset-referenced tokens, and so-called stablecoins. They also extend to service providers such as trading platforms and digital wallets where crypto-assets are stored. The objective of this regulatory structure is to protect investors, maintain financial stability, promote innovation, and enhance the appeal of the crypto-asset sector. See more at https://www.consilium.europa.eu/en/press/press-releases/2022/06/30/digital-financeagreement-reached-on-european-crypto-assets-regulation-mica/.

DeFi also presents challenges in cross-border activities, including the lack of consistent global regulatory frameworks, exposing participants to uncertain legal environments and varying consumer protection levels. Furthermore, cross-border DeFi transactions may be vulnerable to exchange rate volatility and liquidity risks due to the inherent volatility of cryptocurrencies (Biais, Bisiere, Bouvard, Casamata, & Menkveld, 2023; Liu et al. 2022), potentially impacting asset values and user stability.

Resolving the regulatory uncertainty would provide the DeFi space with increased stability and promote broader adoption. With its capacity to minimize financial inefficiencies, foster inclusivity, and stimulate economic growth, DeFi signifies a potentially transformative force in the future of finance. Reaching this potential will require ongoing investments in understanding the landscape, staying abreast of developing protocols, and hiring personnel with expertise in the intersection of finance, blockchain technology, and regulation.

Financial literacy risk

In the rapidly evolving landscape of DeFi, financial literacy emerges as a critical component, particularly for individuals in less developed nations. Financial literacy is essential as it enables individuals to navigate the intricacies of DeFi platforms, make informed decisions, and safeguard their financial assets. Adequate knowledge ensures that users can harness the opportunities presented by decentralized financial instruments while minimizing the risks associated with this space's often volatile and dynamic nature.

Moreover, in less developed nations, where traditional banking infrastructure may be limited, DeFi can be a democratizing force, providing financial services to a broader population. However, without a robust understanding of these tools, individuals may be vulnerable to scams and fraudulent activities in the decentralized space. Equally important is the democratization of the access to high-quality Internet, as it is the gateway to DeFi tools that have the potential to empower individuals economically.

Initiatives that promote financial education, digital literacy, and secure Internet access are crucial in empowering individuals to participate actively and securely in the evolving world of decentralized finance.

Conclusion

Decentralized finance (DeFi) marks a potentially transformative shift in the financial landscape, leveraging blockchain technology to offer innovative services. Its core strengths, including heightened accessibility, enhanced transparency, increased financial inclusivity, and unparalleled transaction efficiency, propel international business (IB) integration by enabling users worldwide to access financial services without traditional intermediaries.

The decentralized nature of DeFi not only facilitates borderless access to financial services but also diminishes cross-border transaction costs, potentially altering the mechanics of international trade and investment. DeFi's focus on financial inclusivity can empower individuals and businesses in underserved regions, allowing them to participate in the global financial ecosystem. Monitoring the evolution of DeFi is imperative for IB professionals to identify opportunities, manage risks, and adapt strategies within this dynamic fintech landscape.

DeFi will lead to many changes in traditional centralized business structures. Yet, it is unlikely to replace centralized business. Certain tasks are more efficiently done decentralized, while others call for some degree of centralization. Many traditional businesses see the opportunity that DeFi offers to improve efficiency and their customers' experiences. Other businesses face an existential threat due to this new technology. A third group of businesses are in "wait and see" mode. The strategy of doing nothing is fraught with risk given this fast-changing technology.

As with any new technology, there are risks. Furthermore, our regulatory system was caught unprepared for this new technology. Importantly, DeFi is not just about trading and transfers of cryptocurrency. DeFi impacts almost all traditional businesses through the innovation of web3. Simply put, web3 is our current web integrated with DeFi. For example, think of renting your or your company's GPUs overnight for AI training and being rewarded in real time with a DeFi token. That token has value because those who demand decentralized cloud computing need to buy the token. Further, there is an obvious comparison with traditional providers. This is just one example. Other applications include decentralized data storage, video and music streaming, social media, and even ride-sharing. Indeed, DeFi upends the current social media model whereby users provide content and the social media companies sell the users' data to advertisers. In the new world, users get paid a token for viewing advertisements. The message here is that DeFi is no longer a niche technology. It impacts almost all global businesses.

Appendix: DeFi Industries

DeFi Industries: This table provides a brief description of each DeFi industry reported in Table 1.

Category	Description
Algo-stables	Algo-stables refers to a category of algorithmic stablecoins within the DeFi ecosystem. These stablecoins are designed to maintain a stable value by utilizing algorithms and smart contract protocols. Unlike traditional fiat-backed stablecoins that rely on centralized reserves, DeFi algo stables aim to achieve price stability through algorithmic mechanisms, often involving automated supply adjustments based on market demand. The most infamous algo-stable was terra which collapsed in 2022.
Bridge	DeFi bridge protocols facilitate asset and liquidity transfers between blockchain networks. They act as bridges, connecting separate blockchain ecosystems and enabling users to transfer tokens across networks.
CDP	CDP protocols, short for collateralized-debt protocols, play a vital role in DeFi. They enable users to create and manage CDPs, smart contracts allowing individuals to collateralize their digital assets in exchange for borrowing other cryptocurrencies or stablecoins. Based on collateral value, users can borrow funds for purposes like trading or investment. Borrowed funds are typically overcollateralized, requiring users to provide more collateral value than the borrowed amount.
Cross chain	Cross-chain protocols are an essential component of the DeFi ecosystem that facilitate interoperability between different blockchain networks. These protocols enable the seamless transfer of assets and data across multiple blockchains, allowing users to access a broader range of decentralized applications (dApps) and utilize various tokens and services.

Category	Description
Derivatives	Derivatives protocols enable trading and creating derivative products via blockchain. Users gain exposure to financial instruments like futures, options, swaps, and synthetic assets without intermediaries. DeFi derivatives protocols facilitate decentralized trading, hedging, and speculative investments. They use smart contracts for creating and settling derivative contracts, ensuring transparency, security, and automated trading.
DEXs	DEX protocols, short for decentralized exchange protocols, are vital in DeFi. They allow users to trade cryptocurrencies and digital assets directly peer-to-pool, bypassing traditional intermediaries. Operating through smart contracts on blockchains, DEX protocols execute trades transparently and decentralized. DEX employ automated market-making algorithms and liquidity pools for continuous liquidity and efficient trading.
Farm	Farm protocols in DeFi enable users to engage in yield farming or liquidity mining. Users can earn rewards by providing liquidity to pools or participating in farming strategies. They lock up their cryptocurrency assets in liquidity pools used by decentralized exchanges or lending platforms for trading and lending. Providing liquidity earns users rewards in additional tokens or fees from the platform.
Gaming	Gaming protocols merge DeFi with gaming, letting users interact with gaming platforms and earn blockchain rewards. Players can trade in-game items, bet, and join decentralized virtual worlds. These protocols may use DAOs to govern the gaming ecosystem, empowering players in decision-making and encouraging participation.
Indexes	Index protocols in DeFi provide curated token indexes, allowing users to access a diverse range of assets and track sector performance. These protocols create indexes by selecting and weighting tokens based on criteria like market cap and liquidity. Users benefit from diversified investment options, representing the broader DeFi market rather than individual assets.
Insurance	Insurance protocols in DeFi mitigate risks and offer coverage for various activities. Users purchase coverage against smart contract vulnerabilities, hacks, and protocol failures by paying premiums. Coverage is provided collectively by a pool of participants who contribute to the insurance pool. Funds are used to compensate policyholders for valid claims. Smart contracts govern coverage terms, premiums, and claim processes, ensuring transparency and automation.
Launchpad	Launchpad protocols are platforms within the DeFi ecosystem that facilitate the launch and initial offering of new tokens or projects. These protocols serve as a launchpad for blockchain-based projects to raise funds, gain exposure, and attract early investors. These protocols often utilize smart contracts to automate the token sale process. They may also incorporate token vesting schedules, governance rights, or tiered investment structures.
Lending	Lending protocols in DeFi facilitate peer-to-peer lending and borrowing of digital assets without traditional intermediaries like banks. Users can lend idle cryptocurrency holdings and earn interest, while borrowers can access funds. Smart contracts automate borrowing and repayment terms. Borrowers provide collateral, reducing credit risk and bypassing credit checks. In default, lenders can liquidate collateral to recover funds. Protocols dynamically determine interest rates based on factors like supply, demand, and borrower creditworthiness.

Category	Description
Leveraged farming	Leveraged farming protocols allow users to amplify their exposure and potential returns by employing leverage in yield farming strategies. These protocols enable users to borrow additional funds to increase their capital and yield-generating potential. Through these protocols, users can deposit their assets as collateral and borrow additional funds, often referred to as leverage, to increase the size of their positions. These protocols often provide features such as automatic borrowing, interest rate optimization, and risk management mechanisms to help users navigate the leverage process.
Liquid staking	Liquid staking enables users to stake assets, earn rewards, and retain flexibility to use staked tokens elsewhere in DeFi. This flexibility provides added liquidity and allows users to explore other DeFi opportunities without forfeiting staking benefits. Liquid staking protocols use smart contracts to synchronize rewards with the staking process, offering rewards in additional tokens or assets periodically.
Liquidity manager	Liquidity manager protocols streamline liquidity management across decentralized exchanges (DEXs) and pools. Users connect wallets to interact with multiple DEXs and pools from one interface. This is sometimes know as DEX aggregation. These protocols automate liquidity provisioning, portfolio rebalancing, and asset allocation. Users deposit assets into pools, earn trading fees, and engage in yield farming. The protocol manages and reallocates assets across pools.
NFT lending	NFT lending protocols enable users to borrow and lend non-fungible tokens (NFTs). Users can leverage their NFT assets for liquidity or passive income. NFT owners deposit their NFTs as collateral and borrow cryptoassets such as stablecoins. The borrowed assets' value is based on a protocol-determined loan-to-value (LTV) ratio, ensuring lender security. Lenders supply funds to lending pools and earn interest on their assets lent to borrowers. Interest rates are determined by supply and demand dynamics within the lending market.
NFT marketplace	NFT marketplace protocols in DeFi facilitate the trading, buying, and selling of non-fungible tokens (NFTs) in a decentralized and transparent manner. Users can discover, list, and transact with NFTs like artwork, collectibles, virtual real estate, or in-game items directly on these platforms. Features such as bidding, auctions, and fixed-price listings allow users to set pricing and engage in competitive or curated sales. Additionally, protocols offer functionalities like curation, community governance, and reward mechanisms to enhance user experience and promote engagement.
Options	Options protocols in DeFi focus on decentralized options trading, eliminating intermediaries. Users can trade options contracts transparently, with the right to buy (call option) or sell (put option) an asset at a predetermined price (strike price) within a specific timeframe (expiration date). These protocols facilitate creation, trading, and settlement of options contracts via smart contracts and blockchain technology. They offer European or American style options and various underlying assets, including cryptocurrencies. Features include order matching, price discovery, and automated settlement of options contracts.

Category	Description
Options vault	Options Vault protocols enable users to engage in options trading while offering features such as liquidity provision, risk management tools, and automated settlement. Through options vault protocols users can deposit their assets into vaults serving liquidity pools for options contracts. These vaults facilitate the buying and selling of options, allowing users to participate as both buyers and sellers based on their trading strategies and market expectations. These protocols often provide a range of strike prices and expiration periods to accommodate different trading preferences.
Oracle	Oracles are essential in DeFi, providing external data to blockchain-based applications and smart contracts. They act as bridges between on-chain and off-chain data sources, retrieving real-time data like price feeds and market data. Smart contracts use these data to make informed decisions and execute actions based on real-world conditions, automating financial transactions and DeFi applications. Oracle protocols employ mechanisms like data aggregation and consensus algorithms to maintain data integrity and reliability, reducing risks associated with single data sources.
Payments	Payments protocols facilitate secure peer-to-peer transactions using cryptocurrencies or digital assets. They offer wallet integration, address management, and transaction tracking, allowing users to manage assets and initiate payments from their wallets. Supporting multiple cryptocurrencies provides users flexibility. Protocols may include features like recurring payments and subscription services for added functionality.
Prediction market	Prediction market protocols allow users to predict and trade on future event outcomes, such as elections, sports events, or cryptocurrency prices. Users purchase shares representing predictions, with share prices indicating perceived event probabilities. Trading establishes decentralized consensus on outcome likelihood. Share prices adjust as new information emerges or events near, reflecting changing market sentiment.
Privacy	Privacy protocols enhance transaction privacy and confidentiality in blockchain networks, offering increased anonymity for DeFi activities. They employ features like zero-knowledge proofs, ring signatures, and confidential transactions to obfuscate transaction details, making it challenging to trace actions to specific users.
Reserve currency	Reserve currency protocols establish stable and reliable currencies within the decentralized ecosystem. Users transact with stablecoins backed by collateral or algorithmic mechanisms to maintain value and stability. Unlike fiat currencies controlled by central banks, DeFi reserve currency protocols offer a decentralized alternative. They ensure stability by maintaining a collateral pool or adjusting stablecoin supply based on demand and market conditions.
RWA	RWA protocols tokenize and trade real-world assets like real estate, stocks, bonds, and commodities on a blockchain. Real-world assets become digital tokens, enabling users to access and invest in them. These tokens are backed by the underlying asset, offering transparency and fractional ownership.
RWA lending	RWA lending allows users to earn interest by lending digital assets and using RWA tokens as collateral or borrowing RWA tokens against their collateral. Users deposit digital assets into lending pools to earn interest, while borrowers access RWA tokens by providing collateral, usually cryptocurrencies or digital assets.

Category	Description
Services	Services protocols in DeFi provide users with a variety of functionalities within the decentralized ecosystem. Acting as service providers, they offer tools, applications, or infrastructure to support DeFi participants' needs. These protocols offer services such as portfolio management, yield optimization, data analytics, liquidity aggregation, lending/borrowing facilitation, and smart contract auditing.
Staking	Staking protocols enable users to validate and secure blockchain networks while earning passive income. Users lock up their digital assets in staking contracts, cryptocurrencies, to receive staking rewards, often in additional tokens. Reward distribution and rates vary based on the protocol and network. Most protocols offer delegation, allowing users to earn rewards by delegating their stake to trusted validators without running their infrastructure.
Synthetics	Synthetics replicate real-world asset value and performance using blockchain tokens. Users create and trade synthetic assets called "synths" through protocols. Synths are created via smart contracts and collateralized with cryptocurrencies. Users lock up collateral to mint synths based on a protocol-determined ratio, ensuring stability. Protocols offer price feeds, oracle integrations, and trading interfaces. Synths are tradable on decentralized exchanges and used within DeFi for purposes like loan collateral or yield farming.
Uncollateralized lending	Uncollateralized lending protocols in DeFi enable borrowing without requiring collateral. Unlike traditional systems, they assess borrowers' creditworthiness using transaction history, credit scores, or decentralized identity. Interest rates fluctuate based on market dynamics and perceived risk. These protocols offer loan terms, automated agreements via smart contracts, but pose risks for lenders due to the absence of collateral. To manage risk, protocols employ reputation-based lending, insurance pools, and risk assessment algorithms, promoting responsible borrowing.
Yield	DeFi yield protocols aim to maximize cryptocurrency asset returns by offering users strategies, tools, and platforms for generating passive income within the DeFi ecosystem. Users can engage in liquidity provision, yield farming, lending, and staking to earn additional tokens or rewards. These protocols use smart contracts and algorithms to identify optimal yield-generating strategies, with features like automated portfolio rebalancing and compounding earnings to enhance returns.
Yield aggregator	Yield aggregators aim to optimize and maximize user yield generation by automating various yield-generating strategies within the DeFi ecosystem. Acting as intermediaries between users and multiple DeFi platforms, these protocols enable users to deposit their digital assets into a single interface. The yield aggregator protocol then allocates these assets across different strategies, including liquidity provision, yield farming, lending, and staking, to maximize returns.

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