Crypto tokens and decentralised financial applications

Decentralised financial applications deliver financial services in combination with crypto tokens across distributed networks, replacing intermediaries such as banks, exchanges or insurers. This fast-growing business area is a melting pot of innovation, and the boundaries between decentralised financial applications and the conventional financial system are becoming increasingly porous.

Participants in these networks use blockchain technology and modifiable open source program code to develop technical solutions such as algorithm-based consensus mechanisms and what are known as smart contracts – programs that automatically execute transactions – to replace trust in intermediaries and minimise administrative intervention in the financial services offered. Decentralised financial applications' use cases are much the same as those found in the conventional financial system: there are decentralised trading platforms, decentralised forms of lending or deposit business, decentralised stablecoins, decentralised derivatives issuance and trading, and also the first forms of decentralised insurance policies.

Decentrality has many sides to it, and in its purest form, appears to be more of a theoretical construct. Even the decentralised financial applications used in practice employ centrally managed governance processes as stabilisation mechanisms or to fix code bugs, for instance. And at the end of the day, the conventional financial system as a whole can also be regarded as a hybrid of centralised and decentralised structures.

Decentralised financial applications are still in their infancy and need to overcome some major challenges: software bugs can be a source of security risks which centralised administrative structures could manage to keep in check; not all programmed incentive systems are capable of eliminating misconduct altogether; the public blockchains used often cannot cope with larger business volumes; interoperability across blockchains and with off-chain systems is limited; and interconnectedness means that problems can ripple out across applications, potentially endangering the ecosystem as a whole.

Assuming the risks can be kept in check and effective governance mechanisms are assured, decentralised financial applications can be expected to provide important impetus for the financial system. These technologies might end up being adopted by the conventional financial system, say, or the governance mechanisms built into individual decentralised financial applications might evolve centralised structures, causing them to become part of the conventional financial system. It is also conceivable that parts of the conventional financial system will be crowded out, or that financial market incumbents will offer their customers access to decentralised financial services as intermediaries.

All in all, decentralised financial applications are likely to promote innovation in the conventional financial system. Effective regulation of decentralised financial applications could increase trust in this market segment and boost growth there, even if regulators face particular challenges in this regard.

Decentralised financial applications: origins and basic idea

Decentralised financial applications deliver financial services in combination with crypto tokens

The financial system has seen innovation over the past ten years, not least due to the emergence of crypto tokens[1] such as Bitcoin and Ether. Crypto tokens have attracted a great deal of attention, mainly on account of their volatility, but their technological features have also met with interest. These developments, which are based on distributed ledger technology (DLT),[2] remain a rich source of innovative potential, having already led to the issuance of stablecoins, the debate conducted almost worldwide on tokenised forms of money, including central bank digital currency (CBDC), and the increasing uptake of DLT for settlement in the conventional financial system.[3] A whole raft of decentralised financial applications have also emerged. These DLT-based solutions deliver various financial services in combination with crypto tokens without any need for centralised intermediaries such as banks, exchanges or insurers. The use cases are much the same as those in the conventional financial system: there is trading based on crypto tokens, for example, or collateralised lending in crypto tokens.

Decentralisation means "intermediary-free", primarily, …

Views differ on what it means for a network to be "decentralised", though many would agree it primarily means the network is free of intermediation[4] – that is to say, transactions take place directly between the network participants without intermediary involvement. A conventional credit transfer from one agent to another, for example, would normally require the involvement of at least one account-keeping bank. However, involving intermediaries is always a question of trust, which makes it a potential source of uncertainty. Hence, the declared aim of decentralised financial applications is to create a system in which transactions can be settled without any need for trusted third parties. That means defining procedural rules and incentives that enable the system to run without administrative intervention and stabilise itself if required.

… but has multiple dimensions

The reasons mentioned in the literature for the push towards decentralised applications, above all in the world of finance, are of a technical, political and economic nature: distributed systems, it is claimed, are less vulnerable to cyber risks, are censorship-proof,[5] and eliminate the potential risk of intermediary misconduct.[6] Intermediaries can perform all manner of functions, from the safekeeping or management of assets to pricing, and all the way to running infrastructures and optimising their workflows. Accordingly, the degree of decentralisation – the freedom from intermediation – can be measured by multiple criteria, such as the absence of central agents, the existence of open source code that anyone can program, process transparency, transaction traceability, or the inability to identify stakeholder network participants.

Conventional financial system as a hybrid of centralised and decentralised structures

The conventional financial system as a whole can be regarded as a hybrid of centralised and decentralised structures. While intermediaries such as banks, depositories, payment systems, central counterparties and custodians play important roles, and even tend towards monopolising market infrastructures in some cases, the most extreme form of centralisation – central provision – does not exist in practice in its unadulterated form. Indeed, custodians and

1 Crypto token is the name given to a digital token transferred across a network using a technical protocol based on cryptographic procedures. See Deutsche Bundesbank (2019).
2 Distributed ledger (DL) normally means a database shared across a network which gives participants joint rights to write, read and store entries in the ledger. The most common DLT applications are based on blockchain technology, which has proven to be a particularly useful ledger for recording histories of transactions. See Deutsche Bundesbank (2017).
3 See Deutsche Bundesbank (2021).
4 See Nakamoto (2008).
5 See Ludwin (2017).
6 It is often noted in this regard that Bitcoin was created in 2008 partly in response to the financial crisis. The first block of the Bitcoin blockchain (the "genesis block") from January 2009 contains a reference to a report on the UK government's second bailout for banks, which is read as a critique of intermediaries.

depositories tend to be rivals; there are generally legally enforceable rights for participation in financial market infrastructures; and the levels of transparency and objectivity surrounding procedural rules are significant, protecting the interests of individual agents. Most notably, agents can invoke antitrust law to limit the negative implications of monopolistic tendencies in cases where market infrastructures are operated by private agents.

Pure decentralisation more of a theoretical construct

By the same token, most decentralised financial applications are unlikely to be entirely decentralised in reality, either. In most cases, not all their participants have equal rights to modify program code and the like. Furthermore, many applications permit administrative intervention to repair the applicable procedural rules as appropriate, and they work on the basis of governance rules that tend to distribute design rights unequally, despite having full decentralisation as their declared aim.

Decentralised financial applications can operate autonomously, free of administrative intervention

The technical ability to program automated smart contracts is the key precondition for whether a blockchain is a suitable layer on which to run decentralised financial applications. Smart contracts automatically release assets held as digital tokens as soon as predefined terms and conditions are met.[7] The automated transaction validation process of the underlying blockchain makes sure that smart contracts run without interruption. As a result, it is possible to hardwire complex governance rules and business logics into the program code, which facilitates the implementation of new and transparent forms of process automation, thereby reducing process and transaction costs.

Combining smart contracts to create decentralised autonomous organisations

Expanding smart contracts or linking them algorithmically can automate the settlement of complex, tiered transactions. Taken to the extreme, it is possible to automate entire process chains, like in an enterprise. Decentralised financial applications operated collectively using what are known as governance tokens are therefore also known as decentralised autonomous organisations (DAOs).[8] Governance tokens enable their bearers to vote jointly on changes to the program code, the idea being to facilitate collective management depending on how the tokens are distributed.

Decentralised financial applications seeing brisk growth, with boundaries between them and the conventional financial system becoming increasingly porous

The theoretical considerations on DAOs gradually took shape and evolved into individual decentralised financial applications for various use cases. "Decentralised finance (DeFi)" is the umbrella term used in the literature for decentralised financial applications, but definitions of this term tend to vary. In an effort to address technical hurdles as well as incentive and trust issues inherent in the system, various solutions based on different blockchains have been developed and offered. As these solutions become more advanced, the boundaries between decentralised financial applications and the conventional financial system could become increasingly porous, warranting closer analysis. There are also questions surrounding potential implications for the financial system and, looking ahead, for financial stability and for regulation and taxation regimes.

Decentralised financial applications and their ecosystem

How decentralised financial applications work

The chart on p. 35 shows in simplified terms how decentralised financial applications are structured and interact with other actors. Decentralised financial applications are based on a

7 Smart contracts are not contracts in a legal sense, but aid execution of the same. The term "smart contract" was coined by IT specialist Nick Szabo, who used the idea of a vending machine as a crude prototype of a smart contract. The vending machine, he explained, represents a smart contract between the vendor and whoever buys an item stored in the vending machine. Anyone with the right coins can operate the vending machine. Security mechanisms protect the stored coins and contents from attackers, sufficiently to allow profitable deployment of vending machines in a wide variety of areas. See Szabo (1997).
8 See Buterin (2014), Fraunhofer-Gesellschaft (2017) and Jensen et al. (2021).

The DAO

Perhaps the best-known decentralised autonomous organisation to date was a virtual investment fund called The DAO. This "company without people"[1] was implemented on the Ethereum blockchain in 2016. Users could buy shares in The DAO with Ether (the Ethereum blockchain's native crypto token). Following this first phase, project proposals were to be submitted to the virtual fund via smart contracts. Subsequently, users were intended to be able to vote on which projects The DAO would invest in. The entire process, including interest and dividend payments, was to take place automatically.

This decentralised alternative to investor-supported risk financing generated a great deal of interest and, helped along by rising Ether prices, secured total investment equivalent to US$150 million – a record sum for similar forms of crowdfunding at the time. This "social experiment" – as it was dubbed by one of the programmers – was intended to be an enterprise without entrepreneurs, without a formal place of business, without an executive board, and without responsible parties.

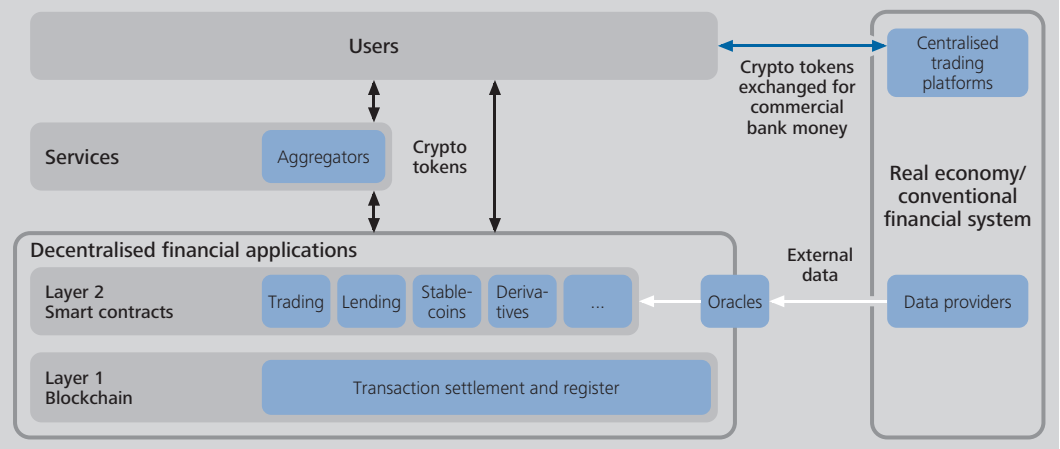
In the end, however, the project never reached the investment stage, as a coding error in the share-buying phase was discovered which allowed an "attacker" to withdraw around a third of the contents of the fund. As the smart contract could not be altered, the programmers could not stop the withdrawal.

To limit the damage to the reputation of Ethereum as a basis for smart contracts and the reputation of other DAOs, the majority of the Ethereum community agreed to implement a hard fork. This meant supposedly immutable entries on the Ethereum blockchain were retroactively cancelled, allowing the stolen funds to be confiscated from the "attacker". Practically, this meant a minority was expropriated by the majority, the justification given for which was the use of funds in a manner that grossly violated The DAO's intended purpose.[2]

These events are important, beyond the community involved, for two reasons. It was the first time a decentralised autonomous organisation of significance had ever been implemented. This had a positive effect on Ethereum's reputation beyond blockchain enthusiasts. It also demonstrated that the lack of governance in such structures makes them very vulnerable in various ways, such as to cyber risks.

1 See Grasegger (2016).
2 A comprehensive retelling of the events surrounding The DAO can be found in Santos (2018).

Decentralised financial applications and their ecosystem



Deutsche Bundesbank

Decentralised financial applications are part of a multi-stakeholder ecosystem

distributed ledger – usually a blockchain of some kind (layer 1) – and on smart contracts (layer 2).[9] While the blockchain serves as the transaction settlement system and register, the smart contracts specify which terms and conditions for transactions via the base blockchain need to be verified and what actions they trigger. This means that a wide variety of different use cases can be modelled. Users tend to purchase crypto tokens on centralised trading platforms in return for commercial bank money and credit them to an electronic wallet they need to open for each individual blockchain. Service providers can bundle together different applications and offer them to their customers on a single platform as a way of enabling them to access and use different decentralised financial applications (aggregators). The only bridge to the real world are usually actors known as oracles, which source external data that many applications use.

Blockchain is the organisational base layer for decentralised financial applications

The organisational base layer for decentralised financial applications is provided by a blockchain, a string of largely immutable blocks storing information on transactions with the aid of cryptographic mechanisms. Blockchains normally support the storage and transfer of what are known as native tokens, which are built directly on-chain and exist exclusively on the distributed ledger.[10] Some blockchains furthermore allow additional digital tokens to be created, e.g. for governance purposes (governance tokens), to represent unique real-world assets (non-fungible tokens, or NFTs) such as works of art, as synthetic assets (stablecoins based on crypto tokens on other blockchains or real assets), or as electronic securities. A blockchain of this kind can serve as a common settlement ledger and register for a variety of different decentralised financial applications. Crypto tokens cannot, however, be directly transferred from one blockchain to another.

It would be possible to use commercial bank money in decentralised financial applications if it could be issued by credit institutions as tokens on the base blockchain on which the applications in question are based. The same holds true for central bank money, which could theoretically be issued by central banks as

9 The terms blockchain and DLT are often used interchangeably, and the blockchain is indeed a particular type of DLT and its best-known use case. In terms of its encryption technology, validation process and consensus mechanism, blockchain is a decentralised architecture in the broadest sense of the term.

10 The Bitcoin blockchain, for instance, allows the decentralised transfer and storage of electronic tokens that exist in the form of Bitcoins. Beyond that, the underlying programming language does not support complex calculation logic, which means it is unsuitable as an organisational base layer for decentralised financial applications. See Fraunhofer-Gesellschaft (2017) and World Economic Forum (2021).

tokens, or for any other assets that could be represented by a digital token.[11]

Consensus mechanisms replace trust in intermediaries

Decentralised financial applications are normally based on public blockchains that support pseudonymised[12] use and have no access constraints (public permissionless blockchains). In order to extend the blockchain for all network participants with matching and error-free transactions, there need to be what are known as consensus mechanisms.[13] Network participants use a consensus mechanism to agree on transactions to be added to the blockchain, and in what order. The choice of consensus mechanism, then, plays a major role in the security of a blockchain and thus also in the level of security offered by the decentralised financial applications based on that particular blockchain.

Open source program code

The program code used in decentralised financial applications is open source software with source code that anyone can inspect. This means it can be used by developers as a blueprint for new projects.[14] By combining existing lines of code and adding new ones, it is possible to create new applications with relatively little programming effort. At the same time, network participants at least stand a chance of understanding how applications are designed and how they work.[15]

Oracles send external data to smart contracts

Smart contracts can only access data located within the blockchain network, but decentralised financial applications sometimes need to access external data such as foreign exchange rates and securities prices to verify when predefined terms and conditions have been met. This task is performed by oracles, which collect data from the real world, send them to the network and convert them into a format readable by smart contracts. They act as a bridge between on-chain and off-chain inputs and support a variety of use cases. The trustworthiness of oracles is of crucial importance for the level of security offered by applications and ultimately for user acceptance as well.[16] This is because smart contracts execute transactions autonomously, so erroneous external data could result in the irreversible execution of erroneous transactions.

Governance processes to facilitate administrative intervention

Decentralised financial applications are based on predefined program code, which means that, without outside involvement, they are unable to respond to unforeseeable events or changing circumstances. To nonetheless allow external administrative intervention to take place, it is commonplace to implement decentralised governance processes. For this purpose, decentralised financial applications generally use governance tokens to technically represent decision-making processes on the underlying blockchain (a set-up known as on-chain governance).[17] If proposals are made to improve the application, the bearers of these governance tokens can use a weighted voting system to decide on those proposals.[18]

Development of the market

Most decentralised financial applications based on Ethereum blockchain

Since starting in 2015, the Ethereum blockchain has established itself as the most important foundation for decentralised financial applications. It was the first blockchain enabling the deployment of complex smart contracts.[19] The applications based upon it are interoperable and benefit from a broad user and developer base, as well as the network effects that this entails.[20]

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11 See OECD (2020).
12 Pseudonymisation is the act of using a pseudonym rather than a name or similar identifying characteristics, the idea being to make it impossible to uniquely identify a network participant.
13 See Deutsche Bundesbank (2017).
14 See Jensen et al. (2021).
15 See Schär (2021).
16 See Federal Office for Information Security (2019).
17 Off-chain governance, on the other hand, enables developers to send the network participants proposals for modifying the software protocol via mailing lists or discussion forums and the like. Network participants who agree with the modifications adopt a new version of the original protocol.
18 See Schär (2021) and Jensen et al. (2021).
19 See Buterin (2013) and Schär (2021).
20 Network effects exist when the utility an individual user derives from a good or service depends on the number of other users of that good or service. Network effects are positive when increasing user numbers incentivise the use of a given good, service or technology.

Other public blockchains which support smart contracts and exhibit a comparatively high degree of decentralisation exist besides Ethereum, with examples including Tezos, Solana and Cardano.[21] Ethereum is also in the process of being upgraded to Ethereum 2.0, with a view to increasing transaction throughput and thereby cutting transaction costs.[22]

Value of liquidity lodged in decentralised financial applications can be used as rough indicator of their prominence

Total value locked (TVL) can serve as a rough indicator for the growth of decentralised financial applications. It refers to the amount of collateral deposited and liquidity provisioned by users – in the form of respective crypto tokens – in decentralised financial applications. In both cases, users temporarily deposit crypto tokens in smart contracts for the purposes of specific use cases.

In June 2019, the TVL on the Ethereum blockchain equated to an average of around US$0.5 billion; by June 2020, this value had risen to US$1.4 billion. In June 2021, the TVL tied up in the Ethereum blockchain had already reached US$58.1 billion, a development partially the result of price appreciation across a number of crypto tokens. The majority of liquidity is deposited in applications for the generation of decentralised stablecoins, in decentralised lending platforms and in decentralised trading platforms.[23]

It must be said that the TVL metric suffers from a lack of precision, however. Converted into US dollar or euro, prices for the deposited crypto tokens display a high degree of volatility. In addition, assets can end up being counted twice, for example if tokens are deposited in one application as collateral for token issuance in another application. Furthermore, in the case of certain applications, the TVL volume can only provide a limited idea of how they are actually being used. When it comes to decentralised lending platforms, for instance, the TVL does not reveal anything about what proportion of the crypto tokens deposited as liquidity are being extended as loans.

Financial use cases

Decentralised financial applications deliver broad range of financial services

The development of decentralised financial applications is still in its infancy. Use cases can be found in trade, credit-like and deposit-like transactions, and stablecoin and derivative issuance. In addition, services which could be classed under the insurance or asset management umbrella are evolving, although these currently still occupy a comparatively minor place in the ecosystem of decentralised financial applications.[24]

Decentralised trading platforms

Decentralised trading platforms only viable for the exchange of crypto tokens …

Decentralised trading platforms enable network participants who do not know each other to exchange different crypto tokens among themselves without the intervention of a central party as broker, price-setter or crypto custodian. Users retain control of their crypto tokens throughout the entire trade process, in a set-up known as non-custodial exchange.[25] In this way, users can avoid the risk that their crypto tokens – which have to be deposited when trading on centralised trading platforms – might be stolen.[26] Decentralised trading platforms only allow the exchange of crypto tokens issued via the same underlying blockchain, for example the blockchain's native token, stablecoins or governance tokens.

In technical terms, decentralised trading platforms are typically based on what are known

21 One blockchain with a comparatively low degree of decentralisation is Binance Smart Chain; only 21 network participants are involved in the creation of new blocks. See Binance (2020).
22 See ethereum.org at https://ethereum.org/en/eth2/
23 See Defi Pulse at https://defipulse.com/ and, at https://coinmarketcap.com, CoinMarketCap. These sources can serve as a sign of how the market is developing. The values quoted are not necessarily fully reliable but, for want of alternatives, are frequently referred to.
24 There are, for example, insurance products to provide cover against losses due to software bugs in decentralised financial applications. See Schär (2021).
25 See Lin (2019).
26 For a detailed examination of the dangers associated with centralised trading platforms, see Corbet et al. (2020).

… and are typically not based on an order book

as automated market-makers.[27] Liquidity pools for certain crypto token trading pairs are established using smart contracts. Network participants can provision these pools with liquidity in the form of crypto tokens. In return, they receive liquidity tokens which represent the liquidity that they have contributed. In the form of these liquidity tokens, holders generally receive the fees accrued for trades; this can be seen as compensation for the provision of liquidity. At the same time, liquidity providers bear the risk of price changes when it comes to re-exchanging the liquidity tokens for the liquidity that they have contributed. A trading transaction takes place when an asset is added to the pool and another asset withdrawn at the same time. The swap shifts the ratio of the token trading pair to each other in the liquidity pool. On the basis of an algorithm, these changes in the value ratio lead to price changes, whereby the user who carried out the exchange loses out (known as slippage loss). The greater the shift an exchange transaction produces in the value ratio of a trading pair, the greater the slippage loss. It is therefore important to have a sufficiently large pool of liquidity; otherwise, even small trading transactions would lead to high slippage loss. Since the relative prices of tokens formally change in inverse proportion to the volume ratio in the liquidity pool, they do not necessarily reflect supply and demand in the market. This gives rise to an incentive for arbitrageurs[28] to exploit price differences between trading platforms to generate profit. For example, a token whose value has dropped as a result of its being added to a liquidity pool may be purchased relatively cheaply and then sold on another trading platform.[29]

Decentralised lending platforms

Loans via decentralised lending platforms are typically collateralised, …

Decentralised lending platforms enable liquidity in the form of crypto tokens to be borrowed and lent, with interest applied.[30] To ensure that loans are repaid in spite of the anonymity of their parties, borrowers are usually required to provide collateral.[31] By means of collateralised borrowing of this kind, borrowers can leverage their own positions.[32] Those holding crypto tokens for speculative reasons, for example, can opt to pledge these as collateral. If the crypto tokens taken out as a loan also climb in value, the borrower can make a profit, provided that the amount by which the value of the borrowed crypto tokens and the borrower's collateral has increased exceeds the amount that they have had to pay in interest.[33] Depending on the application concerned, the collateralised lending is executed either via what are known as lending pools, which bundle liquidity provided by network participants in a smart contract, or directly between individual network participants.[34] Applications based on lending pools tend to be more liquid, and thus more popular. They work in a similar way to the liquidity pools of decentralised trading platforms. On account of the highly volatile and illiquid nature of many crypto tokens, borrowers often have to over-collateralise their liabilities – for example, at a rate of 150% – so as to incentivise repayment. The collateral is parked in a smart contract and then released again

27 By contrast, trade via centralised trading platforms is based on order books in which buy and sell orders are recorded in lists and matched up. As a rule, there is a constant flow of market-makers prepared to act as counterparties, which generally guarantees a high degree of liquidity. In the case of decentralised trading platforms, market-makers would – due to the underlying blockchain technology – have to pay fees for each order change and transaction, and this would quickly render market-making in the traditional sense of the term uneconomical. See Jensen et al. (2021).
28 Arbitrage describes the process of buying and selling the same asset in different markets to profit from differences in price.
29 See Daian et al. (2020) and Adams et al. (2020).
30 See DeFi Rate for an overview of the current lending and deposit rates at https://defirate.com/lend
31 See Jensen et al. (2021).
32 Leverage describes the way borrowed capital can magnify return on equity. This effect arises when capital can be borrowed at a rate of interest lower than the total return generated through the investment for which those borrowed assets are used. The collateral posted in decentralised lending platforms then corresponds to the share of equity capital.
33 See Bitkom (2020).
34 In the case of direct lending a user will deposit, for instance, NFTs as collateral in a smart contract and, in return, receives individual offers of credit from other users.

once the loan has been repaid. Most decentralised lending platforms have variable lending and deposit rates. In the case of lending pools, these rates are determined by rules-based protocols depending on the size of the pool concerned. If the pool starts to run low on liquidity, interest rates rise, creating a more pressing incentive for borrowers to repay their loans. At the same time, other network participants have a bigger incentive to supply liquidity. The same principle in reverse applies in the event of an over-abundance of liquidity.[35]

… with the exception of flash loans

Uncollateralised loans can be made, for example, in the form of a flash loan. Flash loans have to be repaid within the same blockchain block, otherwise the entire transaction is unwound. This effectively does away with the credit risk for the lender. Flash loans serve, for instance, as arbitrage instruments, in that price differences between different decentralised trading platforms are monetised. However, flash loans can also be misused to mount malicious attacks on decentralised financial applications, for example through the acquisition of governance tokens and subsequent alteration of the application's program code to benefit the attacker.[36]

Decentralised stablecoins

Decentralised stablecoins seek to be as stable in value as possible – without the need for trust in third parties

Decentralised stablecoins try to be as stable in value as possible in relation to a reference value. Unlike centralised stablecoins, such as Tether or the planned Diem, the idea is for there to be no need for trust in an issuer; in other words they are "non-custodial". Decentralised stablecoins can be backed[37] only by crypto tokens (on-chain). The stablecoin is minted by users depositing crypto tokens as collateral in a smart contract. The amount of stablecoins produced depends on the current exchange rate of the deposited collateral to the reference value, information which is obtained through an oracle. Stablecoins are typically collateralised at rates of over 100%. As a result, drops in the value of the collateral do not immediately mean losses in the value of the stablecoin. If the value of the deposited collateral falls below a certain threshold, it can be bought by third parties at an additional discount in exchange for the stablecoin. When this happens, the collateral is taken out of the smart contract and the returned stablecoin is destroyed. This mechanism is designed to prevent undercollateralisation of the stablecoin and thus keep its value stable.[38] This cannot be guaranteed, however.[39]

Decentralised derivatives

Decentralised derivatives can derive their value from any underlying asset or event

Decentralised derivatives are crypto tokens which derive their value from the performance of an underlying asset or from the occurrence of a particular event. A host of assets are suited for use as the underlying – stocks, commodities or crypto tokens of other blockchains, for example. Decentralised derivatives work in a similar way to decentralised stablecoins. However, the underlying assets of decentralised derivatives generally exhibit significant fluctuations in value, rendering collateralisation of several 100% necessary. Users deposit collateral in the form of crypto tokens in a smart contract and receive the derivative in return. Oracles feed the smart contract with information on how the underlying asset is performing.

Event-based derivatives rely on an observable variable which can have clear outcomes over a specific period of time.[40] There is a separate

35 See Aave (2020) and Schär (2021).
36 See Gudgeon et al. (2020) and Aave (2020).
37 The value of centralised stablecoins is usually kept stable by their being pegged to, and collateralised with, a genuine currency. An alternative approach to the on-chain collateralisation of decentralised stablecoins consists in the attempt to use algorithms to control the volume of the issued stablecoin or the interest rate applying to it in such a way as to hold the stablecoin's price in relation to a reference value as steady as possible. This approach is not particularly common at present, however. See Deutsche Bundesbank (2019).
38 See Klages-Mundt et al. (2020).
39 See Deutsche Bundesbank (2019).
40 A derivative of this kind was issued in respect of the outcome of the US presidential elections held in 2020. See Schär (2021).

token for each conceivable outcome. Once the event occurs, the smart contract disburses all of the staked assets to those holding the tokens that represent the outcome which has transpired.[41]

Potential for development

Fast-paced development in the field of decentralised financial applications

A multiplicity of decentralised financial applications has developed in the course of just a few years, varied both in terms of the use cases that they represent as well as in design. So far as it is possible to tell, both the amount of liquidity locked in as well as the volumes being handled are growing apace.[42] A not insignificant part of the reason why the market for decentralised financial applications is proving dynamic and innovative is that many applications are developing free from consideration of regulatory requirements or because regulatory intervention has so far had barely any inhibiting effect. This fosters the development of business models which are unsustainable or even detrimental to users in some cases.

Compared with the conventional financial system, decentralised financial applications are of quantitatively minor significance at present and, so far, they appear to have made barely any meaningful inroads in terms of relevance to the real economy. Their growth as well as the innovativeness of the solutions being developed could point towards an increasing relevance in future, however. In addition, decentralised financial applications stand before various challenges – some inherent – which could prove to be barriers to development. These include, in particular, security risks associated with the program codes used, poor incentive systems, a lack of scalability, restricted interoperability, contagion risks arising from interdependencies, insufficient governance and partly unclear or non-existent regulatory requirements.

Security

Software bugs bring security risks, …

The use of decentralised financial applications entails security risks. This is because external security checks and incentive systems are not able to eliminate the possibility of software bugs and misuse by individual network participants. The way decentralised financial applications work from a technical perspective is, in principle, transparent. Software errors (or smart contract bugs) can lead to unintended problems, however. Since individual participants do not generally have write permissions for the program code, the fixing of these errors must first be put to the network for consensus. Decentralised governance thus militates against swift and effective intervention in an emergency.[43] Bugs in the program code also offer a major attack surface for abusive conduct and examples of this have been seen in the past even when individual program codes have been checked by external security companies.[44] What follows is that trust in intermediaries must necessarily be replaced by trust in the program code functioning properly.[45]

… as do incentive systems

From an economic point of view, incentive systems are meant to stop network participants wrongfully enriching themselves at the expense of the network's other participants or acting contrary to the way that the network is intended to work.[46] An example of their use is with oracles. As an information interface with the outside world, oracles are of crucial importance for decentralised financial applications. Oracles usually receive a reward when they

41 See Schär (2021).
42 See Dune Analytics for developments in the volume of trades executed on decentralised trading platforms (https://duneanalytics.com/hagaetc/dex-metrics) and decentralised lending platforms (https://duneanalytics.com/hagaetc/lending) based on the Ethereum blockchain. The figures quoted are not necessarily fully reliable but are often used as a reference point.
43 See Klages-Mundt et al. (2020).
44 See Groce et al. (2020).
45 See Pesch (2019) and Federal Office for Information Security (2019).
46 For this to work, from a purely technical point of view, the program code must be assumed to run perfectly with no bugs.

provide correct data. This reward may take the form of, say, governance tokens. Misbehaviour, meanwhile, would be penalised by taking away governance tokens. The idea is to render the provision of incorrect or manipulated data economically unattractive, even if this cannot be completely prevented.[47]

Scalability

Public blockchains lack scalability

In the case of public blockchains, which are typically operated by a large number of network participants, there is a conflict between the twin aims of scalability and decentralisation. Compared with private blockchains, which are run by a restricted circle of network participants, transaction costs are often high and they enable a comparatively low transaction throughput. The main reason for this lies in the consensus mechanisms which they employ. As the number of network participants involved in the consensus mechanism increases, the process of reaching a consensus tends to become more secure but the cost and duration of the procedure will also rise.[48] In order to facilitate higher transaction throughput, some blockchains rely on a more centralised consensus mechanism involving a smaller set of network participants.[49] Some decentralised financial applications enable settlement of off-chain transactions which no longer need to be individually validated on the underlying blockchain ("layer 2 solutions").[50] Such procedures are similar to ancillary system settlement in the conventional payments space. A side effect – as with conventional payments – is liquidity fragmentation, however.

There is currently no effective fix for the trade-off between a high degree of scalability and a high degree of decentralisation. But without sufficient scalability, the usability of decentralised financial applications is heavily curtailed.

Interoperability

Limited interoperability between different blockchains and with systems not based on blockchain

A common infrastructure and shared standards enable a high degree of interoperability between decentralised financial applications. Moreover, smart contracts can be modified and combined in manifold ways, paving the way for new and more complex use cases. However, interoperability between different blockchains – the organisational bedrock of decentralised financial applications – as well as with other systems not based on blockchain is significantly restricted. Decentralised financial applications can interact with applications external to their ecosystem only to a limited degree and it generally requires the involvement of intermediaries. This can result in solutions being developed in isolation – contributing to fragmentation of the market and of liquidity – as well as, sometimes, market power ending up in the hands of a small number of providers. Various projects are attempting to find a solution to these limitations without the need for intermediary involvement. These are still in the early stages of development, however.[51]

Interdependencies

Problems experienced by one application can ripple out to others

The combined use of different applications produces interdependencies which, depending on the degree of integration, can entail commensurately high risks for the ecosystem as a whole. For example, a user may deposit collateral in one application, using it to obtain a stablecoin. Suppose they then place this stablecoin on a trading platform to acquire liquidity tokens; these liquidity tokens could then, in turn, be

47 See Federal Office for Information Security (2019) and Klages-Mundt et al. (2020).
48 Where data are held and updated decentrally there are physical barriers with regard to communication between network participants. These arise because only a limited amount of data can be transferred within a certain timeframe. This places a constraint on block size, and hence the number of transactions which can be processed per block. See Federal Office for Information Security (2019).
49 See, for example, Binance (2020).
50 See Schär (2021).
51 See European Central Bank (2021).

lent via a lending platform. Such operations create chains of dependence. These chains harbour contagion risks which may be triggered, for example, by particularly volatile market developments pertaining to the crypto tokens concerned or through technical problems such as in the event of a software bug.[52] The risks stemming from interdependencies within public blockchains demand particular attention.[53]

Governance

Effective governance requires centralised elements

Decentralised governance essentially means that all stakeholders are jointly and equally responsible for changes to the program code or for averting threats. However, the bulk of applications are based on decentralised governance processes founded on collective voting procedures using governance tokens. Decentralised financial applications often begin life with a higher degree of centralisation than is ultimately aspired to as the original developers retain larger shares of governance tokens or earmark them for investors.[54] There is also a risk of individual agents using governance tokens to obtain a majority of votes and modify the program code to their advantage (governance attack).[55] This danger is heightened by network participants' pseudoanonymity and the associated lack of transparency when it comes to decision-making structures. Risks of this kind could be addressed by implementing program changes with a system time delay. This would, at least theoretically, give network participants enough time to exit if they disagreed with the changes. But, at the same time, delaying the implementation of program changes leads to sluggishness in the system.[56]

Regulation

Addressee of regulatory requirements in the context of decentralised financial applications unclear

Decentralised financial applications are often not captured by existing regulation, especially as the term decentralisation is sometimes interpreted in different ways. Even regulatory provisions that should otherwise be applicable often cannot be sufficiently enforced as there are no natural or legal persons to act as addressee, meaning no one can be held responsible or liable for any damages.[57] The possibility that providers will attempt to obscure their actual central governance by referring to the decentralisation of an application in order to evade any regulation also cannot be ruled out.[58] Regulators are thus faced with a series of by no means trivial issues.

- What functions of decentralised financial applications and their underlying blockchains are covered by existing regulatory frameworks and which require regulation?

- What parties (e.g. developers, holders of governance tokens, users) can be subject to regulation? How can they be identified?

- Which jurisdiction is responsible for an application without a legal seat? Can an effective international framework be developed to prevent regulatory arbitrage?

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52 See Gudgeon et al. (2020) and Schär (2021).
53 For example, in the conventional financial system, Regulation of the European Central Bank (EU) No 795/2014 requires systemically important payment systems (SIPS) established in the euro area to identify critical participants who could present a risk for the entire system if they were to default.
54 See Bitkom (2020) and World Economic Forum (2021).
55 See Klages-Mundt et al. (2020) and Gudgeon et al. (2020). This potential risk can also result in, for example, providers of collateral pushing up the value of governance tokens to reduce the risk of a damaging attack and to protect their collateral. This runs counter to the actual purpose of governance tokens, i.e. the collective management of the application.
56 See Schär (2021).
57 The European Commission published its digital finance package on 24 September 2020. This includes, amongst other things, legislative proposals for the regulation of crypto tokens and stablecoins that are not subject to any other existing European regulation, as well as a proposal for a pilot regime for market infrastructures based on DLT. In their current versions, both proposed regulations essentially address issuers of crypto tokens, certain service providers and market infrastructure operators – i.e. specific legal persons. The decentralised financial applications considered here and the blockchains underlying them would thus not fall under the regulations included in the digital finance package.
58 See Walch (2019).

– How can regulation be effective and, at the same time, sufficiently technology-agnostic as to allow for secure innovations?

– How can networks be identified whose agents only give the impression of decentralisation to evade regulation, for example?

In some cases, regulatory regimes already exist for the interfaces between decentralised networks and the conventional financial system, such as centralised trading platforms. A particular focus here is the purchase and sale of crypto tokens in exchange for commercial central bank money, with regulation seeking to combat money laundering and terrorist financing, for instance.[59]

Regulatory treatment could boost growth of decentralised financial applications

A clear framework which also includes participants in decentralised financial applications with core functions (e.g. oracles) could provide legal certainty and thus protect the interests of consumers and investors. Regulation and the trust it establishes could thereby boost the appeal and acceptance of decentralised financial applications. At the same time, it would contribute to the stability of the system and, given the increasing degree of interconnectedness, ultimately also the financial system as a whole. In this context, regulators worldwide should collaborate to prevent opportunities for regulatory arbitrage so that existing risks are regulated equally, irrespective of the technology employed and different providers. This would create a level playing field for decentralised networks vis-à-vis conventional financial market agents. Regulation could be a precondition for sustainable growth as it is likely a necessary step in bringing decentralised financial applications to the attention of a broader set of users.

Potential implications

Links to the conventional financial system and possible impact

Decentralised financial applications can promote innovation in the conventional financial system …

Decentralised financial applications might prove to be drivers of innovation for the economy as a whole by stimulating technological developments in the conventional financial system, too.[60] Decentralised financial applications could also help tap into new business areas or contribute to developing hybrid business models through the combination of decentralised and centralised elements.[61]

… as links between both spheres are possible

As things stand, there are barely any major links to be seen between conventional financial actors and decentralised financial applications on account of the fact that the latter are still at such a premature stage of development. Nevertheless, if the use and prevalence of decentralised financial applications increases, this could have an impact on the financial system and the role of the central bank. For this to happen, however, the described constraints of decentralised financial applications would have to be removed.

There are four ways in which decentralised financial applications may conceivably seep into the conventional financial system.

– Technologies employed by decentralised financial applications could be absorbed by the conventional financial system.

– Individual decentralised financial applications could centralise and become part of the conventional financial system as new competitors. A greater degree of centralisation means that key agents could more easily be covered by regulatory regimes, allow-

59 See Deutsche Bundesbank (2019).
60 See Teis (2020).
61 See Brühl (2021).

ing some of the obstacles to development to be overcome.

– Financial services provided by decentralised financial applications that are not offered in the conventional financial system could complement the supply of services. In such a scenario, the conventional financial system could offer its customers access to decentralised financial applications or link these applications to the services it provides.

– Decentralised financial applications could crowd out parts of the conventional financial system on account of more efficient services or a lack of parity in regulation.

Decentralised financial applications can yield benefits for financial stability, …

Potential effects on the stability of the financial system depend on a number of factors and are difficult to gauge at the current stage of development.[62] In principle, increased competition that improves capital and risk allocation, and decentralisation of such exposures as have so far been focused on individual or handfuls of actors would be welcome. As a result, the systemic importance of individual actors and the accumulation of large exposures could be reduced. In addition, the use of different technologies in the world of finance can limit the risks, such as in the form of cyberattacks.

… but also harbour risks

However, decentralised financial applications can also lead to new vulnerabilities due to inherent weaknesses regarding infrastructure, the technology used and potential links to the conventional financial system, for instance. It is often impossible to adequately assess the way individual applications work, their response in the event of market turmoil as well as potential interdependencies with other applications and agents. Furthermore, concentration, liquidity and maturity transformation risks, for example, may arise just like in the conventional financial system. Additionally, the potential outflow of liquidity from the conventional financial system to decentralised financial applications may give rise to structural changes in the financial system. The automatic mechanisms in decentralised financial applications could also contribute to procyclical developments, particularly in times of crisis. Mechanisms of this kind can come into play, for instance, if a sudden decline in the value of crypto tokens used as collateral for loans or stablecoins triggers automated margin calls. If these calls are not met, self-reinforcing liquidation spirals could ensue if loans or stablecoins are, for their part, used as collateral for other transactions.

Liquidity crises can be amplified

Decentralised financial applications could make the provision of liquidity and the function as lender of last resort, which is based upon this, more difficult for central banks. In this capacity, central banks can provide illiquid but solvent financial institutions with liquidity in the form of central bank money to offset temporary liquidity shortages that could otherwise escalate into a liquidity crisis.[63] A financial system with decentralised financial applications, alternative and less transparent market structures and reduced dependence on the conventional cash cycle, and therefore also on central bank money, could prove to be more fragile compared with the current financial system and could increase the risk of liquidity crises.

Competition and innovation in the financial system

Welfare losses through monopolies could be lessened

Conventional financial intermediaries contribute fundamentally to reducing market participants' transaction costs – in favour of overall economic welfare.[64] However, network effects can cause individual financial intermediaries to gain dominant market positions, which, in turn, may lead to monopoly rents being extracted. Competition with regard to certain financial services and in the payments space could benefit from new providers in the form of decentralised financial applications. In addition, the decentralised nature of their govern-

62 See Financial Stability Board (2019) for a more detailed discussion on the following remarks.
63 See Financial Stability Board (2019).
64 See Benston und Smith (1976).

ance structures could make it hard for them to monetise a dominant market position. This could lessen welfare losses stemming from high market concentration on the provider side.[65]

New technologies promise reduction in transaction costs

Technological advancements could help DLT to realise its potential for reducing process and transaction costs in a broader sense. Transactions in decentralised financial applications could better ensure the execution of contractual services and reduce the need for custodians and central counterparties. This could result in costs being saved and inefficiencies remedied.[66]

Complex technology obstructs consumer sovereignty

As already indicated, however, trust in intermediaries, legal frameworks and institutions needs to be replaced by trust in decentralised systems. Although transparency exists in decentralised financial applications, relevant expertise is also required. It is highly unlikely that the majority of end users will be capable of understanding the program codes within a reasonable period of time. Compared with conventional finance applications, it can be harder for users to understand products as a result. Users have to trust that qualified individuals – in other words, trusted third parties after all – monitor the program code to avoid software bugs or damaging attacks occurring. Otherwise, decentralised financial applications will not be able to successfully reduce the transaction costs in an economy.

High degree of inherent innovative potential …

If decentralised financial applications grow in importance, a number of conventional business models in the financial sector could come under pressure. This could be fuelled by an environment free from regulation and therefore conducive to innovation. Unlike in the conventional financial system, there are low barriers to market entry as a result of often unenforceable or non-existent regulation and low investment expenses for new program code. Furthermore, open source program code and the ability to combine applications open up the possibility of strong momentum for enhancements, which do not require the permission of the original developers.[67]

… could be hindered due to lack of monetisation possibilities

However, there is a risk that the economic incentives are insufficient for sustainable dynamic growth. Achieving positive returns from corresponding investment in projects concerning decentralised financial applications might tend to prove difficult since existing code can be copied and newly published with minor modifications.[68] Owing to a lack of licensing income, the labour-intensive development of innovative solutions with the objective of harvesting profits in future would therefore carry significant risks. Nevertheless, developers could attempt to generate returns using additional services, such as consultancy or by providing services in the area of software support.[69]

Overall, financial uncertainty does not currently appear to be slowing down the dynamism pushing forward innovation in the field of decentralised financial applications. Furthermore, many of the innovative developments could also be transferred to existing centralised systems. This represents possibly the greatest technological potential for existing economic structures given the inherent problems associated with complete decentralisation.

A number of established enterprises could absorb innovations or offer interoperability with their own applications in combination with the implementation of DLT. Regulatory uncertainties and the need for a high level of cooperation among competitors to create interoperable infrastructures may stand in the way of this.[70]

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65 See Pike and Capobianco (2020) for comparable effects for public blockchains.
66 See Schär (2021).
67 See Chen and Bellavitis (2020).
68 In a vampire attack, the program code from an application is copied, tweaked slightly and then published. Users are given an incentive to switch to the new application by being rewarded with governance tokens. See Berg (2021).
69 See Chaum et al. (2021).
70 See World Economic Forum (2021).

Conclusion

Decentralised financial applications support an ever broadening range of financial services. Creative business models and types of enterprises are of particular interest alongside new technology. Fast-moving innovation and rapid growth could imply an increasing impact of decentralised financial applications on the conventional financial system.

However, numerous challenges and risks arise from the decentralised structure, which can act as obstacles to growth. By tendency, many barriers could be mitigated through forms of centralisation, such as organised governance.

Increasing integration with the conventional financial system is conceivable as a further stage of development. This could result in stronger competition accompanied by lower transaction costs. At the same time, risks for the financial system may emerge, making regulatory adjustments necessary, although regulation of decentralised financial applications represents a particularly challenging undertaking in this context. In the light of this, the evolution and macroeconomic impact of decentralised financial applications should be the object of greater investigation and scrutiny.

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