Lessons Learned from Decentralised Finance (DeFi)

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Abstract. On a global scale blockchain and Distributed Ledger Technology are deployed to transform existing centralised financial services. The purported divide between centralised and decentralised financial services could lead to the discrimination of either service.
In this white paper we analyse the properties of DeFi and provide lessons learned for both centralised as well decentralised financial services. Based on our analysis and the lessons learned we conclude that the best of both worlds is achieved if centralised and decentralised financial services cooperate.

1 Introduction

Decentralised Finance Applications (DeFi) have taken the world by storm since its inception in 2017. DeFi may be defined as the transformation of traditional financial products into products that operate without an intermediary via smart contracts on a blockchain [45]. In principle, any existing financial service that is centralized could be transferred to a similar decentralised financial service.

There appears to be a schism between traditional financing and DeFi. Whereas traditional financing is considered to be centralised because an intermediary manages a ledger, DeFi is considered to be decentralised as its financial services operate without an intermediary. This apparent schism is further fuelled by popular headlines in the grey literature, for example [18] [57] [59] suggesting that DeFi could replace traditional banking. In this white paper we analyse if a schism exists between centralised financial services and decentralised financial services.

We do this by first discussing the current views on DeFi in Section 2. Then, in Section 3, we analyse and discuss ten common properties of DeFi. We show that these properties can be a double edged sword. On one hand the properties allow for an improvement of existing processes, and even introduce new financial services. However, on the other hand, these properties may have severe consequences for the entire DeFi system on a global scale. To further clarify these properties, we describe and analyse a DeFi use case in Section 4. In Section 5 we propose 15 lessons learned for both centralised institutions, as well as for the DeFi community. Finally, in Section 6 we argue that DeFi aims to improve on the current centralised financial processes. Although, indeed, improvements are made, financial services in DeFi are not without risk or drawbacks. Here, in fact, centralised financial services could support DeFi in sharing knowledge and expertise on particular services that include, for example, Know Your Customer (KYC) regulation. Finally, we conclude that both traditional financial services and DeFi should cooperate to create global financial services that incorporates the best of both worlds.

2 DeFi defined

The literature contains multiple views on *what* DeFi is, such as a paradigm or a financical model, and multiple definitions of DeFi can be found. In this section we discuss these views and definitions of DeFi.

DeFi as a paradigm. A paradigm can be considered as an example [32]. Centralised finance is a paradigm of a financial system that is characterised by a central party managing a ledger. DeFi is a paradigm of a financial system that is characterised by decentralisation where multiple parties manage a ledger.

DeFi as a financial model. DeFi is a financial model on which financial services exist [21]. Brown and Oates [23], for example, explore the design of the different levels of government in assisting the poor. They discuss both a centralised approach as well as a decentralised approach ('decentralised finance and administration') in assisting the poor.

A DeFi-nition. There are many definitions on DeFi. Meegan [45], for example, defines DeFi as "... the transformation of traditional financial products into products that operate without an intermediary via smart contracts on a blockchain". Another definition is given by Gudegeon et al. [33] who argue that DeFi is a "peer-to-peer financial system, which leverages distributed ledger-based smart contracts to ensure its integrity and security". Both definitions include smart-contracts as a key component of DeFi. However, whereas Meegan focuses on the process of transformation of traditional financial products, Gudegeon et al. focus on which properties are achieved (integrity and security).

Popescu defines DeFi as "an ecosystem of financial applications that are being developed on top of blockchain and distributed ledger technology (DLT)" [53]. Here Popescu includes both blockchain as well as distributed ledger technologies, whereas Meegan [45] only considers blockchain, and Gudegeon et al. [33] only considers distributed ledger technology. However, Popescu's definition of DeFi excludes smart contracts.

Samani [43] makes a clear distinction in what type of blockchain is deployed in the following definition: "DeFi enforces financial contracts through code running on censorship resistant and permissionless public blockchains". Following Samani's definition there is an exclusion of public and permissioned, and private and permissioned ledgers. In contrast, Popescu [53] and Gudegeon et al. [33] include DLT in their definition of DeFi.

Musan [49] argues that "DeFi are DApps that enable interoperable protocols for leveraging and trading exclusively ERC-20 tokens". A DApp is a smart contract and some form of user interface, such as a website. Musan extends the definitions provided by Meegan [45] and Gudegeon et al. [33] by including a user interface.

The definitions as discussed above include:

- *What* DeFi is (e.g. an ecosystem of financial applications)
- *Which* components are used in DeFi (e.g. smart contracts)
- *Which* properties are achieved (e.g. integrity, security)
- *How* these properties are achieved (leveraging DLT, through a blockchain)

Clearly, currently there is no consensus on a definition of DeFi. We aim to separate these questions and provide a broad definition based on the question 'what is DeFi?'. In this white paper we use the following definition of DeFi:

DeFi are financial services that operate on a public permissionless blockchain.

Currently, the majority of such financial services consists of [53]:

- Translating monetary banking services (e.g. Issuance of stablecoins)
- Providing peer-to-peer (or pooled) lending and borrowing platforms
- Enabling advanced financial instruments such as Decentralized Exchanges (DEX), Tokenization Platforms, Derivatives and Predictions Markets

3 Decentralized Finance properties

DeFi properties are referred in the literature as promises [26], opportunities [58], and principles [52]. We identified the following ten DeFi properties based on our literature study:

1. Composability
2. Flexibility
3. Decentralisation
4. Accessibility
5. Innovativeness
6. Interoperability
7. Borderlessness
8. Transparency
9. Automation of business processes
10. Finality

In what follows we discuss each property:

3.1 **Composability.** Composability is, arguably, a defining property of DeFi. Gudgeon et al. [33] define composability as "the ability to build a complex, multi-component financial system on top of crypto-assets". A common metaphor for composability in DeFi is that of 'money Lego'. The main idea is that the community benefits from individual progress [53]. Composability is a property of a system where the components of a system can be easily connected [53]). Here, blockchain provides a foundation on which financial services can be built. Following the above metaphor, a blockchain can be considered as a bin in which the 'Lego' components reside, i.e. the financial services. The benefits of composability are:

- Components can be easily connected [53], in contrast to siloed and centralized payment systems.
- Components are publicly available, and can be re-used to create new financial services.

However, a major downside of composability is that an intertwined system of debts and obligations is created [33]. This, potentially, could lead to a financial crisis, similar to the financial crisis in 2008 [20]. It is yet unclear how DeFi will manage this potential effect of composability.

3.2 **Flexibility.** Flexibility is mentioned as a property of DeFi by numerous authors [45], [49], [53], although none of these authors define what flexibility in DeFi exactly is.

Flexibility can be defined as the ability to be easily modified [54]. We discuss flexibility in DeFi from the perspective of sofwtare and lack of regulation.

DeFi is built on open source code. This allows for flexibility of the software (such as smart contracts), as it can be used by anyone, and can also be copied and adjusted by anyone. Following the Lego analogy in the property Composability, the Lego blocks can also be modified in size, colour, and shape.

Furthermore, DeFi is flexible because there is a lack of regulation [44]. This lack of regulation allows for creating and using services, in principle, without any limitations. However, clearly there is a downside of the lack of regulation on DeFi, as it also easily can be used for fraudulent activities [44].

3.3 **Decentralisation.** The DeFi literature mentions decentralisation as an adjective to the following nouns: verification [24], network [24], exchange [24], business models [26], governance [53], and application [53]. However, in most cases the literature does not further define decentralisation.

In the context of DeFi, decentralisation can be described as the facilitation of financial services without the need of a trusted intermediary [53]. Catalini and Gans [24] consider that DeFi services are without a centralized intermediary. They also argue that decentralisation can be considered the verification, settlement, and agreement on the validity of digital information without a central party. However, it remains unclear what a centralized intermediary is. For example, this could be a single entity, but also a limited set of multiple entities. Popescu [53] also does not further define who the trusted intermediary is (a single entity, multiple entities), nor which party trusts this entity. Catalini and Gans [24] however, argue that trust shifts from a central party to code and consensus rules. This suggests that trust is needed despite the absence of a central party. Indeed, as an example, the users of Ethereum trust that eight miners do no collaborate, as this would result in a monopoly of those miners on the Ethereum network [30].

Clearly, there is no consensus on what decentralisation is, nor is there consensus on to what noun decentralisation applies to in the DeFi literature.

In this white paper we consider that decentralisation references to the technology, which is DLT including blockchain, on which financial services are being offered. Here, decentralisation refers to that multiple parties propose, verify, and reach consensus on ledger updates.

3.4 **Accessibility**. Schär [58] argues that DeFi protocols can be used by anyone. This is in line with the definition Schär uses for DeFi, where financial services are built on top of public platforms, such as Ethereum. However, a broader definition of DeFi also includes DLT [45], as discussed in Section 2. As some DLT platforms are permissioned private, accessibility to financial services on such platforms becomes limited.

However, accessibility on public permissionless ledgers creates a tension as on one hand countries that currently have limited access to financial services would be able to start using such services. On the other hand, lowering the barrier of entry would also allow for malicious actors in a financial eco-system to participate and use these services. Clearly, accessibility is a coin with two sides, and corporations should consider what controls should be in place to ensure that, for example anti-money laundering (AML) and Know-Your-Customer (KYC), requirements are met.

3.5 **Innovativeness.** By publicly sharing core technologies through open-source licensing, financial platforms such as Bitcoin [50], Ethereum [63], and Diem [25] allow anyone to (re-)use these technologies. As an effect, new applications can be built on top of these technologies, allowing for innovations of these platforms as well as the applications.

This is in contrast to centralized financial institutions [31]. With a few exceptions [22] [29], we are not aware of any centralised financial institution that has open sourced its core technology.

We argue that this is would be a shift in mindset for central financial institutions. Having used proprietary software for decades, and the complexity of that software makes it currently hard for these institutions to open source their core technology.

3.6 **Interoperability.** Schär [58]) differentiates between functional interoperability and technical interoperability. In functional interoperability services can work together because they exist on the same platform. In technical interoperability two different platforms can work together.

Chen [26] argues that DeFi can enhance interoperability. As centralized financial institutions maintain their own ledger, one financial service may not be interoperable with another, or moving capital between two or more financial institutions may become costly and cumbersome [26]. Chen also argues that currently DeFi has not achieved full (technical) interoperability yet due to the lack of interoperability between blockchains. As such, full functional interoperability also has not yet been achieved in DeFi.

There is much attention on interoperability by the blockchain community [38] [61] [62]. This suggests that, if interoperability will be achieved in DeFi, DeFi has a major benefit over centralised financial services as it is expected that a financial service offered on a DeFi platform can seamlessly interoperate with other financial services.

As an example, transfer of tokens from one blockchain to another blockchain can already happen anywhere in the world within minutes. This is in contrast to a traditional payment system where transferring money from one continent to another continent may take days [27]. This could, for example, provide a major competitive advantage if a company where to use a DeFi payment transfer service, instead of a centralised payment transfer service.

3.7 **Borderlessness**. Chen and Bellavitis [26] argue that borderlessness is achieved if financial services are not being tied to geographic locations or a fiat currency, and that these financial services are accessible to anyone on the globe. According to Chen and Bellavitis centralized finance can therefore not be truly borderless, because centralised finance is always tied to geographic location or a fiat currency. Furthermore, Chen and Bellavitis argue that cryptocurrencies that are blockchain-based are borderless, because anyone on the globe has access to these cryptocurrencies.

A downside of borderlessness is that financial services may not be able to comply to AML and KYC regulation. Popescu even argues that AML and KYC are concepts that "do not really fit into the DeFi ecosystem" [53]. In contrast, we argue that AML and KYC are concepts that do fit in the DeFi ecosystem. The current lack of regulation and the early discussions on AML, KYC, and DeFi can not be an argument for excluding these concepts from DeFi. Instead, large financial institutions can bring their knowledge and experience regarding AML and KYC to this debate, with the goal to embed these concepts into DeFi. We expect that adoption of DeFi will take flight by large corporations too, once this debate has been clarified.

3.8 **Transparency.** Schär [58] argues that transparency of data on a blockchain is an opportunity of DeFi. Transparency may apply to either 1. smart contracts, or 2. financial data. In both cases, anyone would be able to observe the contents of either the smart contract or the financial data.

Transparency in smart contracts allows anyone to review the code of the smart contract. As such, any individual may choose to use the financial service offered by a smart contract based on a review of its code.

Schär [58] also argues that transparency of financial data may mitigate a financial crisis. We argue that mitigating a financial crisis alone is not sufficient for financial data to become transparent. Instead, whereas privacy is a human right [28], if only a single financial system were to exist that offers transparency of both smart contracts as well as financial data, then this financial system seems not to be in line with this human right. Although several efforts are ongoing to enhance privacy in public blockchains [35] [39], we envision that centralized and decentralised finance will cooperate in offering financial services that protect the privacy of its users.

3.9 **Automation of business processes**. Smart contracts allow for the automation of business processes [52]. As business processes are automated, executing these business processes becomes more cost-efficient, as argued by Popescu [52]. Once a smart contract is created, two parties can do business with each other without the need for an external authority [52], which leads to an increase of autonomy.

However, the two parties that aim to do business with each other are dependent on the creator of the smart contract, which implies that an external

authority (i.e. the coder of the contract) must be present. Furthermore, if the smart contract does not function as expected, see for example [46], then three questions arise:
(a) Who is liable for the correct functioning of the smart contract?
(b) How can the transaction be reversed in an immutable blockchain? [52]
(c) How can the two parties ensure that the next smart contract does function according to expectations?

To mitigate the risks attached to the use of a smart contract additional measures must be put in place. Such measures will increase the cost of doing business through a smart contract. Whether or not these costs exceed the cost of a centralised party is an open question. In contrast to Popescu [52] who argues that DeFi is more cost-effiecient, Chen [26] argues that centralised parties may reduce cost. Clearly, it is an open debate on whether or not DeFi truly is more cost-efficient than a centralised institution.

3.10 **Finality.** Finality of transactions is achieved under the assumption that, eventually, all network nodes receive the transaction and agree on its validity. Furthermore, the assumption is made that once the transaction is stored on the blockchain, it can no longer be reversed or modified [47].
There are, however, also challenges if we were to assume that a blockchain can achieve immutability. Two known challenges are the occurrence of rigidity and inflexibility [48]. As DeFi is built on top of blockchain, DeFi inherits these properties, too. This may impede experimentation, learning, and discovery [26]. Also, as another effect of blockchain is that progress may stall on updating a platform when the network does not reach consensus [48].

4 DeFi use case: Aave

Aave is an open source and non-custodial liquidity protocol for earning interest on deposits and borrowing assets [17]. Aave is a decentralised application that runs on Ethereum blockchain.

In essence, Aave is a liquidity protocol that operates solely via smart contracts on Ethereum. Loans are not individually matched in Aave, instead loans rely on pooled funds, as well as the amounts borrowed and collateral posted [3]. This enables instant loans on Aave [3]. Aave can be considered as an open lending protocol, providing a market (protocol) for loanable funds, where the role that an intermediary would play in traditional finance has been replaced by a set of smart contracts [34].

Borrowers using Aave must lock-up collateral that is a greater than the value of the loan they are taking out from 'reserves' in a lending pool. All borrowing positions in Aave are backed by collateral. Lending pool 'reserves' accept deposits from lenders, who are using Aave to earn interest on their deposits. When a lender deposits into Aave, they receive an interest earning representation of their deposit, known as an 'aToken'. The amount of interest a lender earns on their deposit (represented as an aToken) is determined algorithmically in a smart contract and is based on supply and demand for that asset. For example, for borrowers in Aave, the cost of money for an asset at any particular time is dependent upon the amount of funds that have been borrowed from a 'reserve' for that asset. If the 'reserves' of an asset are low from high borrowing, a high interest rate will ensue for that asset.

Aave's interest rate strategy is calibrated to manage liquidity risk and optimise utilisation [6]. The interest rate model is used to manage liquidity risk through user incentives to support liquidity: when capital is available there is low interest rates to encourage loans and when capital is scarce there is high interest rates to encourage repayments of loans and additional deposits [6]. The borrow interest rates of assets in Aave derive from the 'Utilisation Rate' of those assets. The 'Utilisation Rate' is the percentage of reserves that have been borrowed from a pool of reserves. The more an asset being utilised (borrowed), the higher the interest rate will be for it.

Aave manages liquidity risk of asset reserves by setting an optimal utilisation rate for each asset it has available on the protocol. The optimal utilisation rate is the rate targeted by the Aave model, beyond which the variable interest rate for an asset in a pool rises sharply [11].

There are three interest rate models that are primarily used in the DeFi ecosystem to derive an interest rate from the utilisation rate of an asset: 1. linear, 2. non-linear and 3. kinked interest rate models [34].

Aave's interest rate model is a kinked interest rate model. If an asset is being utilised beyond what Aave deems to be optimal, a kink in the interest rate will occur to deter borrowers from taking out loans and encourage outstanding loans to be paid back.

For example, if Aave set 80% as the optimal utilisation rate for an asset, it means if less than or equal to 80% of a pools reserves are being utilised (borrowed), there will be no kink in the interest rate and the interest rate slope will climb slowly as assets are being utilised. After more than 80% of liquidity is being borrowed from a pool of reserves, a kink ensues and the interest rate slope climbs rapidly to deter borrowers from taking any more liquidity out and encourage paying back their loans. This brings the utilisation rate of the pool back down lower towards the optimal utilisation rate of 80%.

The optimal utilisation rate parameter, targeted by Aave before a kink occurs in the interest rate, changes depending on Aave's risk assessment for a specific asset. If Aave (or Aave governance) see a sustained rise in asset utilisation from increased borrowing, they are able to adjust the optimal utilisation ratio to ensure sufficient liquidity of reserves are available by increasing the cost of borrowing. Using a model that derives an interest rate from a utilisation rate of assets being borrowed in a pool of reserves can result in high yields (known as APY (Annual Percentage Yield) in DeFi) for depositors with funds in those reserves. High yields on offer in DeFi are a key attraction, especially in a low / negative interest rate environment.

A recent study by Gudgeon et al. [34] concluded that protocols for loanable funds (e.g. Aave) often synchronously operate at times of high utilisation. Whilst a money market operating at a time of high utilisation is attractive to lenders as they receive a higher variable interest rate on their deposits, it exposes them to liquidity risk. Gudgeon et al. [34] further conclude that lenders in protocols for loanable funds can be concentrated to a very small set of accounts, such that at any time a small number of lenders withdraw their funds, they could significantly reduce the liquidity available on markets and perhaps make such markets illiquid. This further proves that whilst interest rates on deposits in DeFi protocols can be very high in comparison to traditional finance, they are not without risk.

The biggest difference between Aave and a traditional bank now is the maturity of unsecured lending. It is uncertain if DeFi protocols are actually in direct competition with banks at all. Gudgeon et al. noted that protocols for loanable funds are not directly acting as a fully-fledged replacement for banks [34], because traditional banks are not intermediaries of loanable funds: rather, they provide financing through money creation [37]. In Aave, loans are predominantly secured (over-collaterised), there is no money creation as the borrower must post collateral that is greater than the loan they are taking out.

Aave requires an over-collaterisation of a loan to mitigate borrower default risk for lenders who have deposited reserves into a lending pool. Lenders are the ones who have provided liquidity into the reserves that a borrower utilises and are directly exposed to the risk of borrower default. To mitigate risks for lenders, Aave has public risk framework documentation, which analyses the fundamental risks of the protocol and describes the processes in place to mitigate them [12]. Aave's risk framework documentation focuses on the risk assessment for currencies supported by Aave (e.g. value/risk trade-offs of adding assets, market/counterparty/smart contract risks of existing assets, risk assessments to quantify risks per factor of assets and a risk quantification criterion).

Aave uses risk parameters to mitigate market risks of the currencies supported by the protocol [12]. Each asset in the Aave protocol has specific values related to their risk, which influences how they are loaned and borrowed [12]. Aave's risk assessment methodology uses historical data to quantify market, counterparty and smart contract risks of an asset. The historical data is then computed through a risk quantification algorithm, created by Aave, resulting in risk ratings for sub-factors of assets ranging from A+ to D-. After retrieving sub-factor risks of an asset, Aave then aggregates the average of sub-factor risks to find one overall risk rating of an asset.

Each loan is guaranteed by a collateral that may be subject to volatility, therefore sufficient margin and incentives are needed for the loan to remain collateralised in adverse market conditions [12]. If the value of the collateral falls below a threshold, part of it is auctioned to repay part of the loan and keep the ongoing loan collateralised, hence mitigating risks for lenders. Risk parameters for lending and borrowing in Aave include collateral, loan-to-value, liquidation threshold and liquidation bonus. Where collateral is the asset posted to take out a loan, loan-to-value (LTV) ratio is the amount that can be borrowed for $1 of collateral and the liquidation threshold is the max LTV above which a loan is defined as undercollateralised (and therefore can be liquidated) and liquidation bonus is the discount on the price of the asset when liquidators purchase it. For each wallet, these risks parameters enable the calculation of the health factor:

$$H_f = \frac{\sum Collateral_i \ in \ ETH \ \cdot \ Liquidation \ Threshold_i}{Total \ Borrows \ in \ ETH \ + \ Total \ Fees \ in \ ETH} \tag{1}$$

When

$$H_f < 1 \tag{2}$$

the loan is undercollaterised and it may be liquidated to maintain solvency. This is automated via smart contracts.

Risk parameters are generally adjusted to market risk of assets in Aave. Aave mitigates liquidity risk through liquidation parameters and volatility risk (risk of the collateral falling below the loan amounts) through the level of coverage required, e.g. by lowering the Loan-To-Value of volatile assets (i.e. requiring more collateral for borrowing).

Aave controls what assets can be lent or borrowed in its protocol. Currently, assets in Aave are limited to only ERC-20 tokens. ERC-20 is a standard for Fungible Tokens on Ethereum, i.e. they have a property that makes each Token be exactly the same (in type and value) of another Token [7]. Popular ERC-20 tokens that are borrowed and lent on Aave are stablecoin tokens. A stablecoin is a cryptocurrency that aims to mirror the value of a fiat currency, such as USD. Using stablecoins in DeFi is popular because stablecoins are exposed to significantly less volatility risk than cryptocurrencies, such as ETH. The price of stablecoins in DeFi are predictable, because it is unlikely (although not impossible) that the value of the stablecoin will move off-peg to a fiat currency (e.g. USD). In the past, stablecoins used to lie idle in user wallets, not being put to work. Now, DeFi lending protocols offer users a yield and a chance to deposit previously idle assets for a return. In this way, Aave's most popular use-case, borrowing and lending stablecoins, is somewhat similar to how a traditional bank functions today.

A separate, elusive innovation in Aave was their introduction of flash loans to the mainstream. A flash loan is a loan that is only valid within one blockchain transaction and is essentially non-collateralised, risk free debt [56]. Flash loans are atomic, either a loan is made with the principal and interest being paid back to the creditor at the end of a block, or it reverts back to its original state if the borrower fails to pay back the principal and interest required by the protocol within the same block. Flash loans allow borrowers with potentially no upfront capital, to make trades (often arbitrage) by borrowing upwards of millions of dollars without needing to post any collateral. Arbitrage is a common use-case for flash loans because a borrower can make trades in the required time-frame of a flash loan to be taken out and paid back [56].

4.1 DeFi Properties Analysis

The quintessence of Aave demonstrates all properties that we have found based on our literature study.

Composability. The composability of DeFi enables Aave to connect with the rest of the ecosystem [9]. Aave's composability works both ways. That is, other DeFi protocols can connect to Aave and Aave itself connects to (or makes use of) other DeFi protocols in its own design. Aave's flash loans are a popular 'money lego' that is used in DeFi's multi-component financial system. A user in DeFi can use a flash loan from Aave to self-liquidate their loans on other DeFi protocols to save costs [14], create a decentralised autonomous organisation (DAO) to find DeFi arbitraging opportunities on exchanges [8], or refinance debt via an interest rate swap by taking a flash loan out from Aave to repay outstanding debt on one DeFi protocol to receive the collateral back of that loan and use it to open a new borrow position with more favourable rates on another DeFi protocol (whilst returning owed amount back to Aave at the end of the transaction) [14]. Bear in mind that flash loans are atomic. If Aave does not receive the full flash loan taken out by a user conducting these operations (plus interest) within a block, the flash loan will revert. In terms of Aave connecting outside of its own protocol, Aave's most recent improvement proposal (as of time of writing) AIP-9, explores synergies with Balancer, a decentralised exchange (DEX) on Ethereum. Balancer is an automated market maker (AMM) with certain key properties that cause it to function as a self-balancing weighted portfolio and price sensor [16]. An AMM is a general term that defines an algorithm for creating and managing liquidity [5]. AMMs shed the concept of an order book entirely, market makers no longer specify price when providing liquidity, they merely supply the funds and the AMM takes care of the rest [15]. Balancer turns the concept of an index fund on its head: instead of a user paying fees to portfolio managers to rebalance their portfolio, a user collects fees from traders, who rebalance their portfolio by following arbitrage opportunities [16]. AIP-9 allows Balancer market makers / liquidity providers (LPs) of a specific Aave/ETH pair on Balancer DEX, to stake (lock a token in a smart contract for a period of time to earn rewards) their AAVE/ETH LP token (known as aBPT token) in Aave's safety module [4]. Aave's safety module is a smart contract that accepts AAVE ERC-20 tokens (and now aPBT tokens too). The AAVE/aBPT ERC-20 tokens locked ('staked') in Aave's safety module smart contract are used as a mitigation tool in case of a shortfall event in Aave money markets. In the case of a shortfall event, some of the AAVE locked in the safety module is auctioned off in the open-market part to be sold against the assets needed to mitigate the occurred deficit [13]. On a high-level, this example of composability is a win-win for both Aave and Balancer. Balancer LPs who are earning fees from traders in the specific AAVE/ETH pool on Balancer can earn additional yield on top of their revenue-earning LP token by staking their aBPT token in Aave's safety module. Aave is incentivising Balancer LPs (holding aBPT token) in AIP-9 to stake their aBPT tokens in Aave's safety module by rewarding them with a share of 550 AAVE/day (Aave ERC-20 tokens) [10]. Aave encourages composability to attract liquidity into the protocol for security. In turn, Aave has greater liquidity of its native ERC-20 token AAVE and increases security of its own protocol in case of a shortfall event. AIP-9 ensures greater liquidity in both protocols, which is a key driver for DeFi growth. It can be said that composability in Aave is ubiquitous. There are other examples of Aave composability in DeFi not mentioned here. The public, open-source nature of permissionless blockchain, makes it easy for DeFi protocols such as Aave to connect and plug-in to other DeFi protocols to build synergistic, interconnected financial services.

Flexibility. Aave's flexibility comes in the form of adaptation, governance and availability. Related to Aave's composability, the protocol can be flexibly adjusted to add extra assets. For an asset to be added to Aave, it must be voted on by Aave governance (holders of Aave's native ERC-20 token). Aave is fully governed by token holders of the protocol, meaning if a new asset is to be added, it must first be proposed by a user, for which other users holding the governance token of Aave can vote on whether or not it should be added. Another comment that can be made about Aave's flexibility is regarding the availability of the protocol. Aave's money market operates 24/7.

Decentralisation. Aave decentralises money markets by removing the intermediary. Decentralising the money market shifts trust from central parties in traditional finance to code and consensus rules. Instead of relying on an undefined central entity, Aave relies on validators on Ethereum to verify, settle and agree on the validity of digital information. The impact of Aave operating on a permissionless blockchain that reaches consensus on ledger updates through multiple parties proposing, verifying and reaching consensus is difficult to quantify but is a contrasting property to traditional finance nonetheless.

Accessibility. Aave is available for anyone in the world to use. To connect to Aave, all that is needed is an Ethereum address and an internet connection. Creating an Ethereum address is free and there is no limit to the amount of Ethereum addresses that can be used on Aave. Aave has lowered the barrier to enter money market financial services globally. It should be noted that an Ethereum address is just a 20 byte address represented in hexademical format. There is no name or face to an Ethereum account, meaning participants interacting with Aave are pseudonymous. As concluded from our research, making financial services more globally accessible with anonymous participants could enlarge the boundary for economic actors to act maliciously. To act maliciously in Aave, one might default on their loans deliberately and have incentive to do so if they remain anonymous. However, to mitigate the risk of default, Aave requires an over-collaterisation on secured loans being taken out. In this sense, secured lending mitigates default risk for Aave. If a user has funds, Aave recognises the funds and does not discriminate towards the user itself depositing the funds, as the protocol will always be covered with adequate collateral to liquidate if an actor tries acting maliciously. Aave's non-discrimination promotes its accessible nature.

Innovativeness. Innovation in Aave is assisted by Aave's accessibility. Aave is accessible to use and edit because it is open-sourced, meaning it is publicly available to view online and use. Aave has a repository on Github, a code hosting platform for version control and collaboration to modify its protocol. Any user (even without an Ethereum wallet) is able to propose improvements to Aave by using the Aave Improvement Proposal (AIP) template on Github. AIPs describe standards for the Aave Protocol, including core protocol specifications, client APIs, and contract standards [1]. AIPs have five stages: Work in Progress (WIP), Proposed, Approved, Implemented and Rejected. When a user drafts an AIP using Github, it must submit the draft first to the governance forum on Aave's discord. The governance forum then discuss the drafted AIP for future inclusion in a platform upgrade [1]. If the drafted AIP is successful, the AIP is progressed to approved, where it is then in queue to be implemented on Aave's live protocol (mainnet). As of time of writing, there has been nine AIPs that have been implemented to upgrade the protocol [1]. Accessible open-source improvement proposals and community governance are experimental. However, public improvements of Aave might contribute to its innovativeness in the future, as improvement proposals for the protocol are not limited to those who initially developed it (known as the Aave genesis team).

Interoperability. Aave has functional interoperability of ERC-20 tokens on its protocol. As of time of writing, Aave is not technically interoperable. For example, when a loan is taken out in Aave, a user is able to transfer the funds to any Ethereum account, globally. The user can interact with any other DeFi protocols on Ethereum with its borrowed funds, so long as the protocol accepts the ERC-20 tokens. Borrowed funds from Aave are able to be transferred across borders within seconds if a user pays a high enough transaction fee (known as Gas on Ethereum). Aave's functional interoperability makes it seamless to transfer funds obtained on Aave to any other protocol using Ethereum.

Borderlessness. It can be said that Aave is borderless by convention. As previously mentioned, there is no discrimination in Aave towards who can borrow or lend tokens. Aave itself is incorporated in UK [2], however that is not to say that financial services available in Aave are limited to just the UK. In fact it is quite the opposite, as users interacting with Aave can transfer tokens globally with no restrictions. In traditional finance, transacting with no restrictions is worrisome. Financial institutions must actively monitor transactions to make sure events such as money laundering to sanctioned countries is monitored and documented. So, although the utopian vision for borderless finance to remove friction is made possible with Aave, there is a chance in the future that regulators might feel uneasy towards this less restrictive borderless paradigm due to money laundering concerns.

Transparency. All transactions on Aave are able to be viewed on Etherscan. Etherscan is an Ethereum 'block explorer'. All transactions that have been confirmed on the underlying blockchain of Aave (Ethereum) can be viewed on Etherscan. Ethereum has a public ledger, which Etherscan indexes and makes available on its website. Users interacting with Aave (e.g. sending a transaction), can view the status of their transaction (e.g. confirmation of its success), using Etherscan. All users of Aave have an Ethereum account, which is able to viewed (not edited) on Etherscan. Ethereum is public, therefore all assets that an Ethereum user accounts owns can be publicly searched and viewed, including all transactions made on Aave.

Automation of Business Processes. Aave uses smart contracts to automate business processes. Automating business processes using smart contracts have many advantages, such as accuracy, transparency and speed [51]. However, automation of business processes might not always equal less costs of doing business. As noted in our DeFi properties review, risk in DeFi is transferred from traditional intermediaries (counterparty risk) to smart contracts (technical risk). In Aave, counterparty risk is replaced with technical risk of smart contracts. A user interacting with Aave, has a reliance on the underlying smart contract being secure. If the smart contract is not secure, the funds a user has deposited/borrowed might be vulnerable to attacks.

Aave is yet to suffer an attack on its protocol, so it may be argued that they have mitigated technical risk well. However, it is not to say these types of attacks are not a possibility in Aave in the future, as attacks are common on DeFi protocols, even when audited [36]. The automation of business processes in Aave on a public permissionless blockchain has many advantages over traditional money markets, such as accuracy transparency and speed. However, we argue that the benefits of cost efficiency and better security that come with automating money markets via smart contracts is debatable and introduce new technical risks.

Finality. Aave inherits transaction finality properties from the underlying blockchain the application is built on, Ethereum. In Ethereum, transaction finality is probabilistic, meaning there is a period of time a user must wait before their transaction is irreversibly published on the blockchain (i.e. confirmation a transaction is immutable on the longest chain that validators acknowledge as the appropriate single source of truth).

Probabilistic finality is an advantage for network security and immutability however it negatively impacts transaction latency, or, time it takes for a guarantee on transaction finalisation. In traditional finance, settlement finality is critical and refers to the moment at which funds are transferred to the receiving entity at which point they have legal ownership over those funds. Settlement finality is important in traditional finance because if immediate settlement is not made, it leaves the receiving party exposed to counterparty risk and liquidity risk. However, transaction finality is more of a cause for concern for institutions than retail, because in many cases government guarantees an insurance on retail deposits up to a certain threshold in traditional finance. For now, Aave is utilised predominantly by retail investors and deposits made on Aave are not insured by government.

Finality is a property that enhances security and immutability but it comes at the cost of greater settlement and liquidity risk. Settlement and liquidity risk are not generally a problem for retail investors in traditional finance because they are insured by government. The same assurance cannot be given on deposits in Aave. Therefore, it can be concluded that transaction finality using probabilistic consensus on Ethereum can enhance security at the expense of introducing new risks.

5 Lessons learned from DeFi

In this section we describe the lessons learned from Sections 3 and 4 for both centralised as well as decentralised financial services.

5.1 **Composability is the catalyst for innovation in DeFi.** Composability allows DeFi developers to easily connect and re-use existing components on the blockchain to create new financial services, as discussed in Section 3. Composability is an effect of open sourcing the financial services in DeFi. Corporate institutions may consider open sourcing their services, so that any other party could re-use or build upon this service. However, some services may not be open sourced as it would lead to a decrease of a competitive edge, and some services may not be open sourced due to current legislation.

    Furthermore, there are parallels that can be drawn from the global financial crisis in 2008 [45]. Debts and obligations may become intertwined when new financial services are built on top of existing financial services. Gudegeon et al. [33] argue that composability in DeFi exposes the ecosystem to 'financial contagion'. Financial contagion in DeFi can be best described as the potential damage that could be done to all protocols relying on an underlying protocol if the underlying protocol does not function as intended by the protocols that have built on top of it. It is therefore optimal to remain cautious about composability in DeFi given the property has the potential to undo all of the innovation in DeFi as fast as it has accelerated it. Corporate institutions should therefore consider to what extent they open source their existing financial services, as well as to what extent new services can become intertwined.

5.2 **DeFi is flexible.** Transactions can be sent globally 24/7 in much less time than what customers of centralised financial institutions are able to do right now [39]. Financial intermediaries remove complexities of cross-border transactions at the cost of efficiency, whereas DeFi adds complexity whilst simultaneously creating an opportunity for efficiency.

    This utility trade-off could be analysed more deeply to find an equilibrium for how much banking customers will tolerate greater levels of complexity if it results in better levels of efficiency of their financial transactions. We find reason to believe using a mixture of traditional financial methods and DeFi might be a winner in the future to reduce cross-border transaction times and costs whilst still being able to properly monitor who is receiving the transactions.

5.3 **DeFi legislation may improve DeFi adoption.** If regulators announce favourable legislation of DeFi, it is more likely that financial institutions will adopt DeFi. However, there is still a long way to go in the regulation of DeFi. One glaring area that we see as holding DeFi back from adoption right now is the lack of clarity on where liability lies if a DeFi protocol does not work as intended.

5.4 **Centralised institutions can benefit from DeFi's Borderlessness.** For centralised institutions it is costly to comply to multiple regulations in different jurisdictions. Also, Thanks to the underlying distributed ledger technology, DeFi covers multiple geographies. In principle, anywhere on the globe, and even outside of the globe [41], anyone with an internet connection can have access to the financial services of DeFi as DeFi covers multiple geographies. Centralised financial services may consider partnering with decentralised financial services to create partnerships where expertise of both can be combined. Although DeFi currently appears to be a domain on its own, we envision that centralised and decentralised financial services will converge at some stage as both have unique capabilities that are beneficial to the other. There is however the challenge for centralised institutions of making sure that their assets stay within countries that are white-listed.

5.5 **DeFi is a coin with two sides**. Current DeFi innovation is focusing on micro-effects, not macro-effects. The current innovation in DeFi, such as the issuance of stablecoins, or providing peer-to-peer lending platforms, (as introduced in Section 2), as well as the use case in this white paper (as discussed in Section 4) aim to improve existing, centralised financial services, or propose new types of financial services. This is what we consider micro-effects of DeFi. However, the macro-effects of decentralisation of financial services have been discussed before the introduction of blockchain in 2009 [50]. These effects are currently lacking in the discussion on DeFi in the literature. For example, decentralisation may have "dangers" [55], "pitfalls" [60], and "may be in need of rethinking" [42].
Although DeFi may seem to offer many opportunities by improving existing or introducing new financial services, its macro-effects should be taken into account as well. We consider a discussion on the macro-effects of DeFi as future work.

5.6 **DeFi properties are not always realised in practice.** Properties of DeFi including efficiency, transparency, decentralisation and finality are beneficial in theory, however, in practice the benefits of these properties are not always realised. Transaction costs, for example, are higher in some cryptocurrencies than transactions in a centralised payment system [40]. As another example, (Bitcoin and Ethereum are less decentralised than envisioned [30]. Although DeFi sounds great in theory, it appears that there are multiple hurdles to overcome before DeFi can be used by current corporations.
Although, arguably, the improvements of existing centralised financial services can be achieved without DeFi, we consider that exploring the possibility of combining DeFi with existing financial service that are centralised could offer a solution, too.

5.7 **There is not a clear definition of DeFi, yet.** As discussed in Section 1, DeFi is a paradigm, a concept, and an application of financial services that use a blockchain. Also, in Section 2 we observed that DeFi can relate to public blockchains, as well as permissioned blockchains. Therefore, to have a sensible debate about DeFi, any corporation should aim to define DeFi first before discussing its application, benefits and challenges. In this white paper we have proposed to define DeFi as any financial service that resides on a blockchain.

5.8 **DeFi literature requires a critical review.** Most academic literature that we have reviewed outline the benefits of DeFi, yet little insight is given into the inherent risk an organisation might take by utilising a nascent technology, such as blockchain. The literature shows a positive effect of DeFi. However, a critical view of these papers suggests that there may be challenges, too, as we discussed in Section 3.

5.9 **Currently there is a tension between transaction transparancy and basic human rights.** DeFi offers transparency of financial transactions at the cost of privacy. The transparant property of DeFi may go against basic human rights, as discussed in the property Transparancy in Section 3. However, DeFi may offer improvements to the current centralised financial services that are being offered. As such, large corporations should seek to cooperate with DeFi companies, instead of reinventing the wheel. Similarly, DeFi companies could learn and adopt the knowledge, experience, and processess that large corporations have in place, such as AML and KYC.

5.10 **Defi is not without risk.** Some of the DeFi literature appears to be biased towards DeFi. The examples provided in the literature are only one side of a coin, and may only apply to a single type of use case. However, when transactions are made with large sums of money, than the participants in such a transaction wish to have several risks to be mitigated. Some of the current DeFi literature seems to simply neglect some of these risks [45]. This is where DeFi can learn from the vast experience of centralised institutions. In our opinion, it would be naive to assume that a technology can replace an institution. For example, given the current state of smart contracts, a smart contract could never replace a third party such as a lawyer, as the spirit of the law can not be captured in code alone.

5.11 **There is currently no liability in DeFi.** Proponents of decentralisation may argue that little to no liability in DeFi is a benefit, rather than a disadvantage of DeFi. However, we argue that greater liability in DeFi will add to DeFi's credibility. The decentralisation property of DeFi shifts an end-users trust in the quality of the platform from that of an intermediary, to that of one who wrote the smart contract on which the DeFi protocol operates. There has been a trend in DeFi for founders to release protocols anonymously, for which sometimes millions of dollars can pour into a smart contract in a matter of minutes.

5.12 **Full (de)centralisation may be suboptimal**. Nakamoto [50] argues that a system where financial institutions serve as a trusted third party suffers from the inherent weaknesses of a trust based model. However, Brown and Oates [23] argue that a fully decentralised system will be suboptimal and may need central participation, in their particular use case. A downside of decentralisation, for example, is that it may lead to disparity and adversely affect the distribution of equity, it may jeopardise stability, and it may undermine efficiency [55].

The extent to which a fully decentralised financial system is optimal is subject for future research, although some research has already been performed. Darcy et al. [19], for example, argue that blockchain technologies may propel and lower the cost of institutional evolution.

A fully centralised and fully decentralised system both have inherent weaknesses. Following this white paper, we envision that the future of payment systems will be one where centralised and decentralised systems are combined to best serve the need of its customers.

5.13 **Tying real world assets to DeFi remains a challenge.** Right now most innovation in DeFi is about improving financial services. Such services in DeFi include digital tokens and mostly exclude real world physical assets. Note that we make a distinction in our white paper between digital tokens and digital assets. These digital tokens only exist in a digital form and have no counterpart in the real physical world. An example of a digital token are cryptocurrencies. By contrast, digital assets do have a counterpart in the real physical world. An example of such a digital asset is a house. A token could be created for a house, such that this particular token is a digital representation of its physical equivalent.

There has been a slow uptake of tokenisation of assets, which could accelerate DeFi liquidity even further. However, the main challenge is to ensure that there is a link between the digital token and its physical equivalent. For now, it appears that a central party (such as a notary) is required to ensure and guarantee that such a link exists. This would suggest that combining the benefits of DeFi with a centralized party is needed.

5.14 **More work on DeFi risk is needed.** If corpporate institutions are to take DeFi seriously, more work on DeFi risk is needed. Traditional financial institutions are risk averse and aim to redistribute risk where possible.

In DeFi it is not clear which risks exactly are present, although first steps are taken to identify these risks [45]. Once these risks have been identified, the next step is to determine how to mitigate these risks. Currently, it seems unlikely that a single smart contract would be able to do so.

5.15 **AML in DeFi could be assisted by financial institutions.** Onboarding and offboarding of customers that want to use DeFi services can be provided by financial institutions. This way a DeFi service could comply to AML regulation. However, as this is uncharted territory, more research is needed to determine the validity of such corporation between centralized banks and decentralised financial services.

6 Conclusion

DeFi is a new paradigm where decentralised financial services are offered based on blockchain. In this white paper we analysed ten DeFi properties and discussed the benefits and downsides of each property. Our analysis suggests that DeFi may offer improved or even new financial services. As such, centralised financial institutions can learn from DeFi on how to improve existing processes. However, we also showed that DeFi is a coin with two sides - there are serious risks in DeFi that should be considered. This is where centralised financial institutions can in fact help DeFi companies in addressing these risks.

Despite that these centralised and decentralised financial services appear to be different, based on our analysis we envision that these two services combined will bring benefits to both centralised institutions, to DeFi, and more importantly, its customers.

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