Blockchain in Financial Services: Current Status, Adaptation Challenges, and Future Vision

Anisha Mia  
Fordham University

Mohamed Rahouti (mrahouti@fordham.edu)  
Fordham University

Senthil Kumar Jagatheesaperumal  
Mepco Schlenk Engineering College

Moussa Ayyash  
Chicago State University

Kaiqi Xiong  
University of South Florida

Fredery Fernandez  
Fordham University

Modupe Lekena  
Fordham University

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Blockchain in Financial Services: Current Status, Adaptation Challenges, and Future Vision

Anisha Miah¹, Mohamed Rahouti¹*, Senthil Kumar Jagatheesaperumal², Moussa Ayyash³, Kaiqi Xiong⁴, Fredery Fernandez¹ and Modupe Lekena¹

¹Department of Computer and Information Sciences, Fordham University, Bronx, 10458, NY, USA.
²Department of Electronics and Communication Engineering, Mepco Schlenk Engineering College, Sivakasi, 626005, Tamilnadu, India.
³Department of Computing, Information, and Mathematical Sciences and Technology, Chicago State University, Chicago, 60628, IL, USA.
⁴Florida Center for Cybersecurity, University of South Florida, Tampa, 33620, FL, USA.

*Corresponding author(s). E-mail(s): mrahouti@fordham.edu;
Contributing authors: amiah6@fordham.edu;
senthilkumarj@mepcoeng.ac.in; mayyash@csu.edu;
xiongk@usf.edu; FFernandez13@fordham.edu;
mlkena@fordham.edu;

Abstract
Blockchain is undoubtedly considered one of the most innovative technologies in financial services from the past decade. Interests in blockchain technology continue to grow on a daily basis, while many promising blockchain-enabled applications and services continue to draw financial interests in the industrial sector and the broader financial services communities. Furthermore, as blockchain matures, it increases the value of a diversified range of industries and institutes with a better return on
Blockchain technology is undoubtedly the most important innovation to come out of late 2008 as blockchain-based cryptocurrencies such as Bitcoin and Ethereum, have dominated the financial world. With the various use cases of blockchain across several industries, the financial service realm requires much more guidance and regulated integration models before jumping on to the new technology bandwagon [1].

Blockchain technology is a distributed shared ledger that is designed to replace a centralized structure with a decentralized one by incorporating algorithms [2]. This ledger technology is immutable and stores information about transactions and assets where no single entity is in-charge. This unique technology eliminates the need for a third party to authenticate processes. Instead, it operates through a distributed register with universal authentication (Figure 1). Its best-known application is Bitcoin, a cryptocurrency that employs blockchain to enable users to perform transactions without a third-party intervention [3].

While this technology is still relatively evolving and in its emerging stages, it is thought to have the potential to deliver a new strain of innovation to the financial world and in financial technology (Fintech). Some key features of blockchain include:

- Distributed ledger technology (DLT): In a blockchain network, all network participants have access to the distributed ledger, which contains information of all transactions from the beginning of time without any duplication [4]. This maintains the integrity and efficiency of all transactions being conducted.
- Immutable records: Records within ledgers cannot be modified by any user [4]. This means that if a mistake had been made in a transaction, another transaction has to be done to fix the mistake without removing the history of both transactions. This ensures traceability and a sense of trust among users in the blockchain network.
• Smart contracts: Smart contracts are small identifications that hold information to fasten the speed of transactions [5]. For example, it may hold conditions for corporate bond transfers, including terms for travel, how much insurance is to be paid to a certain in iterations, etc. [4]. This provides users with the comfort to save time on repetitive transactions/processes being conducted within the blockchain network.

Essentially, blockchain is considered an ideal solution for information and data delivery as it enables not only immediate but transparent and shared information, which could be accessed by permissioned network participants only [4]. Since every participant in the platform shares a common (single) view of the truth, the details of an end-to-end transaction can be easily traced, providing the users in this network with assurance as well as new efficiencies.

In financial services, blockchain provides many benefits as well as potential challenges during its implementation phases.

1.1 Scope of the Paper

Blockchain technology, in general, brings vital improvements over the traditional security solution approaching in different perspectives for financial services. First, it improves the trust prospects of financial services with a better return on investment. Consequently, some features that might not appear
to a human view can be extracted with ease by completely adapting the core features of blockchain and its enabling technologies.

In this paper, we review a wide range of blockchain services and explore the financial applications that have benefited from blockchain technology. The paper identifies the impacts of blockchain, its benefits, and challenges in different blockchain-enabled financial services. It also discusses the characteristics and market quo and guides matching them with the appropriate blockchain technology. This survey also focuses on the adaptation model for blockchain technology that various government agencies and financial institutions could use for deploying trustworthy financial services. Moreover, a robust blockchain-enabled framework is provided in order to help the lending and banking institutions understand the advantages and challenges of the blockchain and smart contract implementations in their organizations and services. Last, this survey also explores the details of the vision of blockchain from various future financial services.

1.2 Related Papers

Researchers in both academic and industrial sectors have been exploring and investigating the various opportunities that blockchain technology brings into different financial applications, such as the integration of blockchain in the mortgage lending process [6, 7]. In a similar context, another area under investigation for blockchain implementation is the monopolistic credit reporting
Financial technology companies are being established on a worldwide scale. National security experts are tracking these developments as they sense that a lack of involvement from developed countries can bring significant national security risks [11].

To the best of our knowledge, there is no significant literature dedicated to the survey of the specific implications of blockchain for a large range of trustworthy financial services. There are few works presenting common usage of blockchain technology that has been used in certain minimal economic aspects. The work presented in [12] by Wang et al. focused on blockchain approaches in financial trust mechanisms. However, that work did not consider the broad range of blockchain from a market perspective and adaptiveness, which is the focus of our survey. Moreover, their focus is sparse on the blockchain, while we also consider current trends, adaptation, and future focus of using blockchain for a diversified range of financial services.

Liu et al. [13] have reviewed different classes of applying blockchain technology for addressing the primary financial market and discussed the potentials of using these technologies in the future financial markets. Nonetheless, they also did not study the role of blockchain on the adaptation aspects and diversified range of market status.

The work in [14] by F. Schär et al. provides a survey of decentralized finance for smart contract-based financial markets. In that work, the authors highlight the potential risks of a decentralized finance ecosystem, such as asset management protocols, decentralized exchanges, and debt markets. This work focuses on robust and transparent financial services, while our work is not wholly dependent on decentralized finance, but includes it as one of the core concepts in the applications of blockchain-enabled financial services. Further, in [15], the authors addressed the economic benefits of using blockchain technology. While this work primarily focuses on the clustering analysis considering various themes, it differs from our work on the usage of blockchain for a wide range of financial services.

Beyond the specific works on blockchain, Chen et al. [16] reviewed decentralized business models along with several empowerment strategies, including a transparent and distributed trust for decentralized financial services. Furthermore, they have also summarized the challenges and limits in achieving the full potential usage of decentralized finance. Last, a comparison summary between our paper and related works is presented in Table 1.
Table 1: Summary of existing surveys related to blockchain-enabled financial services.

<table>
<thead>
<tr>
<th>Refs.</th>
<th>Year</th>
<th>Financial Services Review</th>
<th>DeFi Review</th>
<th>Market Status</th>
<th>Adaptation Aspects</th>
<th>Future Visions</th>
<th>Insights</th>
<th>Overview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walsh [17]</td>
<td>2015</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>Discusses the applicability of bitcoin blockchain in the financial market infrastructure</td>
</tr>
<tr>
<td>Underwood [18]</td>
<td>2016</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>Discusses applicability of blockchain technology in financial and commercial applications, and the associated implications</td>
</tr>
<tr>
<td>Fanning &amp; Centers [19]</td>
<td>2016</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>Reviews the functionality of blockchain technology and its impact on financial services (Blockchain 2.0)</td>
</tr>
<tr>
<td>Casey et al. [20]</td>
<td>2018</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Studies the influence of blockchain technology on finance, challenges, and associated trends</td>
</tr>
<tr>
<td>Xu et al. [15]</td>
<td>2019</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Analyses research themes related to economic benefit, blockchain technology, fintech revolution, and sharing economy. Future recommendations are also presented</td>
</tr>
<tr>
<td>Zhang et al. [21]</td>
<td>2020</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>Review the blockchain technology and its application in the financial and economic field, status and challenges.</td>
</tr>
<tr>
<td>Liu et al. [13]</td>
<td>2021</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>Reviews the technical basis of blockchain financial model and application scenarios in the financial market</td>
</tr>
<tr>
<td>Schar [14]</td>
<td>2021</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
<td>Discusses opportunities and potential risks of the DeFi ecosystem</td>
</tr>
<tr>
<td>Our Paper</td>
<td>2022</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Reviews a wide range of blockchain services, explores financial applications that have benefited from blockchain technology, identifies the impacts, challenges, and future visions for blockchain-enabled financial services.</td>
</tr>
</tbody>
</table>
1.3 Contributions

This article focuses on blockchain technology playing a vital role in the financial services market. The article aims to explore the potential applications, opportunities, and challenges associated with the deployment of blockchain technology in financial services and applications. The contributions of this survey can be summarized as follows:

- We present a detailed review of the current literature on the deployment of blockchain technology in financial services with a particular focus on enabling services, applications, and associated opportunities and challenges.
- We pay particular attention to the various benefits and drawbacks related to the adoption of blockchain technology in financial services, including primary market, secondary market, and clearinghouse market.
- Being an evolving and growing component of financial services, we further discuss the adaptation models for blockchain technology to facilitate global banking services from different perspectives.
- We provide a robust blockchain-enabled framework for lending and banking institutions to help understand the advantages and challenges of the blockchain and smart contract implementations in their organizations and services.
- Building upon this, we further provide a vision for the future of blockchain in financial services and applications. Here, we cover such a vision from the essential aspects related to financial services, including trade finance opportunities, asset tokenization, and enhancement of clearing and settlement via Distributed Ledger Technology (DLT).

The roadmap of this paper is depicted in Figure 2. Precisely, Section 2 discusses the key components and enabling technologies of blockchain and provides a detailed description of its technology involved in industrial services and applications. Section 3 reviews the decentralized finance and blockchain involvement. Section 4 provides an overview of the literature on blockchain technology in financial services with a particular focus on applications and services. Next, Section 5 explores the impact of blockchain technology on the market segments, focusing on the primary market, secondary market, and clearinghouse. Section 6 provides insights about adaptation models for blockchain technology in global banking services and a robust framework for blockchain-enabled banking and lending services. Section 7 gives a vision for the future of blockchain technology in financial services in general. Finally, Section 8 concludes the paper. All related acronyms used in this paper are given in Table 2.

2 Features and Applications of Blockchain

Blockchain has become an important solution to break the bottlenecks involved in financial services by virtue of its advantages of decentralization, immutability, auditability, and fault tolerance. In this section, a brief overview
of the key features and primary advantages of blockchain technology is presented at first. Following that, the appealing characteristics of blockchain for various applications are discussed. Further, types of blockchain implementations, along with their programmable capabilities through smart contracts, are discussed.

### 2.1 Types of Blockchain Networks

- **Public blockchain network:** A public blockchain allows any user to join the network, allowing almost full transparency of all transaction details to all participants. Substantial computational power is required since the number of users is not limited and maintains a weak to moderate security structure. An example of this type of network is Bitcoin \[4\]. Public blockchain networks can also be set up as permissioned blockchain networks (Please see Permissioned blockchain networks below).

- **Private blockchain network:** In a private blockchain network, although it maintains a similar decentralized peer-to-peer network like a public blockchain network, an organization is in charge of governing the network. This authority can control the number of participants, execute a consensus protocol, and maintain authority over the shared ledger. Depending on the

### Table 2: A Summary of acronyms used in this article.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4AMLD</td>
<td>Fourth Anti-Money Laundering Directive</td>
</tr>
<tr>
<td>AML</td>
<td>Anti-Money Laundering</td>
</tr>
<tr>
<td>CFMM</td>
<td>Constant Function Market Maker</td>
</tr>
<tr>
<td>DAO</td>
<td>Decentralized Autonomous Organization</td>
</tr>
<tr>
<td>DDoS</td>
<td>Distributed Denial of Service</td>
</tr>
<tr>
<td>DeFi</td>
<td>Decentralized Finance</td>
</tr>
<tr>
<td>DLT</td>
<td>Distributed Ledger Technology</td>
</tr>
<tr>
<td>DoS</td>
<td>Denial of Service</td>
</tr>
<tr>
<td>eIDAS</td>
<td>Electronic IDentification, Authentication and trust Services</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>FCA</td>
<td>Financial Conduct Authority</td>
</tr>
<tr>
<td>FDIC</td>
<td>Federal Deposit Insurance Corporation</td>
</tr>
<tr>
<td>Fintech</td>
<td>Financial Technology</td>
</tr>
<tr>
<td>INATBA</td>
<td>International Association of Trusted Blockchain Applications</td>
</tr>
<tr>
<td>LP</td>
<td>Liquidity Pool</td>
</tr>
<tr>
<td>KYC</td>
<td>Know your Customer</td>
</tr>
<tr>
<td>M2M</td>
<td>Machine to Machine</td>
</tr>
<tr>
<td>NYDFS</td>
<td>New York Department of Financial Services</td>
</tr>
<tr>
<td>OTC</td>
<td>Over-the-counter</td>
</tr>
<tr>
<td>P2P</td>
<td>Peer-to-Peer</td>
</tr>
<tr>
<td>PoS</td>
<td>Proof of Stake</td>
</tr>
<tr>
<td>PoW</td>
<td>Proof of Work</td>
</tr>
<tr>
<td>PE</td>
<td>Public equity</td>
</tr>
<tr>
<td>SSI</td>
<td>Self-sovereign Identity</td>
</tr>
</tbody>
</table>
Table 3: Characteristics of public and private blockchains.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Public Blockchain</th>
<th>Private Blockchain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Open read/write</td>
<td>Permissioned or federated read/write</td>
</tr>
<tr>
<td>Identity</td>
<td>Pseudo anonymous</td>
<td>Known identities</td>
</tr>
<tr>
<td>Speed</td>
<td>Slower</td>
<td>Faster</td>
</tr>
<tr>
<td>Security</td>
<td>PoW/PoS</td>
<td>Pre-approved participants</td>
</tr>
</tbody>
</table>

scenario, this is a network best implemented for organizations where trust and confidence are highly prioritized [4].

- Permissioned blockchain network: A permissioned blockchain network is a network where restrictions are placed on users to participate in or view certain transactions occurring in the network. Users will require an invitation to join this network [4].

- Consortium blockchain network: A Consortium blockchain network is similar to a Private blockchain network, but with multiple entities sharing responsibilities of the blockchain maintenance. Pre-selected organizations are able to determine which participants have the authority to submit transactions or access data. A consortium blockchain deals with a scenario where all participants will need to have modified permissions and have a shared responsibility for the blockchain network [4].

2.2 Primary Advantages and Key Applications of Blockchain

Once a user submits a transaction, it is registered as a block of data. These blocks are then linked to form a chain, producing a block–chain as more data is added. Besides holding data, blocks are responsible for holding time and sequence information which are then used to connect them in a series [22, 23]. To be more precise, each block is contained as a hash, or a digital fingerprint, storing its previous block hashes so that the history of one transaction can be traced back to its very first block. This method deems blockchain as tamper-evident, lending to the key attribute of immutability [22].

After a transaction is completed, the shared ledger is updated and acts as the single source of truth. Therefore, once the new transaction is amended, all participants in the network receive a copy of this transaction can view the transactions according to permissions provided to them in the network [24].

The key Applications of blockchain technology are summarized as follows:

- Data sharing: It has become customary to mention nowadays that data is a very precious resource and is considered to be a new form of money. This is mainly for enterprises that own data servers, connecting people and the community together. They are exploring new opportunities to extend the revenue stream beyond establishing connectivity. However, as more transactions happen, the volume of data collected will be huge, making the security of financial data more challenging. To reconsider the notion of value
exchange and overcome the challenges existing in data sharing, blockchain has come to the rescue in all trusted environments. Blockchain can help the data handling enterprises reap the financial rewards to a larger extent [25, 26]. It can reshape the industry by enabling trust, enhanced sharing of information, and improved opportunities to trace and track digital assets. Blockchain-based data sharing and data access control system provides masked data circulation, privacy data sharing, and internal data access control mechanisms. The masked data circulation provides intelligent data retrieval, authentication, authorization, traceability, and data circulation tasks [27]. Privacy data sharing innovates the authorization service flow for the user and shares the data according to the authorization credential by placing them on the chain [28]. Further, the internal data access control mechanism empowers the data access application, authorization, approval, and execution of procedures by introducing a smart contract for the realization of automated permission and control of the relative database access [29].

- **Data security:** Blockchain can secure sensitive data in terms of storage enabled by breaking up data into chunks and encrypting them so that only the authenticated and authorized users can access these data. Cryptographic encryption of the data in a blockchain network gives way to the users to ensure that their data are untampered [30]. Security is also imparted by distributing the files to a network so that all the files are available, even if a part of the network is down. However, the security is also limited by the size of the network [31]. If a blockchain network is not large enough or well distributed, they become vulnerable to attacks. Further, more redundancy of data may be needed than other storage solutions.

- **Trust:** Predictability and accountability aspects of security concerns that are prevalent in handling vital data and resources need to be imparted with proper trust mechanisms [32]. The trust and consensus delivered through blockchain technology stand in the topmost layer with the decentralization architecture. Such trust concerns play a crucial role, particularly in smart contracts, digital currencies, record keeping, and securities imparted through blockchain technology. It makes the users trust the services when no one is in charge of the transactions happening in the network. Multi-faceted trust issues in the cryptocurrency ecosystem built using blockchain services [33] reveal the significant effort involved along with the potential solutions from the users and government perspectives. Further, the underlying topology also plays a vital role in trust enhancement. In [34], the authors presented a Peer-to-Peer trust-enhanced blockchain topology for reliable and fast broadcasting, and enables fast broadcast through spanning-tree broadcast algorithm and analyzes the network loads.

- **Distributed autonomous organization (DAO):** One of the interesting forms of blockchain is it enabled new forms of distributed technology, which is anticipated to act as the heart of the social organization. This could
be established by the DAO with the potential of blockchain to revolutionize human social institutions. A DAO is an organization that is managed through rules, coded in smart contracts, and run on the blockchain. Blockchain enables to provide truly distributed organizations at a global scale, which runs by the rules defined by the members through a consensus process and written into a set of contracts that run through computer programs [35]. As DAO is an online platform community, its resources are organized according to the rules agreed in advance and implemented in the code. From the hierarchical structures, organizations have been evolved to the modern bureaucratic organizations, where businesses operate by the rules defined through programs automatically [36]. It enables automated management of the distributed organizations on a more technical level.

- **Decentralized Finance (DeFi):** The financial transactions not controlled by any bank or government are known as decentralized money. It paves the way for the establishment of DeFi with the backbone of blockchain. In DeFi, the financial services are transactions that could be made without any central authority [37]. DeFi requires decentralized infrastructure and platforms for writing decentralized programs. Ethereum can be used as one of the platforms for creating decentralized apps. Decentralized exchanges are also being built on Ethereum platforms, which can be completely autonomous and provisions free access for all exchanges [38]. Furthermore, decentralized money markets also could connect borrowers with lenders and assist in providing autonomous management of loan terms. Such an extensive range of decentralized services provided by DeFI is aimed to replace the current centralized financial system. We summarize in detail the selected works on DeFi in Section 3.

### 3 Innovations and Activities of DeFi

From the development of bitcoin to Ethereum, the financial industry now has a digital platform that provides trustless finance [39]. Ethereum, offering a blockchain with computational capabilities, was a new frontier for blockchain-based financial services innovation. Such an innovation was followed by a series of novel cryptocurrencies and crypto-enabled services [40]. Namely, Stable Coins via Maker, ERC20 Token exchanges, crypto-lending, borrowing, and staking (aka named DeFi Summer, and then liquidity mining via Compound finance). Some of these major concepts will be elaborated on in detail next.

#### 3.1 Primary Innovations of DeFi

The primary innovations of DeFi are summarized as follows.

- **Maker:** Enabled the creation of a decentralized stable coin called DAI. It was initially backed by a single currency, ETH, but later became a multi-collateral stable coin that could be created using any ERC20 token [41]. The key advantage of this stable cryptocurrency is that it enhances the
Blockchain in Financial Services

predictability of currency and allows for its broad use as a means of exchange in commerce.

- EtherDelta and other distributed ERC20 exchange platforms: Enable currency holders to trade tokens with each other. The early iteration was based on an order book which was a popular system for managing the buy and sell sides of an exchange market [42].
- Uniswap: Created the first decentralized ERC20 exchange that did not require the use of an order book like traditional financial exchanges. Instead, it uses an Automated Market Maker, which allows for digital assets to be traded without permission and is automatic through the use of liquidity pools (LP) [43]. Uniswap is arguably one of the most important DeFi projects today.
- Compound: A platform to orchestrate a Lending market. Members who save their digital assets on the platform can not only borrow out those assets but also loan using the saved money as collateral [44]. The advantage of this innovation is its allowance for inception and usage of a liquidity program whereby users are paid to use the platform. This incentivizes users to issue more transactions on the platform, saving more funds or borrowing more assets. This innovation led to the realization of liquidity mining.
- Yearn Finance: Automates the process of lending, staking, and farming. Through the usage of its multi-asset tokens, the underlying assets are automatically moved from one liquidity program to another based upon a predefined strategy written by the community to yield the most liquidity returns [14, 45]. Another major innovation by Yearn is the release of its governance token, its total volume, to the market (without holding a portion of it for the founders or development team, resulting in boosting the price of this token in the past).

3.2 DeFi Activities

As discussed above, there are various DeFi projects and activities related to the industry of financial services. In this subsection, we will review and discuss the practice of trading, storing or saving, lending and loans (including zero collateral loans), liquidity provisioning or staking, and lastly, yield farming, simply called farming.

3.2.1 Trading

One of the first activities enabled by the Ethereum platform was the ability to trade assets [46]. Trading was initially performed using traditional trading techniques, colloquially called TradFi, a centralized entity to orchestrate and execute the trades between different parties, often using an order book. Upon the occurrence of smart contracts, on-chain currency trading was introduced. This led to the establishment of DeFi. Here, the deployment of blockchain to conduct trading removes the need for many intermediary trade management
functions such as Orderbook verification, online payment gateways, stockbrokers (i.e., users manage their own assets while the blockchain manages to perform correct transactions).

The most notable types of decentralized exchanges are called Liquidity Pools (LPs). LPs allow the exchange of cryptocurrencies without permission or authoritative control [47]. Without the need to share their identity, users can perform a trade. LPs operate by creating pools of funds between two different types of currencies. Traders can then exchange one of two pooled tokens for another [48]. One type of LP is called an Automated Market Maker, which prices the trades between pairs via a pricing function such as a Constant Function Market Maker (CFMM). In CFMM, a constant function represents the fact that any trade should change the reserves in such a way that the product of the reserves must remain unchanged (i.e., equal to a constant) [49].

The CFMM comprises three participants:

- Arbitrageurs: Maintain assets’ prices within the portfolio with respect to the market price (exchange for a particular profit).
- LP: Aiming to provide trades against their portfolio (exchange trade for a particular fee).
- Traders: Exchange one asset for another one.

The CFMM is used in secondary market trading to efficiently represent the price of assets on the reference market. The function was initially implemented by Uniswap in accordance with the following equation:

\[ K = (R_\alpha - D_\alpha)(R_\beta + \tau D_\beta), \]  

(1)

Where \( R_\alpha \), \( R_\beta \), \( D \), and \( \tau \) denote the reserves of each asset, the invariant reflecting the reserve’s value, and the transaction fee. According to this equality, trading any amount of either asset will update the reserves such that if the fee is zero, the product \( R_\alpha \times R_\beta \) will stay equal to the constant \( K \). Since Uniswap applies 0.3% as a trading fee charge (added to reserves), each trade will increase by \( K \) in practice.

Besides consensus instability, new challenges arise with the use of these trading facilities, such as front-running of trades and price slippage [50, 51]. Due to the price changes that occur as a result of the constant function variation, large trades that would dramatically shift the price are susceptible to being front-run where other users submit trades ahead of large transactions in order to shift the cost of the manipulated trade, making it more expensive to conduct the trade. Another challenge that occurs when trading through LPs is the trading fees. This can cause some trades to no longer be lucrative to perform (e.g., when the trade fees dwarf the actual fund amount being swapped). Although there has been an immense effort to scale up LPs using off-chain or side-chain computations in order to lower the price, this remains a vital challenge.
3.2.2 Financial Saving

Saving accounts are another well-known method for seeking greater yield on users’ funds. Similar to that of a traditional bank, a user can open a crypto savings account and store their crypto or fiat currencies [52]. However, one of the important differences here is that these accounts do not have the advantage of being insured by the Federal Deposit Insurance Corporation (FDIC). Despite this, like most instruments in finance, with greater risk, there is a greater reward. These saving accounts can often boast higher interest rates even as high as the golden standard of stock market return of 8% (e.g., BlockFi, a cryptocurrency exchange, and wallet platform). Nowadays, saving on the crypto space has begun to take on a new meaning (see Staking and Liquidity Provisioning subsection).

3.2.3 Lending

Although previously available to some degree, lending was solidified by the creation of Compound finance [53]. In traditional finance, the available cash banks have to lend out to potential borrowers is based on the funds that other account holders placed in their savings account. Lending in DeFi follows a similar model except, in this case, the intention of offering funds to be borrowed is more intentional as users offer liquidity to the loan market. As a reward, loan liquidity providers receive interest on those funds. On the other side, users seeking to borrow funds have a large market from which they can borrow funds.

A user’s ability to borrow funds is completely based on their available collateral. That is, a user’s borrow limit is based on the percentage of their available collateral. If the borrowing limit is 75% of one’s collateral, with $100 of collateral, the available borrow limit is $75. This unlocked two things; (1) users can now benefit as loan providers compared to in TradFi (a mobile/web application that allows users to invest in financial instruments [54]), where banks were the greatest winners as they created and facilitated the market. Here platforms like compound simple create coordination, but users are the supply and the demand of liquidity; (2) loans could be taken out at lower rates, and the qualifications of taking funds out are clear and consistent, simply being based on one’s available collateral.

3.2.4 Liquidity Provisioning

The trading activities through LPs, saving on Maker, or lending in Compound share a more general approach in financial activity, Liquidity Provisioning [55]. In many of these platforms, a marketplace is created with a growing demand for liquidity to be supplied. A pair of tokens is provided herein to fund a LP or supply a single or multiple tokens in a borrowing market [56]. To incentivize asset holders to provide liquidity, various liquidity programs have been launched to spur this market [57]. An example of this is SushiSwap (i.e., a cryptocurrency exchange platform and automated market maker built on the
Blockchain in Financial Services

top of Ethereum [58]), a competitor to the Uniswap platform. To encourage users to provide liquidity on their platform, high-interest rates are offered to the new fund providers for a limited time window. This attracts liquidity providers to seek platforms that will offer a much greater return for letting them use their funds on the platform.

With the growing demand for liquidity provisioning, the primary aim is to fund positions with the greatest yield or interest rate. On the Uniswap platform, liquidity providers receive 0.3% in fees charged to users that perform swaps through the supplied LP. The proportion they receive of that 0.3% is dependent on the share of the total provided liquidity [59]. On Compound, each token has its own associated interest earned for liquidity providers [60]. This interest is based on the demand for that particular token. Should the supply available be very low, the interest rate will reflect the need for greater liquidity provisioning and will boast higher interest rates. This is valid in the reverse case as well, where a large supply is backed with low-interest rates. Hence, there is an obvious competition to attract liquidity providers to the various available platforms.

Platforms seeking to attract more liquidity have developed programs called Liquidity Programs. In these programs, additional earnings are offered to users on top of the interest earned through liquidity provisioning [61, 62]. These earnings often take the form of platform-specific ERC20 tokens. The offered platform-specific ERC20 tokens (often used for governance on the product) have remarkably benefitted liquidity providers seeking to improve their earnings (e.g., Compound platform). Here, the interest earned is defined when supplying a token to borrows with the ERC20 governance token, aptly called Compound. Other platforms similarly offer liquidity programs, with some being more aggressive in early paying out liquidity providers to jump-start new pools.

Liquidity provisioning is a highly important activity in the DeFi ecosystem. An important aspect to point out is that it can be a powerful tool not just for those looking to earn better passive income, but also for platforms needing to build better interoperability between their platform tokens and other available tokens [63]. It further enables the success of Automated Market Makers, altogether becoming a cornerstone to the DeFi space [64–66].

3.2.5 Staking

In the blockchain industry, Proof of Stake (PoS) has been studied and implemented for its benefits as a replacement for the Proof of Work (PoW) consensus algorithm [67]. Staking, however, can also play an essential role as a financial investment tool [68]. The idea of staking is to deposit funds to attest the user’s participation in the block creation mechanism. If the user successfully creates the next block, they receive mining fees from the network. For instance, in Ethereum, the stake amounts are multiples of 32 ETH. Once staked, the probability a user gets chosen to attempt to create the next block is proportional
to the amount they have staked compared to the total stacked volume. Once they create a block, mining fees are awarded.

Staking is a relatively straightforward pay-to-play model, and it can be a consistent way of supplementing a user’s portfolio. Within the Ethereum context, the possible risk to staking funds is in the event users’ funds are slashed. That is, the network imposes a penalty and strikes a portion, if not all, of the user funds. This event only happens if the user fails to produce a good block consistently. In other words, the user is repeatedly given an opportunity to extend the Blockchain with a new valid block, but they continuously fail to create a block, or they purposefully create bad blocks [69]. The objective here is to disincentive staking participants from becoming bad actors in the network.

Although staking and earning funds make financial sense, staking is designed and used for a more important role or incentivizing community contribution [70]. The activity of staking, locking up funds in order to participate in an activity, is also being used by projects to allow members to vote in important governance decisions. Here, projects use staking tokens, often referred to as governance tokens, to allow holders of those tokens to vote on decisions impacting the project [71, 72]. Participants willing to make a vote would lock up some funds to be allotted the right to make a vote. The weight of a vote is proportional to the portion of the staked governance token compared to the total volume locked. Once the participated activity ends, the locked funds are returned in addition to a reward for participation.

### 3.2.6 Yield Farming

From a broader perspective, yield farming is the activity of constantly moving funds from one interest-bearing pool to another, constantly trying to place funds in positions with the most annual percentage rate (APR) in the corresponding week [69]. This means that funds could be placed in tokens with riskier positions, but they often have the highest return [45]. For instance, a farmer sets 100k USDT to be loaned out using compound finance. They will next receive 100k cUSDT at a specific interest rate. The following week, if ETH has a higher interest rate, the farmer can move their loan position from the USDT to ETH to lock in the higher rate (which could happen multiple times a week/month). One downside here is that those funds (i.e., 100k USDT locked) cannot be used while locked. The earnings can be further enhanced by taking the returned coin (the cUSDT for Compound), locking those funds in an exchange pool on Balancer (a trading platform and automated portfolio manager on Ethereum [73]), and earning trading fees on that platform (i.e., outdistancing further earnings).

Furthermore, liquidity programs can considerably supercharge field farming. With platforms aiming to attract more activities by issuing platform tokens to users performing those activities, yield farmers who are moving funds around on the platform, earn greater rewards for the moving actions performed on the platform [48]. This provides two key advantages; (1) increase a farmer’s
earnings and (2) lower costs of transaction fees as each activity earns rewards that can reduce the overall cost of chain transactions.

Leverage can be used as a force multiplier in the DeFi space \cite{74}. When leveraging a position, the user depositing funds takes loans against those deposits and repeats the process against the load assets. That is, the interest earned will be multiplied by the initial funds. With the repeated loan and borrow actions, the user performs more liquidity mining, thus boosting the earnings. However, leveraging here also increases the risk on those funds as smaller movements in price and debt ratios have a higher effect on the user’s principle, possibly moving them into liquidation (i.e., there is no reward without risk \cite{75}).

4 Blockchain in Financial Services: Current Benefits and Challenges

The Blockchain technology’s potential to innovate the financial services ecosystem has been widely talked about, including its abilities for regulatory efficiency enhancement (i.e., real time-based financial activities monitoring), facilitation and simplification of operations simplification, reduction of counterparty risks (i.e., execution of agreements in a shared and immutable environment), disintermediation for settlement and clearing of transactions, and lastly transparency and fraud reduction in both capital raising and asset provenance \cite{76}.

As the blockchain grows to become more popular, the use cases in financial institutes have increased from less complex areas such as consumer facing products, business service products, to higher complexity and much more value areas such as back-end process integration (Figure 3). However, in order to generalize the wide range of use cases, there are mainly three well documented and dynamic subsectors, within which use cases are being tested and have concluded (or are in the process of concluding) a proof of market, including in the context of emerging markets \cite{77}.

• Commercial finance: In the commercial financing realm, transactions of goods and services require end-to-end transparency. Blockchain technology simplifies the use of different and incompatible systems by suppliers by displaying transactions to all users in a distributed ledger. Blockchain is able to provide the visibility of order-to-delivery pipeline, provide reduction in the number of discrepancies as well as provide efficiency in time required to resolve discrepancies \cite{22}.

• Trade finance: Trade finance businesses require a way of streamlining the process of earning approvals from multiple legal entities involved such as customs, port authorities, transportation companies etc. Blockchain technology in trading can be used by legal entities involved to sign approvals, communicate statuses with each other as well as updating payment information. Blockchain can provide the solution of condensing complicated processes into a single process where all parties are able to access a shared ledger.
The time required to access funds are reduced since long settlement times and error dispute times are eliminated in the blockchain system. Increased trust and accountability is established among each company, regulators and consumers in this process [22].

- Cross-border transactions: In order to manage nostro and vostro accounts, where nostro accounts are domestic and vostro accounts are foreign accounts, Banks require a simplified method of facilitating these foreign exchange transactions through reconciliations. Accounts can become stored accounts as a transaction on a blockchain, which is able to produce improved efficiency and transparency through automated reconciliation of all accounts. All transactions across the banks can be therefore maintained through a single interface, providing improved visibility of transaction status, currency balance, process health as well as in a consistent and timely manner [22].

**Fig. 3:** Specified use cases of blockchain based on complexity.

### 4.1 Benefits of Blockchain in Financial Services

The blockchain properties are particularly well suited to maximising and boosting the mutual benefits and optimizing the business risks related to the co-investment and collaboration. Blockchain herein allows banks to work jointly on a common platform using a decentralised and distributed database. For one major bank, various advantages of blockchain technology, including,
but not limited to, immutability and irreversibility, are useful but indeed the core tenet is the idea of decentralized information that enables different competitors and countries to work collaboratively and co-invest on a common solution (platform). Moreover, all participants here can maintain their own data and only allows specific data to each other when they want to trade or interact [3].

- **Money Transfers:** Blockchain removes the challenge of transferring money internationally for customers and financial institutions by introducing electronic money transfers which can be done through mobile devices, avoiding the extensive process of visiting a money transfer facility, standing in line, and/or paying fees for a transaction. Blockchain not only saves time but also reduces costs or fees for transmission of payments [78, 79].

- **Inexpensive and Direct Payments:** In order to execute transfer of funds, there is always a third party involved which normally adds an extra layer of complexity and fees. Blockchain process eliminates the third party and can entirely exclude the layer of fees and complexities that come with it. Blockchain also tackles the insufficient funds problem in which due to the nature of blockchain, accounts which lack funding are unable to issue payments whereas traditionally it was possible with checks. Blockchain-based payments can give merchants the confidence of knowing that the transaction is good within a few seconds or minutes. Scams are also avoided by using blockchain-based payments, as they are quick and reversible. They are also less expensive than using banking services, especially for pricey items. Furthermore, it is worth noting that the safest methods of payment are wire transfers, cash, and cashier cheques. However, cash is considered untraceable, whereas wire transfers are time-consuming and cashier cheques may be feasibly forged. With blockchain-enabled payments, all of these challenges are resolved for greater confidence [19].

- **Transaction Details:** The distributed ledger helps track ownership or blocks/transactions and can be used for verification of all information leading back to the first block. Smart contracts are also able to track when a buyer pays and when the seller delivers along with identifying any problems that may arise during the process. This automation would reduce human work for registering and monitoring transactional details as well as human error.

- **Financial Inclusion:** Start-up institutions have a great opportunity for competing with major banks due to blockchain’s low costs and minimum balance requirements. Customers can register with alternative banks for lower banking requirements, as well as take advantage of the use of digital identification in mobile devices that blockchain provides to free customers from the hassle of traditional banking.

- **Reduced Fraud:** The blockchain ledger makes sure that all parties in a network receive a copy of the transactions to help maintain integrity along with the unique block hash. The unique hash in a block makes blockchain robust against the denial of service (DoS) and distributed denial-of-service (DDoS) attacks, hackers, and other fraud types. With the threat of cyber
risks and vulnerabilities being reduced or even eliminated, the cost of conducting business is minimized, enabling all the involved parties to save stress and money.

- Cryptocurrency: Digital cryptocurrencies is a blockchain-based technology that comprise the new wave of assets relying on the Blockchain technology. Although digital currencies are already in use, the blockchain-supported companies are reducing the entry barrier while offering a seamless exchange of the widely used (most popular) digital cryptocurrencies as a banking alternative [78].

4.2 Challenges in Blockchain-enabled Financial Services

- Regulatory and governance: There is a lack of regulatory clarity in blockchain. Dispute resolution mechanism, regulatory agencies and their coordination mechanism, legal standing of documents/instruments stored on the blockchain liability ownerships (of smart contract failure, etc.), definitions, territorial requirements and regulatory reporting are all key aspects upon which financial institutions need much more clarity on. Even where limited blockchain rules exist like the New York’s mandate for cryptocurrency license, these are fragmented/incomplete or prohibitively expensive [80]. The lack of common and transparent governance structure for blockchain puts decision making primarily to market dynamics. This creates a risk of network and infrastructure failure, and broader financial system instability.

- Privacy and Security: Distributed Ledgers by design are available to all users of a blockchain network therefore, in a permissionless ledger, counterparties may be capable of exploring transaction history including those transactions that they are not a part of. Tracking information of users and their wallets is made easy since their relation with the cryptocurrency’s pseudonymous isn’t fully anonymous. There is also a possibility that smart contracts accessing transactions data may leak data regarding the content being processed [80]. Financial institutes have commercial terms which are stored in smart contracts which can be at high risk and vulnerable to confidentiality breaches. In regards to security, blockchain systems lack concrete anti-fraud, KYC (Know your Customer) and Anti-Money Laundering (AML) tools (i.e., KYC is a process by which banks retrieve data about the address and identity of purchasers, whereas AML is a set of rules, regulations, and processes to prevent money laundering, terrorism funding, and other financial crimes). For example, while it could be feasible to identify the owner’s address that is being used in money laundering, it is impossible to block such a transaction in advance. There could be further risks or even machines can be hacked for fraudulent and malicious transactions, weak (highly vulnerable) key generation problems, hacked key problems, DDoS, consensus hijack, as well as double-spending attack problem which arises as blockchain’s security implications.
• Behavioral and counterparty risks: With the differences of interests among financial institutes, there could be a risk of lack of cooperation and/or collaboration among regulators, banks, clearing services, stakeholders, trading firms, exchanges, trade bodies, clearing and settlement services, etc [81]. In addition, there also exists the risk of private-based distributed ledgers which may lead to collisions and cartelizations with algorithms being leveraged and implemented in a manner that may produce anti-competitive results. If a private blockchain is designated as the default network, risks related to competition can materialize if it gets dominated by major players. Furthermore, if there are high barriers to enter the private blockchain, smaller providers may not be able to afford it and therefore be at a disadvantage. With blockchain still gaining its trust amongst players in the game, there lacks sufficient trust in this ecosystem, increasing the possibility of counter-party and systemic risks. For example, smart contracts with third parties outside of the network create counterparty risks, with very limited and/or restrained institutional support to assist the parties obtain their rightful settlements.

• Settlement risks: Finalizing a settlement is considered a legal requirement in settlement and post-trade clearing. However, due to the nature of public blockchains, legal liabilities can be ambiguous and/or challenging to assign [80]. This increases the risk of adversely impacting balance sheets of participants and also their creditors in addition to customer rights [80]. As such, risks of insolvency of one participant undoing the transactions that are actually settled are possible in the financial realm if settlement finality is not guaranteed.

5 Blockchain and Market Status

As the networks enabled in financial services are becoming more decentralized and adhoc, they are prone to attacks and vulnerabilities. In order to sustain the attacks and maintain their status quo in the market, blockchain has been used as an effective solution to prevent and avoid them. In this section, we review the current involvement and impact of blockchain technology in the financial market per status, namely, primary, secondary, and clearinghouse market.

5.1 Primary Market Status

Like other blockchain-enabled financial markets and systems (e.g., clearinghouse, secondary market), the primary market also aims at addressing blockchain technology-related challenges, including data security/integrity, transaction scalability and trust, and liquidity [15].

Nowadays, the integration of blockchain technology in applications related to the securities industry mainly addresses the private equity (PE) and digital securities issuance fields. Nasdaq, an early online global marketplace for buying and trading securities (launched in 2014), is a vital example of integrating blockchain technology into an exchange system [82]. Another example
is the online retailer Overstock.com that developed an issuance application for the company’s new listed blockchain-based stock, which was approved by the U.S. Securities and Exchange Commission (SEC). These initial technological advancements led to the issuance and approval of the world’s first bond developed and handled through blockchain technology (i.e., the ‘Bondi’ bond) [83].

The integration of blockchain technology into the primary market addresses many of its residing challenges and issues. Challenges include (1) the need for a reliable and robust data management system, (2) low/limited liquidity level, and (3) limited application derivatives [13]. Although the incorporation of blockchain technology in the primary market is still insignificant, there are several remarkable works addressing this industry trend.

Furthermore, access-granted users are authorized to retrieve the data stored in the blockchain while preserving the data consistency and transparency [84]. Such an aspect significantly reduces the costs associated with the due diligence (DD) and helps avoid potential errors that may occur in the data copying process. Authors in [85] have further tackled the DD data and demonstrated that it is on-chain, consistent, and transparent, which thus minimizes the data asymmetry and the risk of fraudulent activities.

Halevi et al. [86] showed that switching from third-parties of securitization by blockchain technology enables efficient tracing of the process details, enhances the securities issuance task (e.g., speeds up the issuance), and transaction transparency. These substantial improvements will potentially lead to a liquidity increase. Mills et al. [87] also investigated the potentiality of blockchain technology to minimize fraudulent activities risk due to data asymmetry. Here, tamper-proof and information verification mechanisms can be leveraged to address collusion and trust issues in the financial services market [88].

Other studies such as the one conducted by Benhamouda et al. [89] have addressed the security issue by implementing extensible secure multiparty computation capabilities to the permissioned blockchain technology (using Hyperledger Fabric). Their proposal also implemented a clearing price mechanism for IPO services.

There are several challenges related to the traditional financial market (Table 4), including trading and issuance of the securities market. These challenges range from data asymmetry to trust and system efficiency. Although the deployment of blockchain technology in the primary market can address many of these challenges, transaction scalability (transaction processing) is a key concern in the blockchain itself, which does not fulfill the financial industry needs (e.g., large scale trading and issuance of securities market). Several proposals aimed at enhancing the scalability of blockchain technology by using sharding [90], off-chain computing [91], scalable consensus mechanism [92], or optimization approaches [93].
5.2 Secondary Market Status

The incorporation of blockchain technology and the secondary market is an important research trend for academia and the financial industry. Some notable studies, such as [94], have investigated and explored the integration of blockchain technology along with Ethereum platform for secondary market-based exchanges. Such integration can address some of the vital challenges related to the conventional system of exchange (e.g., centralization, transparency, transaction processing fees, etc.)

The secondary market typically addresses public offerings, where previously issued financial instruments, including bonds and stocks are bought, sold, or exchanged. One of the primary applications of the secondary market is the exchange center, in which blockchain technology is increasingly involved. It is worth noting that the applications systems that are officially announced to date focus on the trading and issuance of over-the-counter/public equity (OTC/PE) market securities and the on-exchange market (i.e., post-trading applications). Among early blockchain-based systems for secondary market services is the trading system for London Securities Exchange (LSE) developed by IBM [82] and the Australian Securities Exchange (ASX) for financial market services facilitation [95, 96].

While several financial services companies, such as Deutsche KfW Financial Institutions, are still performing simulations for blockchain-enabled securities trading, others have fully integrated blockchain technology into secondary market services. A good example is the Nasdaq Linq [97], a PE trading solution developed by Nasdaq in collaboration with the blockchain start-up Chain.com [82]. This platform enables non-listed users to transfer their equity and perform a PE transaction’s settlement. These efforts will pave the way for more companies/organizations to adopt blockchain technology into their financial services (e.g., post-trading, clearing, etc.)

5.3 Clearinghouse Market Status

The incorporation of blockchain technology and clearinghouse has recently evolved as a hot trend in the financial industry, resulting in various applications and use cases. Recent works have studied services and applications associated with the clearinghouse, including inter-bank transactions, clearing, and settlement. Furthermore, the clearinghouse is nowadays considered a vital application of blockchain technology adoption into the financial sector, resulting in the development of many blockchain-based clearinghouses [98].

There are several limitations in the traditional clearinghouse systems, including, but not limited to, the complexity of workflows, information redundancy, lack of information certifiability, high data asymmetry, and low efficiency in information retrieval [99]. The incorporation of blockchain technology in the clearinghouse market resolves its conventional limitations by enabling settlement transactions regardless of the trust level among participating entities [100]. The use of blockchain technology here can further enhance
**Table 4:** Challenges in financial market addressed by the incorporation of blockchain technology.

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Implication</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovery</td>
<td>Mismatch, data privacy, data sharing</td>
<td>Permissioned blockchain</td>
</tr>
<tr>
<td>High cost</td>
<td>Validation process, data privacy, data sharing, due diligence cost</td>
<td>PoW, DAO, tamper-proof</td>
</tr>
<tr>
<td>Trust</td>
<td>Data privacy, data sharing, due diligence cost, contracts execution</td>
<td>DAO, tamper-proof, smart contracts</td>
</tr>
<tr>
<td>Low volume</td>
<td>Transaction volume</td>
<td>High scalability blockchains</td>
</tr>
<tr>
<td>Asymmetric information</td>
<td>Confidentiality, security of transaction data</td>
<td>Multi-signature</td>
</tr>
<tr>
<td>Low efficiency</td>
<td>Contracts execution, mismatch, due diligence cost, data privacy, data sharing, validation process, trading process</td>
<td>Permissioned blockchain, smart contracts, tamper-proof, DAO, PoW</td>
</tr>
</tbody>
</table>

The systems clearing speed and secure the exchange information and updates between banks and clearinghouses.

Moreover, to address the complexity of the settlement and clearinghouse operational process, a mobile-based clearing solution can be used to handle mobile financial services based on a predefined set of rules via smart contract [101]. The solution also enforces information confidentiality and authentication. Last, future exchange trading solutions are recommended to alleviate the challenges related to the high cost and low efficiency in transactions of inter-banking. These solutions may leverage blockchain technology features and credit matching frameworks (e.g., X-Swap).

### 6 Adaptation Model for Blockchain Technology in Global Banking

By 2022, more than 300 technology companies have started developing blockchain for the financial service space. Some of them include BitPaogs, BTCJam, BlockCypher, Coinbase, Bifubao, Kraken, Digital Tangible Trust, BitPay, HelloBlock, and Ripple Labs. Established technology institutes such as R3, IBM, ConsenSys and Chain have started playing a crucial role in the blockchain ecosystem in the global markets which naturally sets the need for regulators and policy makers of financial services to start developing adoption mechanisms for blockchain. A proposal for such an adoption method would help with characterizing and distinguishing the variables influencing the
organizations’ adoption behavior to accept and deploy the new and emerging technology innovations [102].

Given that the financial services industry is a highly regulated sector, the blockchain adoption rate typically depends on the way implementations are being supported by the regulatory entities across the globe. A few regulations connected to blockchain are already in force. For example, the U.S. state of Delaware has officially signed a bill recognizing blockchain-based stock trading. Moreover, the Australian Securities and Investment Commission regulatory framework requires the financial services institutions that deploy the distributed ledger platforms to establish proper and efficient risk management systems and infrastructure in order for them to operate. Additionally, Commodity Futures Trading Commission, which is a U.S. regulator has also established a system to evaluate how the blockchain technology is being deployed in the derivatives market [103].

By being properly guided in an industry of high risk requirements and compliance [80], adoption models are meant to assist coping with and vanquishing the obstacles currently preventing the blockchain technology’s adoption and successful integration in the global banking industry [102].

6.1 Adoption Governance Commissions and Structures

The European Commission (EC) is a regulatory/policy maker of blockchain which is a task force created and entrusted with establishing and developing blockchain-enabled technologies expertise [80]. The EC in 2016 aimed at bringing exchange platforms and providers of the virtual currency custodian wallet within Fourth Anti-Money Laundering Directive (4AMLD) scope. The EC proposes to support a “gold standard” for the blockchain technology deploying the European policies in a regulatory framework.

This gold standard for blockchain comprises the following items [80]:

- Environmental sustainability: The blockchain technology must fulfill sustainability and energy-efficiency requirements.
- Data protection: The blockchain technology must be compatible with Europe’s regulations of privacy and strong data protection level.
- e-Identity: The blockchain technology must align and be compatible with, but also improves the usefulness of, Europe’s emerging e-Identity framework. Therefore, the technology must be compatible with regulations of the e-signature, such as electronic IDentification, Authentication and trust Services (eIDAS: regulations of trust services and electronic identification for internal market electronic transactions). The technology must further support a pragmatic, sensible, decentralised, and self-sovereign identity (SSI) framework.
- Cyber security: The blockchain technology must ensure reliable and high cybersecurity levels.
- Interoperability: The blockchains must support high interoperability with the external world legacy systems.
The elements of EC'S blockchain strategy support their objectives, the most distinctive ones being: having built a pan-European public services blockchain, promoting legal certainty, increasing funding for research and innovation, promoting blockchain for sustainability, supporting interoperability and standards, supporting blockchain skills development, and finally having a continual feedback loop within the community itself.

By building blockchain infrastructure for the public sector and private, the European public sector creates a vital role in the blockchain ecosystem. It promotes legal certainty by developing a pro-innovation legal framework, which protects consumers and provides security for businesses. The EC has recently published a regulating crypto assets proposal. The proposal aims to create a pan-European regulatory sandbox to enhance innovative blockchain solutions and update the regulations for crypto assets related to anti-money laundering [78]. Furthermore, the EC supports funding for blockchain innovation through research grants and investments targeting AI & Blockchain startups and early-stage ventures, promoting the reduction of educational gaps and bringing in more innovative knowledge to further maintain governance. EC enables interoperability as engaging with relevant bodies is critical and substantial in the ecosystem, and interrelates with the blockchain community, academia, and private sectors through two main bodies:

1. The International Association of Trusted Blockchain Applications (INATBA) which is a private/public partnership established to bring the private sector and other stakeholders together with the European member states to further the blockchain ecosystem. It promotes the integration of blockchain technologies and good governance and acts as a guidebook for governments and international bodies to abide by [78].

2. The European Blockchain Observatory and Forum (EU Blockchain Observatory & Forum) which is regarded as a European Parliament designed to establish expertise for the monitoring and identification of blockchain trends and initiatives globally to develop a publicly available and comprehensive source of blockchain knowledge, in support of the blockchain ecosystem within the EU [78].

Further adoption governance structures include the following:

- Financial Conduct Authority: The Financial Conduct Authority (FCA) monitors blockchain developments and research on how the DLT can assist in regulatory compliance. In the UK, FCA provided approval to a limited number of firms for using the technology of blockchain; Nine blockchain-supported firms in November 2016 received sign-off to be governed within their regulation policies.

- New York Department of Financial Services (NYDFS): The NYDFS proposed an adoption model named BitLicence, which is provided to firms for permission to regulate businesses related to virtual currency. The regulations are established to enhance cybersecurity for virtual currency users and restrain money laundering.
6.2 A Robust Banking and Lending Platform

A robust blockchain-based banking and lending framework is depicted in Figure 4. This framework is a holistic overview of an approach financial services organizations, such as banks and credit unions, can use to evaluate blockchain in the context of their operations. Each entity needs to assess the technology, considering its policies and procedures, to better understand the organizational benefits and challenges of a blockchain-based banking lending platform. The basis of this framework revolves around five pillars: (1) superior client experience, (2) regulatory benefits, (3) improved security, (4) enhanced auditing, and (5) human capital advantages. These areas are discussed next.

![Fig. 4: A visual representation of a robust blockchain-enabled lending platform framework, highlighting the five areas organizations can leverage to enhance their conventional lending services.](image)

6.2.1 Superior Client Experience

Over the last several years, the technological evolution has prompted financial services organizations to enhance the client experience. It is important to remember that clients play a critical role in the financial services ecosystem. When working through new implementations, the client relationship needs to take the front stage and should result in substantial benefits to the clientele. Researchers have proclaimed that blockchain can help lower the costs of providing banking products and services. The reaped out benefits from those
implementations can be shared with clients in the form of lower fees. In turn, blockchain can be the catalyst to assist financial services organizations in providing their clients with cost-effective products and services.

It is no secret that some banking institutions have manual and outdated lending workflows. These outdated processes could be highly frustrating to clients as they may lack sophistication or be too archaic to update. The workflows could be enhanced by implementing some automation. For example, the Ethereum blockchain supports the implementation of smart contracts, which allows for a great deal of automation. Another essential component of the client experience is protecting the client’s sensitive information. As such, a blockchain implementation must follow privacy policies to provide an enhanced client experience.

6.2.2 Regulatory Benefits

By design, blockchain was developed to operate by untrusted nodes. When a new node is added to the blockchain, all blocks, from the very beginning to the most current, are validated by each node. Since inception, this validation process can only be completed because the blockchain stores its own history, including an entire trail. While this functionality seems redundant and labor-intensive, particularly as the chain continues to grow, it creates a vital documented trail. This type of built-in functionality is of particular interest to financial regulators. While there is uncertainty about the regulatory compliance for blockchain, the trail of historical activity can bring some level of comfort to regulators.

Immutability features are another essential component of blockchain, particularly for the public ones. This built-in feature allows permanent recording of activity to the blockchain [104]. As soon as data is written to the blockchain, it is nearly impossible to modify. A change requires a significant amount of effort and spent energy, making it impractical to be successfully executed. Furthermore, a minor change in the blockchain will cause the hash values, from that point forward, for the activity that has already been recorded to be invalid.

One of the bedrocks of regulatory compliance is a concept identified as "Know-Your-Customer (KYC)". While not a new concept, the regulatory aspects associated with it, have gained a significant strength [105, 106]. KYC establishes a process to validate the true identity of customers opening an account at a financial services organization. In the case of blockchain implementation, using the technology to record client identity information could transform the process banks use to onboard new clients. This process could significantly enhance the account setup steps and result in loans being granted much faster [107].

6.2.3 Improved Security

One of the primary benefits of blockchain technology is its inherent security. At a fundamental level, a blockchain network utilizes hashing to validate
the transactions in each block. As an extra level of cohesiveness between the blocks, the hash values are recorded between adjacent blocks. Except for the initial block in the chain (i.e., genesis block), the entire ledger can be easily validated to ensure no single piece of data has been modified or tampered with [108].

A vital design function of blockchain is the configuration as a distributed network. This peer-to-peer (P2P) setup allows for numerous data security benefits. Each peer in the network, specifically each full node, stores and maintains its own copy of the entire blockchain. As such, the peers can independently validate the data in the blockchain. This is particularly important when new nodes join the network. One of their duties is to obtain a copy of the blockchain and validate all the records. Performing this task at the onset will ensure they have obtained a valid copy of the blockchain. An additional aspect of the P2P network configuration is that it allows for data redundancy as each node stores a copy of the data set. In the case of a lending platform, this is of utmost importance as it helps prevent a catastrophic data loss, which can have significant negative implications for a business, particularly for banking institutions [109].

Banking institutions are susceptible to Denial of Service (DoS) attacks. These attacks can create significant reputational and regulatory compliance risks for a banking entity [110, 111]. The scale of the attack can land a bank inoperable for an extended number of hours and can even take entire systems offline. In such a case, the damage could affect both internal and client-facing systems. The P2P network configuration can be leveraged to minimize the risks associated with such an attack. In effect, the distributed network configuration serves multiple essential functions.

6.2.4 Enhanced Auditing

Organizations that have not adopted effective auditing policies are likely more exposed to attacks than those which update their policies and procedures frequently. This is an area of primary concern with entities that handle confidential or sensitive information as part of their regular course of business. Blockchain technology has built-in functionalities to mitigate such data attacks [112, 113].

The blockchain maintains a record of all transactions that have been created since inception. In essence, this record provides a complete trail of the activity that has taken place in the blockchain. As part of the validation process, when a new node joins the network, it audits and confirms the blockchain activity. This level of transparency is essential for both internal and external auditors within a banking institution [114]. It further helps boost the trust level of the data and enhances the auditing process in blockchain.

6.2.5 Human Capital & Smart Contracts

One of the great benefits of technological advances is that they allow the financial service industry to allocate more time to interesting and efficient
service-related functions rather than mastering repetitive tasks. While this may sound like a ‘cliché,’ the truth of the matter is that blockchain can enable the use of smart contracts \([5, 23, 115]\) for automatic execution of various banking services in a decentralized network \([115]\).

In the banking world, smart contracts can be highly useful tools. This type of automation is considered the next level of sophistication as it relates to blockchain and cryptocurrency \([116]\). Properly leveraged in a banking blockchain-based lending solution, the technology can be thought of as an intelligent robot performing repetitive tasks on behalf of the employee. While those tasks could be redundant, they are nonetheless important in the context of a lending ecosystem; for example, consider monthly loan payments. Under normal circumstances, loan payments are scheduled to occur on a consistent basis. However, missing a loan payment could have substantial negative implications for a borrower or the financial institution. Concurrently, another example to consider is the reporting of loan data to the credit bureaus, which itself is being researched for a blockchain implementation \([8]\). These are repetitive tasks that could be delegated to smart contracts.

7 Vision for Blockchain Future in Financial Services

7.1 Practical Implications

Many technological advances brought forth by blockchain technology could potentially impact a wide array of industries. However, there are several important practical implications that financial services organizations need to consider before deploying blockchain.

One crucial factor to consider when deploying blockchain is the human investment factor. Employees may need to be trained. Given that blockchain is a relatively new technology and may continue to develop quickly, continuous training may be required. That is an initial investment in employees that may not yield initial results. Furthermore, organizations may need to hire outside expertise to ensure their implementations meet all audit, internal and regulatory expectations as part of the initial deployment. This phase becomes ever more pressing when the organization has had limited exposure to such a technology.

The financial services industry understands that the data it manages is very valuable to bad actors, yielding many benefits and financial motivations \([117]\). While organizations deploy significant resources to ensure their systems are as secure as they can practically be, deployment of new technology comes with a higher level of risk. As such, financial organizations need to perform a higher level of due diligence and need to continuously evaluate the blockchain-based smart contracts deployed for any potential vulnerabilities (e.g., code bug).
Last, an area of increasing concern for blockchain researchers is privacy. While privacy is an ever-expanding aspect of banking, researchers continue to investigate ways to ensure blockchain can meet the regulatory demands [118, 119]. There are global implications with privacy, and successfully using blockchain also implies that privacy needs must be accommodated.

### 7.2 Opportunity in Trade Finance

Most banks have identified trade finance in particular as the area in which blockchain is expected to make a significant impact within the next few years [3]. Many relevant use cases in which bank consortia have established and developed capabilities in this area, including We.Trade, a blockchain-enabled platform implemented by nine banks (Deutsche Bank, Nordea, Rabobank, HSBC, Santander, Natixis, Société Générale, KBC, and UniCredit) [3]. This platform was developed to support cross-border trades automation. A further relevant platform called Batavia was initiated by UBS and IBM in 2016 and is implemented based on proof of concept. This platform brought onboard the Bank of Montreal, Commerzbank, and CaixaBank as additional partners [3].

The feasibility of using blockchain in trade finances enhances the financial transactions by payments through a letter of credit. Furthermore, it helps to integrate the procedures involved in trade finance with logistics tracking through blockchain. This could potentially address the trade-related challenges in insurance, logistics, custom clearance, and automation in other trustless scenarios. However, the core enabling features of the blockchain technology could still be enhanced through gathering valuable data and analyzing and utilizing them for bank endorsement, letter of credit, insurance, and other trade finance processes.

### 7.3 Security Issuance

Primary issuance and payment of cash flows are currently largely tracked and executed on a manual basis which can be transformed by blockchain systems to facilitate procedures via pre-determined smart contracts. With the immutable nature of this technology, blockchain transactions can, for instance, issue bond proceeds on a parametric basis that is instantaneously activated once specific trigger conditions are fulfilled.

A paradigm shift in the establishment of trust and bond in the relation between the investors and issuers could be marked through the blockchain for imparting security insurance. The complete lifecycle of blockchain assists in managing private and public security issuance and complete digitization of the physical documents through smart securities. Other potential benefits of blockchain-enabled security issuance include less intermediate, easy collection of data, quick clearance, and cost cuts in brokerage and sales. However, the legal opinion given through blockchain-based security issuance needs sustainable support from lawmakers for ripping their core benefits and support.
7.4 Asset Tokenization

Blockchain enables an ecosystem for regulated digital shares of any assets (i.e., within any asset class) to be issued and traded on the open market by a legal entity or individual. The tokenization of assets will benefit banks by lowering global trade costs. A tokenized economy therefore provides a highly efficient platform where frictions are eliminated during generation, buying, and selling of tokens [3]. Additionally, the tokenization can make the financial industry and services even cheaper, easier, more accessible, faster, and thus unlocking trillions of dollars in currently illiquid assets, and massively augmenting the trade volumes [3].

By tokenization of assets through blockchain, large disruption in the business transactions in industries enables them to trade, sell and buy digital assets [120]. Such trading of digital tokens makes the financial systems faster, transparent, and universally accessible. However, in spite of the potential growth of blockchain, the conversion process of the real-world assets to digital tokens is still in its infancy. For its widespread adoption, the challenges and obstacles associated with this technology need to be addressed with trustworthy robust blockchain features.

7.5 Clearing and Settlement via DLT

A shared distributed ledger system will expedite the clearing and settlement of assets where large multi-party transactions occur. Stock exchanges and other financial institutions that handle large securities exchange amount have experimented in their settlement processes with blockchain platforms. Notably, Goldman Sachs in 2017 was granted a patent for SETLcoin, which is a transaction-supported settlement system using blockchain technology [3]. According to one respondent, the industry groups are incorporating precursor steps towards continuous 24-hour settlement, otherwise meaning, to establish a genuine global settlement day leading to a full-blown continuous PvP and delivery-versus-payment settlement globally [3].

For the digital property transactions, their account balance management through decentralized platforms supported through DLT can eliminate the need for centralized control registers. It is noteworthy that the impact of DLT in cryptocurrency trading, such as Bitcoins, is overwhelming with permissioned, and shared ledgers through private or public networks. However, the operational and technological challenges in DLT are still under legal threats in the financial industries expecting concrete regulatory principles. Furthermore, the risks involved in asset management without a central authority and the transparency levels in the transactions need assistance through blockchain technology.

7.6 Know-Your-Customer and Identify

As each participant possesses a unique digital identity in a blockchain network, the authentication processes can be automated across a shared KYC
infrastructure. Blockchain brings greater efficiency and transparency and prevents the funding of illegal and fraudulent activities, illicit flows of funds and anti-money laundering [3].

The privacy-oriented decentralized architecture implemented through blockchain enables the KYC through smart contracts in banking and other legal processes. It helps to register the customer identity and safeguard them from the risks in assessing the records by illegal members with illegitimate intentions of foul playing in the records. However, the series of fundamental issues in imparting e-KYC through blockchain needs attention and which could assist financial sectors in identifying and stopping fraudulent actions.

### 7.7 Dominant Institutions and Blockchain Production Leadership

Institutes would (will) drive significant blockchain production over the next two to three years [3]. In order to fit conditional use cases, financial companies will produce their own blockchain ecosystem, then eventually expanding moving money cross-border, bringing suppliers and buyers onto their chain [3, 121].

The potential impact of blockchain in the realization and development of cyber-physical production systems helps identify the complexity in manufacturing systems and helps to adapt to the cyber computing ecosystem. Such blockchain-based distributed networks of industrial production systems are considered a backbone for cyber-physical production systems. However, a unified blockchain architecture is in demand for enabling machine-to-machine (M2M) communication and smart contracts in the production space.

### 7.8 Success-Driven Wider Adoption

Once a single use case is successful, the adoption or integration of others can be likely driven across the industrial sector. It is worth noting that as more industrial organizations perceive what the key components are around mutability and consensus for financial service, then there will be many more additional services that can be adopted or leveraged [3]. Consequently, as adoption increases, the growing technology can further assist with resolving the current challenges and limitations in cross-platform interoperability.

New financial service models need blockchain integration/upgrade for improved and efficient financial services and operations. With the customer-centric demands, it could assist in identifying the credit information, restructuring the financial market, and enhancing payments across borders. The status quo of the economy and financial market will gain its success, which truly depends on the widespread adoption of blockchain with the constructive suggestions from the finance and technological experts.

Last, although the integration of blockchain technology in the financial services market is dramatically evolving, the current development remains slow in practice. This is primarily due to the regulatory restrictions and lack
of regulatory standards [122]. Given the current government’s recognition of the technological advancements of blockchain technology in decentralized (distributed) systems and services, many regulatory restrictions are expected to be released in the near future.

8 Conclusions

Bitcoin and its alternative cryptocurrencies (e.g., Litecoin, Primecoin, etc.) have been considerably impacting financial services for nearly a decade. It is expected that blockchain technology will soon have the largest impact on financial services and industry in general. Such a technology will likely change, at the minimum, the manner financial firms conduct many of their financial activities, in addition to product validation, gambling, auditing, and contracts. Besides, some of the current long-standing professions and businesses will cease to exist due to structural transformations created by firms deploying blockchain technology. As blockchain matures, it increases value in return on investment. However, institutes should continue to take a strict approach to regulations and policies. Each jurisdiction comprises its own regulatory regimes and rules, meaning before (and during) the implementation of a financial service such as intra or inter-bank payment network, the respective regulator should be consulted and provide and approval.

Blockchain technology promises many ground-breaking innovations across many industries. In the case of the financial services domain, blockchain is promising to change the way it operates fundamentally. While some organizations are exploring the use of blockchain to modernize their businesses, newer players in the marketplace have been able to embrace the technology. It is no secret that competitors to banking institutions such as financial technology companies are not missing a beat. A number of these organizations are exploring the benefits of blockchain. Banking institutions also need to jump in and leverage this technology to innovate within their organizations.

9 Statements and Declarations

Conflicts of interests or competing interests due to funding: The authors declare that they have no financial or nonfinancial interests that are directly or indirectly related to the research described in this paper.

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