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Smart Contracts in Banking and Financial Services: A Qualitative Review of Applications, Risks, and Regulatory Perspectives

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Abstract: *Blockchain and smart contracts are bringing a technological transformation to banking and financial service industry. This scholarly article evaluates the revolutionary nature of smart contracts in reinventing the concepts of trust, efficiency, and automation in transactions of diverse financial sectors. By using a qualitative and explorative methodology that uses secondary resources, the research integrates the know-how of academic publications, white papers, policy-related pieces, and case studies published since the year 2020. The results show that smart contracts are increasingly being used in trade finance, cross border payment, insurance claim settlement, credit release as well as compliance with regulations. Such applications have resulted in cost efficiency, transparency, auditability, and speed of operation being strengthened tremendously. Nevertheless, the paper also reveals some of the existing problems such as the lack of legal clarity, weaknesses in the coding of contracts, scalability of the blockchain technology used, regulatory compliance, and privacy. In practice, being used by institutions like JPMorgan and Santander and in DeFi platforms like Aave and Compound, smart contracts are increasingly becoming institutionally friendly. Also, legal and compliance agencies in different jurisdictions, such as European Union, India and United States, are developing infantile legal regimes that plan to control such innovations. This paper provides the conclusion that smart contracts have a potential to become the backbone of an automated, decentralized, and trusted financial world. To achieve successful integration, there must be a coordination between regulators, technologists, the financial institutions, and policymakers. The paper adds value to the academic discussion by offering a clear, detailed, practice-oriented view on the topic of how smart contract is changing future of banking and finance.*

Keywords*: Smart Contracts, Blockchain, FinTech, Banking, Financial Services, Automation, Trade Finance, Regulatory Compliance, DeFi*

1. Introduction

The banking and financial services industry is undergoing an era of a digital transformation with the fusion of the new emerging technologies and with the evolving customer expectations. One of the most innovative things that have revolutionized this industry is blockchain technology which is a form of ledger storage that is decentralized and tamper-proof and its application in the forms of smart contracts. Smart contracts have largely been described as self-enforcing agreements that will automatically fulfill the conditions of an agreement upon the achievement of certain given set of conditions without the intervention of third-party intermediaries (Christidis & Devetsikiotis, 2016; Szabo, 1996). The idea was conceptualised by Szabo during the 1990s and popularised through the use of Ethereum platform.

There is a revolutionary potential of smart contracts in the sphere of banking and finance sector. These are currently being adopted to automate process functions like cross-border payments, trade finance settlement, insurance claims, loan disbursements and regulatory compliance. In contrast to the traditional contracts which may be executed and validated only with human involvement, smart

contracts present a trustless execution framework through which all transactions are recorded on a mutable blockchain ledger that can be viewed by everyone necessary (Zheng et al., 2020). This decreases the chances of fraud, human error, and delays and makes processes quicker, less costly and predictable.

The existing financial ecosystem has been struggling with its inefficiencies that it had to deal with all along including a work-intensive manual operation, auditing black boxes, and costly third-party endorsement and adjudication of legal disputes. These frictions become more intense across borders and systems of regulatory controls as global finance turns evermore borderless. In this case, smart contracts become a technological remedy due to their programmable trust, i.e., the means of inscribing trust in code and letting it be performed by a machine, being verifiable, transparent, and compliant without involving subjective human interpretation (Buterin, 2014).

This necessity of such a type of automation is especially demonstrated by recent occurrences. COVID-19 pandemic spurred digitalization in many sectors, whereas it also revealed the vulnerability of global financial infrastructure, settlement delaying, manual back-office processing, the excessive reliance on paper-based documentation (Kouhizadeh & Sarkis, 2018). In this developing world scenario, smart contracts provide a paradigm shift redefining the manner in which agreements are invented, tracked and enforced.

Even though there have been suggestions that smart contracts have a bright future in the field of banking, the use of smart contracts in banking remains in its early stages, and is currently bogged down by issues such as legal recognition, technical immaturity, lack of standardization as well as lack of regulatory clarity. The above issues give rise to the need to research further into the viability, scalability and implications of smart contracts within existing financial systems.

The purpose of this research article is to critically analyze how smart contracts are changing the face of financial services business based on recently arrived secondary data, real-life case scenarios, and up to date scholarly sources. It discusses the advantages, shortcomings, legal outlook and the way forward on the adoption of smart contract in banking and finance. In this way, the paper adds to the existing shared knowledge and provides some insights to policy-makers, financial institutions, and technologists to promote better adoption of this technology.

2. Objectives of the Study

- To explore applications of smart contracts in banking and finance.
- To analyse the advantages and limitations of smart contracts.
- To examine real-world case studies of smart contract implementation in financial institutions.
- To assess future prospects and policy implications.

3. Research Methodology

The research methodology of this study combines qualitative and exploratory research seeking to evaluate and interpret secondary data in an effort to investigate the role of smart contracts in transforming the banking and financial services sector. Since the emerging trend of smart contract technology in the financial institutions is still in its initial phase, a qualitative approach is capable of penetrating the emergent trends, situational background and practical applications to the fullest extent (Creswell & Poth, 2018).

The study will be mainly founded on secondary sources of data which will be chosen by use of purposive sampling. The sources consist of peer-reviewed scientific journals, industry white papers, conference proceedings, policy papers, corporate case reports, and technology absorption reports first published after 2020, which makes the analyzed information in them timely and applicable. The sources were accessed in Scopus, Google Scholar, IEEE Xplore, ScienceDirect, and SpringerLink, which are well acknowledged databases, and reputable industry platforms, such as World Economic Forum, PwC, Deloitte, OECD, and BIS.

The literature review approach has also been used in the identification and evaluation and synthesis of previous studies pertinent to smart contracts in financial services. The given approach will make it possible to combine theoretical frameworks and practice and create a conceptual scheme that will

provide a background to the discussion of the whole paper (Boell & Cecez-Kecmanovic, 2015). Based on the findings, thematic analysis was applied to classify contents into these main areas: operational efficiency, security and trust, regulatory implications and real-world application of smart contracts.

To achieve methodological rigor, the secondary sources were appraised, based on the following criteria:

1. **Relevance** - Only the financial applications of smart contracts were reviewed.
2. **Recency** - More importance was given to studies and cases post-2020.
3. **Credibility** - The reputation of the source or publication outlet was also considered.
4. **Diversity** – The sources were considered from different geographic, legal, and technological contexts.

Due to the intricacies of the application of smart contracts to the existing banking systems, this paper does not receive the assistance of any single theoretical perspectives but rather combines insights of blockchain theories, financial systems theories, and regulatory innovation systems. Although the qualitative approach helps in giving quality descriptive data, the study also appreciates the weaknesses in the approach especially in the absence of primary empirical data and subjectivity in interpretation. Nevertheless, through triangulating on reputable secondary sources and using a well-structured approach to analysis, the results could provide a generalised picture on the present trends, obstacles, and future possibilities of smart contracts roll-out into the financial industry.

4. Understanding Smart Contracts

Smart contracts refer to self-executing computerized agreements coded in computer programming languages, in which the agreement terms are stated in computer code. They are intended to mechanize the fulfilment of contract terms without involvement of third parties thus lowering the cost of operation, failure to perform due to inefficiency and possible fraud. The idea has been first posed by Nick Szabo in 1997 in the form of digital protocols that would allow automatically enforcing contractual clauses (Szabo, 1997). Their practical application, however, grew when blockchain systems, such as Ethereum, became available, which provided the decentralized infrastructure that was required to run them effectively and in a trustless, transparent way (Buterin, 2014; Mavroeidis et al., 2021).

4.1 Key Features of Smart Contracts

There are a number of transformative characteristics of smart contracts that they have over traditional paper-based or electronic contracts. These include:

- **Self-executing**: The capability to perform the predefined action once the predetermined condition is reached can be considered one of the primary features of smart contracts. The control through this automation greatly increases efficiency and makes sure that compliance happens in a timely manner (Christidis & Devetsikiotis, 2016; Gatteschi et al., 2020).
- **Immutability**: The code and logic of a smart contract cannot be altered once they are put in a blockchain network. This would make the terms tamper-proof, meaning that retroactive manipulation will be impossible, and thereby increase the trust between parties (Zheng et al., 2020).
- **Transparency:** Smart contracts being hosted in a decentralized ledger can ensure that the code of the contract and history of its execution can be accessed by all participating entities. This degree of transparency aids the auditability and accountability (Xu et al., 2021).
- **Security**: The smart contracts on blockchain are carried out in a mature cryptographically-protected system. They are based on distributed consensus protocols i.e., Proof-of-Work or Proof-of-Stake that reduce the possibilities of hacking, unauthorized access, and fraud (Kumar et al., 2022; Li et al., 2021).
- **Trustless Transactions**: With smart contracts, there is no need to trust the counterparty because the execution will be defined by code and not middle parties. Instead, trust is put in the system and protocol on which it relies (Tapscott & Tapscott, 2018).

All of these factors contribute to creating reliability, efficiency, and visibility in the transaction and contract agreements, especially in areas where precision and adherence is the ultimate priority, like in the banking and finance sector.

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4.2 Architecture of Smart Contracts

In designing the smart contracts architecture, there are some key components which form the foundation and enable their smooth operation within the decentralized platforms. Generalized smart contract system normally consists of the following stages:

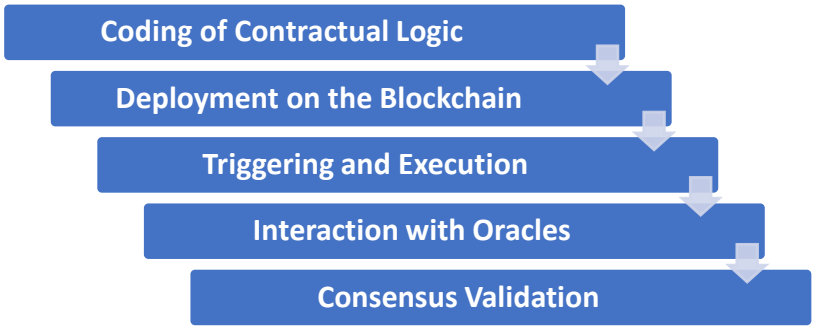

Figure 1: Components of smart contracts architecture

1. **Coding of Contractual Logic**: Smart contracts are programmed in high-level scripting languages such as Solidity (in the Ethereum blockchain), Go (in Hyperledger Fabric) or Kotlin (in Corda). The contract includes conditions, clauses and logic, which simulate real-life contractual relationships (Wang et al., 2020).
2. **Deployment on the Blockchain**: Once coded, then the smart contract is compiled and run on a blockchain network. Each contract has its own address, and it is entered into the ledger of the blockchain that does not allow changes (Golosova & Romanovs, 2018).
3. **Triggering and Execution**: As soon as it is implemented, the smart contract awaits some specific events (i.e., receiving a payment, delivering a product). They are the triggers that lead to automatic execution of the contract, and the consequences will be registered in the blockchain (e.g. delivering funds, transference of the rights of the property ownership) (Swan, 2015).
4. **Interaction with Oracles**: In practice, smart contracts can often need external systems data, e.g., financial market data, or insurance database data. Oracles are connectors between blockchain smart contracts and untrusted off-chain data providers to enable the delivery of credible sources of information into the blockchain ecosystem (Zhang et al., 2020).
5. **Consensus Validation**: Transactions are validated on blockchain networks by consensus mechanisms prior to finalization of the results of the contract. This procedure makes it accurate and avoids the occurrence of double-spending or fraud (Dai et al., 2020).

4.3 Platforms Supporting Smart Contracts

There are several blockchain platforms on which smart contracts can be created and are deployed, each with a different philosophy of design and application:

- **Ethereum**: Ethereum is the first and most well-known smart contract platform which makes use of the Ethereum Virtual Machine (EVM) and enables smart contracts in programming language called Solidity. It is referred to as having a large developer ecosystem and decentralized application (DApp) ecosystem (Buterin, 2014; Alharby & Moorsel, 2017).
- **Hyperledger Fabric**: Hyperledger is a block chain platform that facilitates permissioned enterprise solutions which is managed by the Linux Foundation. It supports smart contracts known as chaincode, which can be written either in Go, Java or Node.js, and provides privacy and scalability on an individual business level (Androulaki et al., 2018).
- **Corda**: Corda is a financial-services specific distributed ledger platform developed by R3 consortium. In contrast to Ethereum, it does not imply the use of a global broadcasting mechanism but, instead, applies a privacy-centered framework where only the interested parties involved in the transaction can view it (Brown et al., 2016).

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These platforms have special benefits and are customized to different use cases. The choice of a platform is subject to regulatory conditions, scale, privacy, and interoperability demands that an organization or institution in question has.

4.4 Smart Contracts in Financial Ecosystems

Financial systems are also incorporating smart contracts in order to automate different services such as but not limited to:

- **Trade finance:** Automating the issuance of letter of credit and settlement of the same.
- **Insurance:** Payment on the automatic claims that are based on predefined parameters.
- **Lending:** Automation of the repayment and escrow features on peer-to-peer lending.
- **Asset tokenization:** Reflecting real world assets (such as real estate or bonds) in the form of the blockchain and settling its lifecycle with the help of smart contracts (Catalini & Gans, 2020; Zetzsche et al., 2020).

The smart contracts are streamlining the financial sector by eliminating the manual processing involved, middlemen, increasing speed of transactions, and capitalizing on transparency.

4.5 Comparative Analysis: Traditional vs. Smart Contracts

Table 1: Comparison between Traditional Contracts & Smart Contracts

FEATURE	TRADITIONAL CONTRACT	SMART CONTRACT
INTERMEDIARIES	Required (lawyers, notaries)	Not required
EXECUTION TIME	Days to weeks	Seconds to minutes
COST	High (fees, overheads)	Low (peer-to-peer execution)
TRANSPARENCY	Low	High
FRAUD RISK	High (human error, manipulation)	Low (immutable ledger)
MODIFICATION RISK	Moderate	Immutable once deployed

5. Smart Contracts in Banking and Finance

The introduction of the smart contracts in the banking and finance sector is a revolutionary move of delivering, managing, and regulating financial services. Smart contracts avoid all the pre-existing frictions related to the manual fulfilment of the contract and minimize counterparty risk since everything is secured by automation. Due to their ability to transform major operations, including trade finance, regulatory compliance, etc., this technology has been implemented in major banks, insurance, and fintech firms all over the world (Zetzsche et al., 2020; Ganne, 2020).

5.1. Trade Finance

Trade finance is an area with many different intermediaries; there are exporters, importers, their freight forwarders, inspection companies and banks. Such a complicated organization may lead to the process delay of the transaction, increased transaction costs, and low transparency. Smart contracts make such operations less cumbersome, automating the verification of the documents, tracking of the cargo, and payments that are settled based on previously established conditions (Tapscott & Tapscott, 2018; Murray, 2021).

In 2020, an exemplary case was that of HSBC and ING, who utilised smart contracts powered by the blockchain that was pegged on the Voltron platform in making a transaction of a letter of credit regarding the transportation of soybeans in Argentina to Malaysia. The efficiency that this technology provides is characterized by the fact that what previously consumed 5 to 10 days was now conducted in 24 hours (Forbes, 2021; World Trade Organization, 2020).

Moreover, smart contracts and the distributed ledger technology (DLT) are used to digitalize the trade finance processings via applications in platforms such as Marco Polo and We.trade, which are more secure, transparent, and efficient (Ganne, 2020).

5.2. Cross-border Payments

Money transfers made across different countries have always been characterized by expensive charges, extended turnaround time, and untraceable nature through the participation of numerous intermediary banks. Smart contracts provide a decentralized answer in that they are able to make direct peer-to-peer (P2P) transactions without an intermediary. The innovation is cheaper and involves shorter transaction latency, as well as

bringing increased transparency and traceability (Peters & Panayi, 2018; Belhadi et al., 2021).

Among the well-known ones, there is RippleNet, the real-time gross settlement (RTGS) system based on the smart contract and the digital asset XRP. Santander, PNC Bank, and SBI Holdings are examples of financial institutions that are able to do cross-border transactions that take a few seconds because they use Ripple to streamline the operational complexities (Mohanta et al., 2020; CoinDesk, 2022).

Moreover, Stellar Lumens (XLM) and IBM World Wire are also using identical frameworks that enable banks to communicate with each other easily and safely applying smart contract mechanisms (Kshetri, 2021).

5.3. Insurance Claims

The milieu of the insurance business is usually associated with delayed claims, claims fraud, and lack of efficiency. Smart contracts provide a significantly more resilient solution because such contracts allow automating the verification and receipt of claims based on data streaming conditions when the timer intersects with the condition (Chen et al., 2021).

An interesting example is the flight delay insurance developed by AXA Insurance Company that uses a blockchain named Fizzy. The platform incorporates smart contracts on Ethereum network with global air traffic databases to automatically trigger indemnities in case of delays of more than two hours. The customer does not face the manual claim process, which significantly increases customer satisfaction and makes the functioning of the process much more efficient (CoinDesk, 2020; Tapscott & Tapscott, 2018).

Additional uses are the parametric insurance on natural catastrophe and crop insurance instances, whose conditions are automatically quantified based on satellite information (or the Internet of Things) to initiate payment via the smart contracts (Zhang et al., 2020; Broby, 2021).

5.4. Loan Disbursement and Credit Scoring

Conventional lending systems entourage complicated procedures of approval, paperwork and time lag. Smart contracts offer an excellent way out by making the loan disbursal programmatic on conditions including verified KYC, collateral levels, or other creditworthiness parameter. Such contracts guarantee greater speed, transparency, and tamper resistant lending procedures (Catalini & Gans, 2020; Mavroeidis et al., 2021).

One good example would be the Aave decentralized finance (DeFi) protocol that operates on Ethereum. It allows offering and providing crypto-assets to clients with the help of smart contracts without the necessity of a traditional credit rating. Rather, the contract provides crypto-assets to be used as the collateral against the loans, which guarantees security as well as immediate payment (Gudgeon et al., 2020).

Likewise, Compound and MakerDAO enable decentralized lending activities with interest rates and the terms of a loan programmed by smart contracts and devoid of human bias and documentation (Schär, 2021).

5.5. Regulatory Compliance and KYC

Complying with regulations such as Know Your Customer (KYC) and Anti-Money Laundering (AML) is one of the most difficult parts of the financial ecosystem. These processes are human error-prone, time consuming, and tedious. Smart contracts open up the potential of compliance automation regarding institutions in real-time environment and data verification (Zetzsche et al., 2020; Kumar et al., 2022).

The Corda platform developed by R 3 is customized to financial environment that are regulated, seeking to combine smart contracts and digital identities to facilitate KYC process. Secure transmission of validated customer information between institutions through encrypted smart contracts will ensure a drastic decrease in duplication and complexity of the audit (R3, 2022).

Furthermore, the committee of banking supervision, Basel Committee on Banking Supervision has recognised the opportunities of distributed technologies such as smart contracts when used to improve compliance monitoring frameworks and risk assessment frameworks (BIS, 2021).

Economic Sciences
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6. Benefits of Smart Contracts in Finance

The use of smart contract in the financial service sector has brought about a paradigm shift in the concept of executing of financial contracts, monitoring and enforcement of the same. These blockchain-enabled protocols facilitate a trustless and self-regulated system that minimizes reliance on the centralized institutions thus providing several advantages. The fact that they self-execute according to preselected conditions will also increase the efficiency of operations, reduce fraud, and promote transparency (Zetzsche et al., 2020; Kaal, 2021). Smart contracts have major benefits in the financial field as discussed below.

6.1. Cost Efficiency

Among the greatest benefits of smart contracts, there is a way to reduce costs due to middlemen removal. In the conventional system of financial activities, the middlemen are banks, brokers, clearing houses and lawyers who authenticate and verify the transactions. The intermediaries are avoided by Smart contracts, which are self-executing and decentralized, which reduces the administrative and legal costs considerably (Catalini & Gans, 2020).

According to a study conducted by Deloitte (2021), smart contracts adoption in capital market can save up to 70 percent of the operation and specifically post-trade settlement costs. These are savings relating to less paperwork, manual reconciliation and third party verification charges.

6.2. Speed and Efficiency

Smart contracts are used to automate complicated financial operations like payment, trade settlements, loan distribution and insurance claim payments. Because of the automaticity of the transactions that the code executes after the set conditions are met, it removes the delays caused by processing and human intervention and bureaucratic procedures (Chen et al., 2021).

For example, cross-border payments, a procedure that usually takes 3–5 business days can be done in seconds by employing blockchain-based smart contracts (Ganne, 2020). This acceleration of a operation improves liquidity and enables to perform a real-time or very nearly real-time financial operations.

6.3. Transparency

Transparency is also another main advantage of the smart contracts. When a contract is placed on blockchain, the terms and the logic of execution of the contract can be seen by all parties. This provides a way of gaining each other trust and accountability especially in multi-party financial contracts (Mohanta et al., 2020).

Considering insurance, for instance, the insurer and the insured can access the logic behind the contract that defines operations inclusive of the entitlement of claim payouts without confusion and chances of manipulation. This advantage is revealed through such platforms as Fizzy by AXA (CoinDesk, 2020) through which flight delay claims can be automated in a transparent way.

6.4. Security and Fraud Prevention

Smart contracts run on blockchain networks, which prevent frauds due to cryptographic protocols and mechanisms of consensus such as proof-of-work (PoW), proof-of-stake (PoS) or practical Byzantine fault tolerance (PBFT). It is nearly impossible to make unauthorized changes with this structure, hence making data more secure and hard to corrupt (Mavroeidis et al., 2021).

Also, smart contracts minimize the chances of a human error and fraud since manual input and paperwork are eliminated. Since an impending number of interactions are logged and confirmed by consensus, it will be computationally infeasible to tamper with the data (Broby, 2021).

6.5. Auditability and Traceability

Each and every move that a smart contract does is documented on the blockchain in an immutable time-stamped manner. This gives an in-depth audit trail that can be visited in order to check and comply and settle disputes (Schär, 2021).

As an example, one of the uses of smart contract would be in the KYC (or AML) procedures in financial institutions, in which the institution will be able to prove its compliance under audit without having to manually compile records. This comes in handy particularly in jurisdiction where the regulation on the transparency and reporting of data and finances are strict (Kumar et al., 2022).

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6.6. Programmability and Customization

Programmability is one of the most distinctive elements of smart contract. The developers are free to implement any extensive variety of financial dealing in smart contracts: such as interest calculations, dividend payout regulations, escrow arrangements, or multi-signing transaction mandates. This enables financial institutions to customize contract to serve in a variety of purposes: like retail loaning to trading derivatives (Tapscott & Tapscott, 2018).

The composability property can also be facilitated by the programmability feature as smart contracts can connect to other decentralized apps (dApps) and protocols. To give an example, token platforms, such as Aave or Compound employ smart contracts that are interoperable with price oracles and stable coins, as well as exchanges (Gudgeon et al., 2020).

7. Challenges and Risks

Although smart contracts appear to be a way of changing the banking and financial industries in a revolutionary way, there are still a number of challenges and risks that cannot be ignored before reaching a mass adoption of this technology. These barriers are legal, technical, regulation and operation barriers. It is important to examine these shortcomings and combat them to make the most out of smart contracts in financial services (Wang et al., 2022; Zetzsche et al., 2020).

7.1. Legal Recognition and Enforceability

The absence of a standard framework of law is one of the main issues related to smart contracts. In as much as smart contracts do not need intermediates, they are still operating in a legal environment, represented by the real world, which necessitates definition of enforceability. Smart contracts are not yet legally established in numerous jurisdictions, though this situation is understood to be resolving as a result of the obscurities surrounding the meaning of the concept of the contractual consent within the coded formats (Werbach & Cornell, 2017).

Without worldwide legal acknowledgement, legal disputes that can occur due to the execution of smart contracts can be hard to settle by means of jurisdiction and the regular law. Nations such as the UK and Singapore are starting to recognize the legality of smart contracts (UK LawTech Delivery Panel, 2020), yet there are numerous others which are lagging behind, thus bringing in uncertainty over cross-border financial dealings.

7.2. Coding Errors and Smart Contract Vulnerabilities

Smart contracts are as good as the code used to write them. Incorrectness in the logic of the contract may have disastrous economic impact, especially since smart contracts cannot be deleted after they have been introduced to the network. The most notable one is the event of DAO (Decentralized Autonomous Organization) hack in 2016 that utilized the flaw in Ethereum smart contract and led to over $60 million of Ether being stolen (Atzei et al., 2017).

Even now, studies indicate that most contracts deployed on blockchains such as Ethereum continue to harbor serious vulnerabilities because of the absence of formal verifications, tests, and reviews (Li et al., 2021). Such risks have been compounded in financial systems where the loss is high, and mistakes can cause the system to become unstable.

7.3. Scalability and Transaction Speed

Transaction throughput is usually a major problem with blockchain platforms - especially with public blockchains. An example is ethereum, which has a transaction rate of approximately 1530 transactions per second (TPS), which is inadequate to take care of high volume financial institutions (Buterin, 2020). Such a restriction forms bottlenecks when there are many transactions in a short period of time, resulting in delays and increased gas fee (transaction cost), which ends up negating one of the benefits of smart contracts, which is swiftness.

Although Layer-2 scaling solutions, like Optimistic Rollups, zk- Rollups or more recent consensus protocols such as Ethereum 2.0 have been created to address scalability, they remain experimental, and have yet to undergo mass adoption (Gudgeon et al., 2020). In order to utilize the idea of smart contracts in the key processes of the core banking, vital improvements should be done to the blockchain infrastructure.

7.4. Regulatory Compliance

Smart contracts can complicate regulation compliance, especially within jurisdictions with

high regulation around Know Your Customer (KYC), anti-money laundering (AML) and data retention. Because smart contracts execute by themselves and in a global world, they can possibly contravene the financial regulatory policies of countries or nations (Zetzsche et al., 2020).

As an example it can be painfully challenging to reverse a deployed contract or alter it to comply with regulatory inquiries, i.e. to prevent the transaction flagged as having AML issues. Furthermore, anonymity or pseudo-anonymity of the users of blockchains represents barriers to regulators in terms of searching transparency and tracks of funds (Chen et al., 2021). This is quite complicated, especially, in cross border financial activities, and where there are several jurisdictions and law systems to deal with.

7.5. Privacy and Data Protection Issues

Although blockchain transparency has been proven as one of the strongest sides of the technology in question, it poses some difficulties revolving around data privacy. In public blockchain, all transactions and contract features can be monitored by all nodes on the blockchain network, which could be against data protection laws such as the General Data Protection Regulation (GDPR) in the European Union (Finck, 2019).

Under GDPR, people can exercise the right to be forgotten and companies should be able to delete or correct any personal information. Immutability of blockchain however makes such deletions very difficult after data has been written to-chain. Such solutions as privacy-enhancing technologies (PETs) such as zero-knowledge proofs and confidential smart contracts (e.g., Enigma, Oasis Labs) are under development. However, they are not ready to be used by mass markets in the financial sphere yet (Zhang et al., 2022).

Moreover, smart contracts tend to use off-chain sources of data (e.g. customer identity, financial history) via oracles. In case they are corrupted or breached, such oracles might accidentally leak sensitive user information to the smart contract.

8. Regulatory Perspectives

8. Regulatory Perspectives

Although the introduction of smart contracts in the financial world is gaining new momentum, the regulatory environment is heterogeneous and developing. The world policymakers have been keeping a watchful eye on what is happening, and they are hopeful of the benefits that the automation and transparency, and a degree of efficiency is bringing forth, but at the same time, there are efforts toward consumer protections, cybersecurity, and legal certainty (BIS, 2022). Various regulatory frameworks at different levels of maturity exist, depending on the jurisdiction and there is no single international standard to regulate the use and implementation of smart contracts.

8.1. International Regulatory Developments

On a global scale, a number of regulatory authorities are finding their way towards deciphering and possibly institutionalizing the status of smart contracts in legal and financial systems. An example can be found with the European Union (EU) which recently proposed the Markets in Crypto Assets (MiCA) regulation that, in part, would lay the foundation of crypto asset regulation, but would also pave the path to addressing blockchain based applications, such as smart contracts (European Commission, 2023). MiCA suggests ways to protect the consumer, integrity in the market, and the license issuers and service providers which signify the proactive approach of the EU.

The Bank for International Settlements (BIS) has expressed hope in the transformative potential of decentralized applications but cautions of the systemic risk with which it can be associated without suitable supervision and regulation. BIS focuses on the necessity of supervisory structures that could provide terms of the safe introduction of smart contracts into the financial systems critical infrastructure (BIS Annual Report, 2022).

The United Kingdom has assumed a progressive position. In reports published in 2021 and 2023, the UK Law Commission said that legally binding smart legal contracts in which the terms of the contract are set out and fulfilled by computer code fill a gap in the law in relation to the phraseology, form and effectiveness of legal lightweight contracts (UK Law Commission, 2023). More rules are also required in order to address smart contract formation, interpretation, performance, and remedies that the Commission also highlighted.

The system is more fragmented in the United States because of the federal structure of responses regarding regulations. Yet there are measures being put in place by the states. Additionally, the State of Arizona acknowledged the legal force of blockchain-based smart contract in 2017 in the House Bill 2417 which places them under the sections of enforceable contracts in the state raw code (Arizona Legislature, 2017). On the same note, states such as Wyoming and Vermont have also enacted blockchain accommodating laws, particularly in the areas of digital assets/smart contracts (Allen et al., 2021).

8.2. India's Regulatory Perspective

India is quite keen on blockchain technology including smart contracts, but its regulatory aspect remains exploratory. Reserve Bank of India (RBI) and Securities and Exchange Board of India (SEBI) agencies are on an active research course of the same questions, using smart contracts in digital currency issue, in securities clearing and settlement, and automated compliance with regulatory measures (RBI Bulletin, 2023).

A discussion paper on blockchain in financial services was published by the Indian government that also found that smart contracts were imperative in ensuring a rise in efficiency in the insurance, lending, and trade finance sectors. In addition, the flagship pilot of the Central bank Digital Currency initiated in India by the RBI in 2022 is positioning and setting up of the potential of incorporating programmable payments in the form of smart contracts in the future (Mehta & Ramesh, 2023).

Regardless of such developments, India has no codified legislation that will expressly approve smart contracts. This can be mildly supported with the Information Technology Act, 2000, the law on digital signatures and electronic records, although it is not enough to address the intricacies of decentralized execution and indelible characteristics of smart contracts (Narayanan, 2021). There must be an all-inclusive policy structure that takes care of validity of contracts, dispute resolution, the clarity of jurisdiction and data privacy.

8.3. Regulatory Challenges and Gaps

As much as the regulatory impetus is encouraging, there are issues of concern including:

- **Lack of harmonized global standards**: Smart contracts are treated differently and with varying levels of legal recognition in different jurisdictions. This poses a problem to cross-border financial applications, namely international trade or global investment settlements (Zetzsche et al., 2020).
- **Jurisdictional ambiguity**: Because smart contracts run on decentralized and distributed systems, it is difficult to establish the relevant legal jurisdiction in case of conflict.
- **Audit and control mechanisms**: Regulators should have a way to monitor and audit smart contracts where the consequences of failure could be large e.g. in a high-stakes financial application like derivatives trading, or in syndicated lending. This becomes especially difficult in the case of a complex smart contract logic or one integrated with the decentralized autonomous organizations (DAOs) (Wright & De Filippi, 2019).
- **Risk of algorithmic bias**: The biases can be inherent to smart contracts facilitated by AI or machine learning tools. Analytical transparency and responsibilities are the extralegal factors that regulators should take into account (Brundage et al., 2022).

8.4. The Way Forward for Policy-Makers

In order to reap the most out of the smart contracts contemplating the risks included, the regulation should pursue a multi-faceted approach:

1. **Legal Clarification**: Governments need to revise the currently established laws on contracts or introduce new digital contract systems where smart contracts are legally accepted and their enforceability, rights and obligations are determined.
2. **Regulatory Sandboxes**: More countries ought to have regulatory sandboxes - safe playing areas in which smart contract programmes can be tested on a trial basis, under regulatory over sights (Narula 2022).
3. **Cross-border Collaboration**: Multinational agencies such as the International Organization of Securities Commissions (IOSCO) and Financial Action Task Force (FATF) should endorse uniform requirements of smart contract policies related to financial solutions.

4. **Capacity Building**: The regulators and the judicial systems must be educated and need capacity building programs on technical aspects to get familiar with the blockchain and smart contracts. This will contribute towards better supervision and conflict management.
5. **Privacy Compliance Tools**: Promote studies and development of privacy-friendly smart contract architecture that could be installed together with the GDPR, and user-facing (Zhang et al., 2022).

9. Real-World Case Studies

Smart contracts are no longer foundational concepts but practical applications with actual usage in different financial organizations. The case studies below show the flexibility and transformational powers of smart contracts in the worlds of banking, trade finance and decentralized finance.

9.1. JPMorgan Chase – Quorum

Quorum is a permissioned blockchain that was created by JPMorgan Chase based on the Ethereum protocol and aimed at specialised needs of financial services, including privacy, high speed and according to regulations (JPMorgan, 2020). Quorum smart contracts enable business activities, such as interbank settlements, processing of syndicated loans, and clearing payments to rely much less heavily on third parties and paper reconciliation.

One such use is of Interbank Information Network (IIN), now branded Liink, based on Quorum-based smart contracts to mitigate the delays in cross border payments that are otherwise delayed by compliance requirements. Liink allows banks to be able to transfer payment-related information in real-time with the help of automation, which makes it faster and transparent (Crosman, 2021).

Also, JPMorgan combined Quorum with ConsenSys in 2020 to advance enterprise-grade solutions on a worldwide scale which can be considered a strategic shift towards a collaborative approach to the adoption of blockchain infrastructure (ConsenSys, 2020).

9.2. Banco Santander – Blockchain Bond Issuance

In 2019, Banco Santander became frontline news when it issued a 20-million-euro bond issued using the Ethereum blockchain. The bank used smart contracts to conduct the whole process of the bond from issuance to interest payment to final redemption (Santander, 2019).

This revolutionary deal shown that smart contracts can be employed to settle transactions in real time and check compliance automatically, without going through traditional clearing houses. The issuance of the bond was made to be the first-ever end-to-end blockchain bond where both cash- and securities-based legs of the transaction were recorded and ran through the use of smart contracts.

This put settlement times down to minutes from several days, a major step forward with respect to efficiency, trustless automation in capital markets (PwC, 2022).

9.3. The DeFi Ecosystem – MakerDAO, Compound, and Aave

One of the other and very successful applications of the smart contracts is the Decentralized Finance (DeFi), and companies like MakerDAO, Compound, and Aave, have dramatically transformed the idea of lending and borrowing. They are the computerized ecosystems that are completely driven by smart contracts to provide permissionless financial services.

- MakerDAO deploys decentralized stablecoin (DAI) through smart contracts which are pegged to the USD. Users can collateralize (like ETH) against smart contracts, and in result generate DAI that allows for decentralized lending (Kuo Chuen & Deng, 2021).
- Compound enables the network to borrow and lend the crypto assets with the rates changing dynamically based on the demand and supply. Anything like collateral management, the accrual of interest and the liquidation do all occurs via smart contracts.
- Aave implements new features such as flash loans which are unsecured loans that need to be returned within a blockchain transaction, and are operated through smart contracts alone. It also brings in algorithmic risk management, which will automatize the level of liquidation and follow-up on the collateral (Schär, 2021).

The DeFi market highlights how smart contracts can produce wholly automated financial products, which

are transparent, unchangeable and accessible anywhere in the world. Nevertheless, it also demonstrates the danger of smart contracts bugs and exploits, as the problem was evidenced in many high-profile DeFi hacks.

9.4. ICICI Bank and Emirates NBD – Cross-border Remittances

During a pilot conducted, ICICI Bank (India) and Emirates NBD (UAE) demonstrated the use of smart contracts with the execution of cross-border trade finance and particularly remittance between the two countries. This initiative enabled, almost in real-time, the processing of cross-border trade documents, invoice financing and remittance settlements to be processed, effectively without paper (PwC, 2022).

The smart contracts ran on a permissioned blockchain and were programmed to automatically beta settlement when certain conditions had been fulfilled- e.g. when the delivery was confirmed or the invoice was approved. The platform ensured:

- More transparent trade documents.
- An increase of more than 60 percent of turnaround time
- Increased data integrity of tamper resistant records

This pilot showed how conventional banks can exploit the benefits of smart contracts in automating a very cumbersome and paper-intensive process, thus setting the stage of widespread use on remittance and trade finance platforms built on blockchain in emerging economies.

10. Future Outlook

The evolution of the global smart contract environment is now gaining search towards being adaptive, intelligent, and interoperable, and systems that interact with other frontier technologies, such as Artificial Intelligence (AI), Internet of Things (IoT), and Big Data analytics are at the forefront. It is predicted that these integrations will change not only the way contracts are built but also with how financial systems self-regulate, develop and expand geographically.

10.1. Convergence with Emerging Technologies

Since smart contracts can synergise with next-gen technologies, they are growing more versatile. Smart contracts have the potential to develop to judge contextual information and modify contract behavior through training machine learning algorithms when used alongside AI. As an example, AI will have the ability to evaluate the credit risk based on alternative data such as social media or device utilization and provide it as smart contracts to automatically adjust interest rates or approving / rejecting disbursements (Zhang et al., 2022).

IoT sensors like a physical tracker in logistics, or a step counter in health insurance, can also act as data oracles providing real-time information to smart contracts. The presence of an IoT sensor on a shipping container in a supply chain scenario can verify the temperature or location and execute smart contact-based payment or alerts (Atlam et al., 2020). Likewise, wearables can send real-time data to the health insurers to automate the process of premium adjustments or validation of claims using smart contracts.

In addition, with the help of Big Data analytics smart contracts can be predictive and not reactive. Risk scoring model, fraud detection, and even dynamic insurance pricing may be applied to the smart contract logic in the form of historical and predictive data analytics (Nguyen et al., 2021).

10.2. Central Bank Digital Currencies (CBDCs) and Smart Contracts

Among the possible frontiers, there is a blending of smart contracts with Central Bank Digital Currencies (CBDCs). CBDCs as programmable digital currency produced by central banks are well suited to policy-carrying smart contracts. One example is the stimulus payment coding that can only be spent on essential goods or an automatic subsidy that will only be paid once a condition has been satisfied e.g. a certain amount of crop has reached (OECD, 2023).

In China programmable versions of digital yuan are currently being tested by People's Bank of China (PBoC) and in Europe the European Central Bank is researching the concept of smart contracts layers which would apply to its digital euro project (BIS, 2022). This integration can make monetary policies automated, make regulations obligatory and promote goal-based monetary distribution, radically changing the structure of the national finances.

10.3. Emerging Trends in Smart Contracts

There are significant trends that are shaping up smart contracts:

a. Smart Legal Contracts

Smart legal contracts (SLCs) are the contracts that are written in legal style format but contain executable code. Although smart contracts are not new as a technology concept, SLCs seek legal execution, also being hybrid documentation that is literate (readable by humans) and executable (runnable by automated computers). There is already the guidance issued by the UK Law Commission which includes the legal nature of those kinds of contracts, and it includes the institutional inclination toward their acceptance in the legal institutions (UK Law Commission, 2021).

b. Tokenized Assets and Securities

It is likely that tokenization of things of both tangible and intangible nature, e.g., real estate, equities, or intellectual property, will enter mainstream. Ownership relinquishment when dividends are to be paid or royalties made due will be taken care of automatically by smart contracts. To give an example, the International Monetary Fund (IMF) has focused on noting that tokenized securities may feature in the solution to financial inclusion, including, via the availability of an investment product to a fraction of traditional price (IMF, 2022).

c. AI-Driven Compliance Automation

There will be a more intelligent and flexible regulatory compliance particularly in KYC (Know Your Customer) and AML (Anti-Money Laundering). Frauds can be identified in real-time and automated when AI-based systems freeze an account with suspicion, create audit trails, or report anomaly to human monitoring via automatic updating smart contracts (Gans, 2019). This will especially be essential in applications requiring Decentralized Finance (DeFi) that do not offer the normal compliance infrastructure.

d. Interoperability and Cross-Platform Integration

The existing smart contract universe is divided among several platforms-Ethereum, Solana, Hyperledger, Corda and so on. The further trend is likelihood to interconnect blockchain. Chainlink Cross-Chain-Interoperability-Protocol (CCIP) or Polkadot or Cosmos is among those projects that attempt to enable smart-contract functionality to be cross-networking and open a new dimension of cross-border applications and composable finance (Wood, 2021; Chainlink Labs, 2023).

10.4. Socio-Economic Implications

The democratization of the financial sector can be regarded as one of the best implications of the evolution of smart contracts. In rural and underbanked regions, they run the program that offers microfinance, cooperative financing and insurance without needing any physical infrastructure (World Bank, 2023) Increasing smartphone penetration and the growth of 5G infrastructure means that smart contracts may be used to provide real-time agricultural insurance, transfers of land registry ownership, or release of educational funding in line with attendance verification.

Moreover, the corruption of the system can be reduced by smart governance models that facilitate the process of public procurement, social welfare, and municipal services, which operate using smart contracts and make the process more transparent (UNCTAD, 2023).

11. Conclusion

Smart contracts are one of groundbreaking inventions in the area of financial technologies, totally changing the landscape of trust, performance and compliance in banking and finance. These blockchain-based protocols assist in enforcing automated financial agreements without the intervention of intermediaries and in a transparent, secure, and efficient way (Christidis & Devetsikiotis, 2016). The application of smart contracts includes cross-border remittances, trade finance, insurances claims, loan disbursement, and regulatory compliance, among others, with the list growing continuously.

The paper has shown the smart contract implementation has seen quantifiable advantages such as reduced costs, operating efficiencies, settlement time, and auditability (Zheng et al., 2020; OECD, 2023). Also, smart contracts feature the immutability, transparency, and programmability

that makes them specifically applicable to support the needs of the digital-first financial economy.

Nevertheless, this revolution does not come without serious challenges. The identified key risks are indicated as the lack of a standardised legal recognition, vulnerability to a coding error, blockchain platform scalability limitations, and questionable privacy of data with regard to such legislation as the GDPR (Werbach & Cornell, 2017; Atzei et al., 2017). These limitations suggest the necessity of the multidisciplinary correlation among technologists, lawyers, regulators, and financial institutions to reveal all the potential of smart contracts.

Global jurisdictions are playing it smartly and cautious but progressive in regulatory terms. MiCA framework of the European Union, exploration of RBI and SEBI of India, and legal recognition by states in the U.S. point out at the increased institutional interest to legalize and mainstream the innovation (BIS, 2022; RBI Bulletin, 2023).

In the future, there are a number of trends that will influence the course of smart contract adoption. These include

- By integration of AI and Big Data, it is possible to realize predictive and responsive contracts
- Interoperability services i.e., smart contracts are able to inter operate between block chains and traditional systems.
- Asset tokenization, which makes it possible to carry out novel forms of digital value ownership and investment.
- The CBDC or Central Bank Digital Currencies may develop into a more programmed currency that will be directly linked to the platforms via smart contract (OECD, 2023).

In order to embrace the power of smart contract in the finance industry, stakeholders should develop sound legal framework, conduct technology upgrade, and establish meaningful digital literacy and confidence with its users. As they go through the process of being digitized and decentralized, smart contracts will probably become the initial layer of an automated, trustless, worldwide scalable financial infrastructure.

The given study will add to the scholarly discourse on the topic of FinTech as it presents a systematic, detailed, and evidence-based presentation of the reemerging transformation of contemporary finance due to the advent of smart contracts. The further development of scientific knowledge in the field can be significantly expanded by carrying out a comparative study of the regions, a study of the legal influence, or an empirical study on the financial solution executed under smart contracts.

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