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Revolutionizing Financial Markets: The Role of Distributed Ledger Technology in Payments, Clearing, and Settlements

Révolutionner les marchés financiers : Le rôle de la technologie des registres distribués dans les paiements, le règlement et la compensation

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Abstract:

Distributed ledger technology (DLT), also known as blockchain, is considered one of the technological innovations with significant potential to revolutionize payments, clearing, and settlement processes. This paper aims to provide a comprehensive understanding of the application of DLT in these areas by evaluating its benefits, opportunities, and the risks and challenges associated with its practical and long-term adoption. This study employs a comprehensive systematic literature review as its primary methodology, involving the identification, selection, and critical analysis of relevant academic and industry sources. By conducting an exhaustive analysis of the literature, the research ensures a thorough and balanced examination of current knowledge, uncovering key trends, advancements, and existing gaps in the field. The findings reveal that current systems for clearing, settlements, and cross-border payments are often inefficient, slow, and costly. A DLT-based alternative has the potential to enhance these processes by making securities clearing and settlement more timely, transparent, efficient, and secure. DLT allows organizations to conduct transactions in payments and settlements systems without requiring a central entity or intermediaries such as banks or clearinghouses, potentially enabling a more efficient, transparent, and secure financial market. Various DLT protocols have been employed in payments and securities initiatives, with central banks across multiple countries launching DLT-related research to assist the financial and commercial sectors in developing this technology. DLT-based systems represent a major opportunity to address the current frictions in payment clearing and settlement processes and are likely to cause a considerable change in market structures. However, the technology is still in its early adoption stage and faces various obstacles, including technological barriers, privacy concerns, and regulatory challenges that need to be addressed by relevant stakeholders. The study emphasizes the importance of collaboration among stakeholders, including regulators, financial institutions, and technology providers, to overcome these challenges and leverage the opportunities presented by DLT in revolutionizing financial services.

This paper contributes to the broader discourse on the potential of emerging technologies to disrupt traditional financial services processes. It underscores the need for continued exploration and resolution of the issues hindering the adoption of DLT to fully realize its transformative potential in the financial sector. By examining these aspects, this paper seeks to shed light on the future landscape of payments, clearing, and settlements, and the role DLT might play in shaping it. The study underscores the importance of collaboration among stakeholders to overcome the challenges and leverage the opportunities presented by DLT in revolutionizing financial services.

Keywords: Distributed Ledger Technology (DLT) – Payments – Clearing – Settlements.
JEL Classification : G23, G28, G15
Paper type: Theoretical Research

1. Introduction

The financial industry is currently navigating a period of rapid transformation, driven by the rise of financial technology, or Fintech, which encompasses a variety of digital innovations reshaping traditional financial processes. Emerging technologies such as Blockchain, Big Data Analytics, Artificial Intelligence (AI), and Robotic Process Automation (RPA) are at the forefront of this change, offering unprecedented opportunities to enhance efficiency, reduce costs, and improve transparency across the financial services sector. Among these technologies, Distributed Ledger Technology (DLT), commonly known as blockchain, has emerged as a particularly disruptive force, with the potential to fundamentally revolutionize payments, clearing, and settlement (PCS) systems.

Initially developed in 2008 to underpin Bitcoin transactions, DLT has since evolved far beyond its original scope (Nakamoto, 2009). Today, it is being explored and implemented across various financial sectors, particularly in PCS processes, where it offers a decentralized, secure, and transparent framework for managing digital transactions. This decentralization allows for transactions to be conducted without the need for a central authority or intermediaries such as banks or clearinghouses, which traditionally play a crucial role in these processes (Mills et al., 2016; Pinna & Ruttenberg, 2016). By eliminating these intermediaries, DLT promises to enhance efficiency, reduce operational costs, shorten processing times, and increase security, all of which are critical issues within the current financial market infrastructure.

The transformative potential of DLT has not gone unnoticed. It has attracted significant attention from academics, industry participants, and regulators alike, who recognize its ability to drive innovation and induce transformative changes in existing business models and frameworks. Various DLT protocols have already been employed in payments and securities initiatives, with central banks in multiple countries spearheading DLT-related research and pilot projects to assess and develop this technology. These initiatives underscore the widespread recognition of DLT as a key driver of change, capable of addressing current inefficiencies in PCS processes and potentially reshaping market structures in significant ways (Bech & Garratt, 2017; Benos et al., 2017).

However, despite its promising potential, the adoption of DLT in PCS processes is still in its early stages and is fraught with challenges. Key issues include the technological maturity and scalability of DLT systems, privacy concerns, and the complexities of integrating DLT into existing regulatory frameworks (Priem, 2020; German Banking Industry Committee, 2016). Prior research has consistently highlighted these challenges, stressing the need for further technological advancements and the development of a robust regulatory framework to support DLT's integration into the financial system (ESMA, 2017; Klimos, 2018). For instance, studies by Mills et al. (2016) and Goldman Sachs (2016) have delved into the potential benefits of DLT in securities settlement, while also identifying significant regulatory hurdles that must be addressed to enable its broader adoption.

Given these complexities and the nascent state of DLT, this study aims to fill a critical gap in the existing literature by exploring the practical application and long-term viability of DLT in revolutionizing PCS systems. The core objective of this paper is to investigate how can DLT be effectively applied to transform payments, clearing, and settlement (PCS) systems, and what are the potential benefits, applications, challenges, and opportunities associated with its adoption?

To address this question, the paper undertakes a comprehensive review of the current literature and conducts an in-depth analysis of various DLT protocols employed within the post-trade financial infrastructure. This exploration is grounded in a thorough examination of relevant scientific research databases, with the goal of identifying and evaluating the key aspects related to DLT's implementation. The primary aim is to advance the current understanding of DLT's business value within the fintech and financial sectors, thereby contributing to the ongoing discourse and providing actionable insights for practitioners and policymakers.

Moreover, this research emphasizes the critical role of collaboration among regulators, financial institutions, and technology providers. Such collaboration is essential for overcoming the existing barriers to DLT adoption and for fully realizing its transformative potential. By serving as a valuable reference for organizations, financial market participants, and regulators contemplating the adoption of DLT, this paper seeks to illuminate the future landscape of PCS systems and to define the role that DLT might play in shaping that future (Avgouleas & Kiayias, 2019; Pinna & Ruttenberg, 2016).

In conclusion, as the financial sector continues to evolve under the influence of Fintech innovations, DLT stands out as a key technology with the potential to address longstanding inefficiencies in PCS processes. This study contributes to the broader understanding of DLT, providing a detailed analysis of its opportunities and challenges, and offering a roadmap for its successful integration into the financial ecosystem.

2. The Digital Transformation of Financial Markets: Foundations, Theories, and Emerging Technologies

The digitalization of financial markets has been one of the most profound developments in the global financial system over the past few decades. Driven by the rapid advancement and integration of Information and Communication Technologies (ICT), financial markets have undergone significant changes, fundamentally altering their structure, operations, and dynamics. This chapter explores the digital transformation of financial markets, focusing on the role of ICT, relevant theories, and the emergence of new technologies such as Distributed Ledger Technology (DLT), which are poised to revolutionize payments, clearing, and settlement processes.

2.1.The role of Information and Communication Technologies (ICT) in Financial Markets

Over recent decades, global financial markets have experienced significant changes, driven largely by the proliferation of ICT. These technological advancements have played a central role in transforming financial systems, particularly in the areas of payments, clearing, and settlement. ICT has been instrumental in reshaping financial markets, often described as "information markets" due to their heavy reliance on data. The rapid diffusion of ICT has enabled faster and more reliable internet access globally, providing the infrastructure necessary for these profound changes (Panagariya, 2022).

ICT's ability to disseminate information quickly and efficiently has reduced market inefficiencies such as time delays and information asymmetries. This has led to the decentralization of financial markets, allowing geographically dispersed participants to engage in transactions with greater ease and increasing market efficiency. Broadband networks, in particular, have facilitated the high-volume transmission of financial data, crucial for the activities in modern financial markets.

A critical aspect of this transformation is the integration of ICT into market infrastructures. The most visible impact has been the shift from physical trading floors to fully electronic trading platforms. These platforms utilize ICT to facilitate the execution of trades, manage orders, and provide real-time data to market participants. The result has been increased market liquidity, reduced transaction times, and lower costs associated with trading (Berndsen et al., 2018).

Moreover, ICT has enabled the development of sophisticated financial instruments and trading strategies, such as algorithmic and high-frequency trading. These strategies rely on advanced algorithms and high-speed internet connections to execute large volumes of trades in milliseconds, capitalizing on minor price discrepancies across markets. The proliferation of such strategies has increased the complexity of financial markets but has also contributed to more efficient price discovery and greater market stability (Li & Perez-Saiz, 2018).

2.2.Theories of Digitalization in Financial Markets

Understanding the impact of ICT on financial markets requires a review of key theoretical frameworks that explain the changes brought about by digitalization.

- **Efficient Market Hypothesis (EMH):**

The Efficient Market Hypothesis posits that financial markets are "informationally efficient," meaning that asset prices reflect all available information. ICT has significantly bolstered this concept by enhancing the speed and accessibility of information, thus contributing to more efficient markets. The rapid dissemination of financial data through ICT reduces information asymmetries, leading to more accurate pricing of assets and minimizing market inefficiencies (Lee et al., 2019).

- **Network Theory**

Network Theory examines the interconnectivity within financial markets, which ICT has transformed into highly interconnected networks. Participants are linked through digital platforms and communication systems, facilitating the flow of information and capital, enhancing liquidity, and enabling seamless financial transactions across borders. Network effects, where the value of a financial service increases as more participants join, are increasingly evident in digital payment systems and online trading platforms (Hoffmann et al., 2020).

- **Transaction Cost Theory**

Traditionally, financial transactions incurred significant costs due to intermediaries, paper-based processes, and the physical movement of documents. ICT has drastically reduced these transaction costs by automating processes, digitizing records, and enabling real-time communication between market participants. This reduction has facilitated the growth of high-frequency trading, algorithmic trading, and other automated financial activities that dominate modern financial markets (Boussafsaf & Taleb, 2019).

- **Theory of Disintermediation**

Disintermediation refers to the removal of intermediaries in financial transactions, a process significantly accelerated by ICT. Digital platforms and technologies, such as peer-to-peer lending and crowdfunding, allow individuals and businesses to bypass traditional financial intermediaries, reducing costs and increasing efficiency (Rejeb et al., 2021). This shift has paved the way for innovations like Distributed Ledger Technology, which further enhances disintermediation by enabling decentralized and trustless transactions.

2.3.The Impact of ICT on Financial Market Infrastructure

Financial Market Infrastructure (FMI) refers to the fundamental backend systems, processes, and institutions that facilitate the functioning of financial markets, such as payment and settlement systems, exchanges, and central counterparties. The evolution of FMI has been shaped by both technological advancements and regulatory changes. ICT has played a critical role in modernizing FMI, leading to increased efficiency, reduced settlement times, and improved risk management (Panagariya, 2022; Berndsen et al., 2018).
Before the 2008 global financial crisis, FMIs were becoming increasingly digitalized, centralized, and integrated. The advent of the internet and advancements in ICT enabled new ways of trading and settling financial transactions, such as electronic trading platforms and

digital payment systems. However, the crisis exposed flaws in centralized financial systems, prompting regulatory reforms aimed at improving their stability and resilience. These reforms, including the implementation of central clearing for certain types of derivatives and the creation of new types of central counterparties, have further entrenched the role of FMI (Li & Perez-Saiz, 2018).

The rise of distributed ledger technology (DLT), particularly blockchain, has provided new opportunities for innovative solutions within FMI, which we can term as DLT-FMI. Blockchain technology has the potential to disrupt FMI by enabling faster, more secure, and more transparent transactions and settlements (Frizzo-Barker et al., 2020). The decentralized architecture of blockchain eliminates the need for intermediaries and increases transparency and security in financial transactions. For instance, blockchain-based payment systems can allow for real-time, cross-border transactions without banks, significantly reducing transaction costs and increasing the speed of payments (Chang et al., 2020).

Another potential use of blockchain technology in finance is the creation of new digital assets, such as cryptocurrencies and non-fungible tokens (NFTs), which can serve as alternatives to traditional fiat currencies and assets. This can lead to the creation of new financial instruments and markets, challenging the dominance of traditional financial institutions (Chen et al., 2023).

Blockchain technology can also improve the efficiency and reduce the risk of the backend systems that support financial transactions. For example, blockchain-based settlement systems enable faster and more secure settlement of trades, reducing the risk of failed trades and increasing overall market efficiency (Kowalski et al., 2021).

However, the widespread adoption of blockchain in the financial sector will depend on various factors, such as regulatory clarity, security, scalability, and interoperability. The financial industry will need to evaluate these challenges carefully to determine the most effective and efficient ways of implementing DLT-FMI (Ahluwalia et al., 2020).

2.4.The Rise of FinTech and the Emergence of Distributed Ledger Technology (DLT)

The rise of Financial Technology (FinTech) represents one of the most significant outcomes of the integration of ICT into financial markets. FinTech companies leverage ICT to offer innovative financial products and services that challenge traditional banking models. These include digital payments, online lending, robo-advisory services, and blockchain-based applications. By utilizing ICT, FinTech firms have democratized access to financial services, providing low-cost, user-friendly platforms that cater to underserved populations, particularly in developing countries where traditional banking infrastructure is limited.

The rapid growth of FinTech has also spurred increased competition within the financial sector, compelling traditional financial institutions to adopt digital technologies and innovate their service offerings. This competition has led to improved customer experiences, lower costs, and the development of new financial products that meet the evolving needs of consumers.

As financial markets continue to evolve, the digitalization driven by ICT has laid the groundwork for the emergence of Distributed Ledger Technology (DLT). Blockchain, a form of DLT, has the potential to revolutionize FMI by enabling faster, more secure, and more transparent transactions and settlements. Blockchain technology's decentralized architecture eliminates the need for intermediaries, increasing transparency and security in financial transactions. For example, blockchain-based payment systems can allow for real-time, cross-border transactions without banks, significantly reducing transaction costs and increasing the speed of payments (Chang et al., 2020).

Furthermore, blockchain technology can improve the efficiency and reduce the risk of backend systems that support financial transactions. Blockchain-based settlement systems enable faster and more secure settlement of trades, reducing the risk of failed trades and increasing overall market efficiency. However, the widespread adoption of blockchain in the financial sector will depend on various factors, including regulatory clarity, security, scalability, and interoperability.

3. Payments, clearing & Settlements processes in the post trade Infrastructure/market

Before analyzing how DLT will potentially reshape Financial Market Infrastructures (FMIs) and, in particular, Payments, clearing and Settlement processes, it seems critical to first understand the existing structure of financial markets.

3.1.The key components of a financial transaction

In general, regardless of the type of asset involved, the clearing and settlement of financial transactions require three main components:
(i) a network comprising direct participants such as banks and indirect participants like businesses and households; (ii) An asset or assets transferred among parties, which can include various financial instruments such as securities, commodities, derivatives, and monetary instruments; (iii) and a defined transfer process outlining transaction procedures and obligations (Mills et al., 2016). However, transfer methods vary between payments and post-trade securities clearing and settlement, often involving different types of financial intermediaries (Mills et al., 2016).

3.1.1. Payment processes

Payment processes involving funds typically require four conceptual phases: submission, validation, conditionality, and settlement. These phases are managed by financial intermediaries such as payment systems (Mills et al. 2016; Klimos 2018).
The process begins with the submission phase, where a payment message is sent to the payment system. This message includes all necessary transaction details, such as the amount, payer and payee information, and the transaction date. Ensuring the accuracy and completeness of this information is crucial for the transaction to proceed smoothly (Mills et al. 2016; Klimos 2018).
Next, the payment system conducts the validation phase. This involves executing validation procedures and security measures, such as authenticating the transmitter to confirm the legitimacy of the source and verifying the validity of the message to ensure that the transaction details are accurate and comply with regulatory and institutional standards. This step is essential to prevent fraud and maintain the integrity of the payment process (Mills et al. 2016).
Once the payment is confirmed to be legitimate and valid, the system moves to the conditionality phase. Here, it checks whether the required settlement conditions are met, such as the availability of sufficient funds or credit in the payer's account to complete the transaction. This phase ensures that the transaction can be successfully settled without any issues (Klimos 2018).
Finally, in the settlement phase, the actual transfer of funds takes place. The payment system debits the payer's account and credits the payee's account, completing the transaction. This final phase ensures that the funds are appropriately transferred and recorded, marking the end of the payment process (Mills et al. 2016; Klimos 2018).
Understanding these processes provides a foundation for exploring how Distributed Ledger Technology (DLT) can potentially reshape these systems. By enhancing transparency, reducing settlement times, and mitigating risks, DLT offers promising advancements in the efficiency and reliability of payment systems (Mills et al. 2016).

3.1.2. Execution, clearing & settlement processes

In the case of securities, commodities, and derivatives, post-trade processes allow for the confirmation and validation of trade terms, clearing, and settlement (Mills & al., 2016). This implies that financial intermediaries (banks and broker-dealers) interact with other intermediary institutions and the FMI, which centralize and facilitate clearing and settlement processes, as well as recording financial transactions (Mills & al., 2016).

- **Execution**

Execution is the initial stage in the transaction lifecycle where the agreement to buy or sell a security is made, and the trade is executed on an exchange or over-the-counter (OTC) market. This stage involves the actual trading of securities, where orders from buyers and sellers are matched, and the terms of the trade are agreed upon (Mills et al., 2016). Execution is crucial because it establishes the trade details, including the price, quantity, and time of the transaction. This process occurs in real-time, and it is the point at which the trade is officially recorded and becomes legally binding (Loader, 2020). The execution of trades can be facilitated through various platforms and intermediaries, including brokers, exchanges, and electronic trading systems, which ensure the efficient matching of buy and sell orders (Pinna & Ruttenberg, 2016).
In the context of payments, execution refers to the initiation of the payment transaction by the payer. This involves the transfer of payment instructions to the payer's bank or payment service provider, which then processes the payment and transfers the funds to the payee's account. This step ensures that the payment obligations are met, setting the stage for subsequent clearing and settlement processes (McGill & Patel, 2008).
Execution in financial markets is critical as it triggers the clearing and settlement processes, ensuring that the agreed-upon trade is processed, obligations are calculated, and assets and funds are ultimately transferred between the parties involved (BIS/IOSCO 2012: Principles for Financial Market Infrastructures).

- **Clearing**

Clearing is the process that occurs after a trade is executed but before it is settled, involving the preparation of transaction instructions through matching, recording, and processing (Loader, 2020). This stage begins with matching the trade by comparing the buyer's and seller's records regarding price, quantity, and other criteria (Turing, 2012). Following this, the parties designate the accounts that will be credited with a payment or a security.
To mitigate the risk of a failed trade, a central counterparty (CCP) is introduced between the dealers, acting as a seller to all buyers and a buyer to all sellers, significantly reducing failure risk through netting (Cytas, 2016). The CCP manages counterparty risk by intervening between the buyer and seller shortly after the trade is executed, ensuring the trade is completed if one party fails. To further mitigate risk, the CCP collects a margin from both parties, calculated using an algorithm based on historical volatilities and correlations of the traded assets' prices (McGill & Patel, 2008).
Clearing also involves netting transactions, consolidating multiple trades in the same security or derivatives contract into a single position for either delivery or receipt. This process is crucial in derivative markets, where contracts can remain open for extended periods, as it helps eliminate counterparty risk. Many derivative contracts are settled by paying the cash value of the position instead of delivering the underlying asset, facilitated by netting (McGill & Patel, 2008).
Clearing securities transactions involves calculating the obligations of market participants to determine what each counterpart is entitled to receive. Providers of clearance include clearinghouses, central securities depositories (CSDs), or international central securities depositories (ICSDs) (de Carvalho, 2004). In traditional financial systems, clearing is typically handled by central clearinghouses. However, with blockchain technology, clearing can be automated through smart contracts, which execute predefined conditions, significantly reducing

processing time and operational risk. This automation enhances efficiency and accuracy, as blockchain provides a tamper-proof record of transactions (Pinna & Ruttenberg, 2016; Mainelli & Milne, 2016).

- **Settlement**

Clearing is followed by a settlement phase in which the delivery and payment obligations of the counterparties to commodities, securities, or derivatives transactions are fulfilled (Mills et al., 2016). Settlement is the process by which securities are transferred to the buyer and money is transferred to the seller (Caytas, 2016). This process can be conducted on an individual basis (transaction by transaction) or on a net basis (netting buyers' and sellers' obligations for a number of transactions).

Countries differ in terms of settlement cycles, currencies, legal systems, and the range of settlement arrangements available for various types of securities (Caytas, 2016). Settlement typically occurs through a Central Securities Depository (CSD), also known as a Securities Settlement System (SSS) (McGill & Patel, 2008). The CSD ensures Delivery versus Payment (DVP), meaning the payment and transfer of securities ownership happen simultaneously, finally, and irrevocably. This eliminates the risk of one party defaulting while holding both cash and securities.

Central Securities Depositories (CSDs) are responsible for the safekeeping of securities, predominantly in electronic format, and enable holders to receive benefits such as income, rights issues, and take-over offers (McGill & Patel, 2008). Settlement finalizes a trade by ensuring that both parties fulfill their contractual obligations, traditionally occurring a few days after the trade execution.

Blockchain technology offers the potential for real-time or near real-time settlement by using a decentralized ledger to record and verify transactions instantaneously. This reduces the risk of settlement failure and counterparty risk, as transactions are executed and settled simultaneously, and the immutability of the blockchain ensures the integrity and finality of the settlement (Mills et al., 2016).

In most developed financial markets, physical certificates for publicly traded securities are rarely held by participants. Instead, ownership is tracked electronically via a book-entry system managed by a central securities depository (CSD), while the cash side of the transaction is generally managed through a banking payment system (de Carvalho, 2004).

A crucial control in this process is Delivery versus Payment (DVP), which ensures that the final transfer of funds only occurs when the final delivery of securities is completed. DVP utilizes three coexisting models to eliminate principal risk during settlement, meaning neither the seller nor the buyer can default on the transaction while retaining the counterparty's asset (either monetary or securities) (BIS 1992: DVP Report, p. 12). In most markets, settlement periods range from T+1 to T+3, but the commitment period should be minimized as much as possible (BIS/IOSCO 2001: Recommendations for Securities Settlement Systems, Recommendation 3, p. 10). The growing prevalence of securities lending transactions increases the pressure on settlement agents to facilitate the same-day receipt and delivery of securities (de Carvalho, 2004).

Besides the share prices, investors must also pay fully negotiated brokerage commissions, clearing and settlement fees based on the trade's volume and value (payable by both buyer and seller), and custodian fees (de Carvalho, 2004).

3.2. Overview of the Financial Market Infrastructure in Payments, clearing and settlement

Trading in financial market instruments follows the same basic principles of clearing and settlement in all markets around the world (Loader, D., 2020).

The post-trade procedures mentioned-above, are commonly managed and facilitated by financial intermediaries such as payment systems, central securities depositories (CSDs), and central counterparties (CCPs), and securities settlement systems (SSSs) who play a key role in Payments, clearing and settlement functions (Klimos, 2018).
A 'central securities depository' (CSD) is defined as an entity that provides securities accounts and central custody services. A 'central counterparty' (CCP) is an entity that intervenes between counterparties to traded contracts in one or more financial markets by becoming the buyer for every seller and vice versa. A 'securities settlement system' (SSS) facilitates the transfer and settlement of securities by book entry, allowing for transfers of securities either for free or against payment (Pinna & Ruttenberg, 2016). Collectively, these intermediaries are known as Financial Market Infrastructures (FMIs).
Financial market infrastructures (FMIs) are the backbone of each country's financial system. They provide extensive networks for daily transmission and processing of financial transactions, as well as for interconnection between counterparties. Consequently, FMIs face considerable financial and operational risks, as well as an increased interdependency among marker stakeholders in which these infrastructures operate (Casablanca Stock Exchange[1]).

- **The Moroccan Financial Market Infrastructures**

In Morocco, the clearing and settlement infrastructure consists of two systems. The Casablanca Stock Exchange handles the clearing of securities, while Maroclear, the Central Depository, manages their settlement and delivery.

- **Casablanca Stock Exchange**

In 2018 the Casablanca stock exchange started planning to establish a new derivatives clearinghouse featuring a SPAN (Standard Portfolio Analysis of Risk) risk calculation module acquired from the CME (Chicago Mercantile Exchange). Several technical platform avenues were assessed and Following conclusive and encouraging results from the POC, the Casablanca stock exchange opted for the in-house development avenue, to ensure the financial equilibrium of the future clearinghouse. A progressive approach was selected to ultimately cover all derivatives eligible for clearing. Concurrently, the regulatory setup process for the new clearinghouse was initiated with regulatory and supervisory authorities.
The "Clearinghouse central counterparty or CCP is piloted by the Casablanca Stock Exchange. Created in 2008, this new infrastructure aims to provide the stock market with a certain stability and efficiency as well as to reduce counterparty risks with exposed capital market participants (Casablanca Stock Exchange annual report, 2022[2]).

- **Maroclear, the Moroccan Central Securities depository**

A CSD is an organization in which financial securities held by authorized financial intermediaries in their own name and or for their clients are accounted, conserved and managed. According to the law n° 35 – 96 related to the creation of a CSD in Morocco, a security might be either: stock, bond, negotiable debt instrument, collective investment fund or a mutual fund. In Morocco, the Central Securities Depository, Maroclear, plays a crucial role to ensure the required security and fluidity for the efficient functioning of the post-market processes by offering several services for securities management e.g. Codification, custody, settlement, administration, and dematerialization of securities. Maroclear, as an administrator of securities current accounts held on behalf of its affiliates, is responsible for securities dematerialization,

[1] *Casablanca Stock Exchange, "Financial Markets infrastructure and monitoring," n.d., https://www.casablanca-bourse.com/en. Accessed May 17, 2024.*
[2] *Casablanca Stock Exchange annual report (2022) https://media.casablanca-bourse.com/sites/default/files/2023-08/rapport_annuel_uk_2022-mot_pca.pdf*

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and their retention, as well as for the Settlement/Delivery system, the stock market transactions, and the voluntary sector.

- **Settlement of securities**

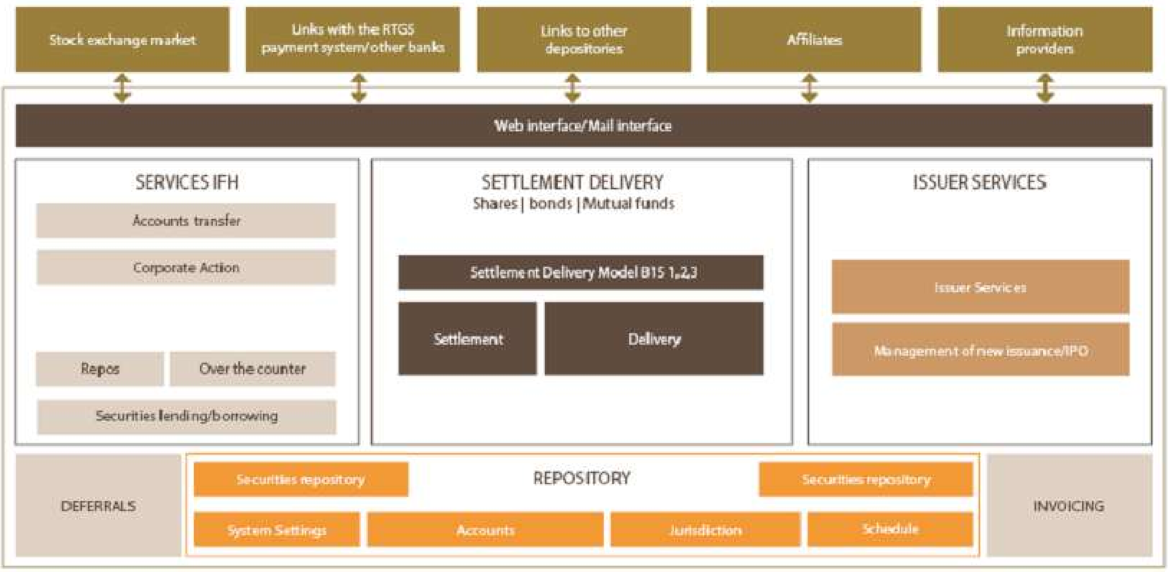
The settlement/delivery system enables the adequate circulation of transferrable securities between different securities current accounts by booking operations of free securities delivery (Franco) or of delivery versus payment (DVP).

The settlement/delivery system facilitates the transfer of securities between various securities current accounts by booking operations such as free securities delivery (Franco) or delivery versus payment (DVP).

MAROCLEAR utilizes Payments Vs Delivery systems, which enable securities transfers between current accounts created on behalf of its affiliates, while simultaneously ensuring the delivery of securities and subsequent allocation cash payments. Securities are recorded in the Central Securities Depository's current accounts, while cash payments are recorded in accounts maintained in the name of affiliates within Bank Al-Maghrib.

Maroclear's settlement of transactions can vary following various models and deadlines depending on the market. Securities in the stock market (Gross/Net model) can be settled within a settlement period of three days (T+3), as for securities in Over-The-Counter (OTC) or Repo's market (Gross/Gross model), they are settled in real-time. The application of the Delivery vs. Payment, as well as the use of central bank currency for cash settlements, ensures a high level of security of the P/D systems of securities (Maroclear[3]).

Figure 1: Architecture of the settlement / Delivery system in Morocco



Source[4]: Casablanca Stock Exchange

4. Challenges and inefficiencies in the current Post-Trade Clearing and Settlement processes

The clearing and settlement system is a cornerstone of financial market infrastructure, responsible for ensuring the accurate and timely transfer of securities and funds between

[3] Maroclear. "Settlement," n.d., https://www.maroclear.com/en/home. Accessed on June 4, 2024.

[4] Casablanca Stock Exchange, "Maroclear, the Central Securities Depositary," n.d., https://www.bkam.ma/en/Systems-and-means-of-payment/Financial-markets-infrastructure-and-monitoring/Maroclear-the-central-securities-depositary. Accessed on June 4, 2024.

transaction parties. Despite its critical role, the system faces numerous challenges and inefficiencies that impede its effectiveness. This chapter explores these issues, detailing the limitations, inefficiencies, and challenges in the post-trade securities lifecycle and the traditional settlement process, as well as potential solutions. In recent years, the escalating volume and complexity of transactions have exacerbated various frictions within the post-trade securities lifecycle. These frictions have engendered financial and operational inefficiencies, resulting in heightened costs and increased transaction risks across global financial markets (Mills et al., 2016).

Case studies have shown the impact of these challenges on settlement processes. For instance, in 2018, a major global investment bank incurred considerable losses due to settlement delays in the settlement of financial transactions. These delays, caused by documentation discrepancies and regulatory compliance issues, resulted in missed market opportunities and financial setbacks.

Understanding these challenges is paramount for devising effective strategies aimed at mitigating risks, reducing costs, and improving the overall efficiency of financial market operations.

- **Complexity and Fragmentation**

The current clearing and settlement system is highly complex, requiring the matching, reconciliation, and resolution of balances in both domestic and international trading systems (Krishnan et al., 2020). Existing post-trade settlement arrangements relying on designated third-party intermediaries tend to be slow, lengthy, costly, and inefficient (Chiu & Koeppl, 2018). This inefficiency arises from the dispersion of information within the trading system and the high reconciliation costs due to the incompatibility of intermediaries' back-office systems with financial market infrastructure. Consequently, settlement cycles in fragmented securities markets are often lengthy and fixed at intervals like T+2 or T+3 to coordinate operations among intermediaries.

- **High Costs and Revenue Implications**

Post-clearing processes, including settlement, custody, and asset servicing, generate substantial revenue in the form of fees and commissions but also represent significant expenses for market end-users (Benos et al., 2017). These high costs are partly due to the involvement of multiple intermediaries, each using its own processing systems, handling inconsistencies, and maintaining updated transaction records. The absence of standardization further exacerbates these issues, resulting in high-cost back-office reconciliation procedures. The World Economic Forum highlights the main pain points as costly intermediaries, safekeeping account complexity, counterparty and operational risks, data inconsistency, and delays between trade execution and settlement.

- **Counterparty and Settlement Risks**

One significant problem in traditional clearing and settlement systems is counterparty risk, where one party in a financial transaction may default, causing financial losses for the other parties involved. The 2008 financial crisis highlighted the severity of this risk, as the collapse of Lehman Brothers set off a series of defaults (Ali et al., 2020; Blake & Cairns, 2021; Carapella & Monnet, 2020). Settling financial transactions, particularly in cross-border scenarios, can take several days or even weeks, delaying the availability of capital and exposing market participants to market and credit risk (Ante, 2021). The involvement of multiple intermediaries frequently results in discrepancies and errors, making reconciliation a labor-intensive process necessary to align the records of the various parties involved in a transaction (Barroso & Laborda, 2022).

- **Operational Inefficiencies**

Operating and sustaining the current infrastructure, which includes outdated systems and intermediaries, incurs significant costs. These expenses are transferred to market participants, diminishing overall profitability (Birch & Parulava, 2018; Barrdear & Kumhof, 2022; Carvalho et al., 2021). The reliance on paper-based documentation, manual data entry, and the physical movement of documents can significantly slow down the settlement process. These manual procedures are prone to errors, demand extensive reconciliation efforts, and create bottlenecks in the settlement workflow.

- **Lack of Standardization**

The lack of standardization across global jurisdictions and regulatory frameworks complicates financial transactions significantly. Varying compliance requirements and reporting standards between countries increase operational costs and cause delays in transaction processing. Market participants must navigate diverse regulatory landscapes, leading to inconsistencies in legal interpretations and documentation procedures. This lack of harmonization not only poses compliance challenges but also creates legal uncertainties and risks for firms operating across multiple jurisdictions. As a result, the absence of standardized regulations hinders efficient financial market operations and innovation in settlement technologies.

- **Lengthy Processing Time**

The traditional settlement process involves multiple steps, starting from initiating the transfer to verifying account details and completing the fund transfer. Depending on the banks involved and the type of transaction, this process can be prolonged, taking several days. Such delays are predominantly due to the sequential nature of verification and authorization procedures within financial institutions. For instance, in cross-border transactions, compliance with different regulatory frameworks and time zone differences further complicates and lengthens settlement times. Therefore, these delays can pose significant challenges for businesses that need immediate access to funds for operational purposes.

- **Risk of Fraud**

Traditional settlement processes are susceptible to fraud risks where unauthorized parties may intercept fund transfers and redirect them to fraudulent accounts. This risk arises due to vulnerabilities in the verification and authentication processes, allowing fraudsters to exploit gaps in security protocols. Even with stringent verification measures, occasional human error or compromised systems can lead to funds being transferred to incorrect accounts, causing financial losses to legitimate parties.

- **High Transaction Costs**

Traditional settlement systems often impose high transaction costs on participants, with financial institutions charging fees for each transaction processed. These costs can accumulate significantly, particularly for businesses engaged in frequent and large-scale transactions. The fees cover various aspects such as transaction processing, regulatory compliance, and maintaining secure transaction channels, contributing to the overall operational expenses of market participants.

- **Limited Access to Funds**

Due to the extended processing times inherent in traditional settlement systems, recipients often experience delays in accessing transferred funds. This delay can be particularly problematic for businesses requiring immediate liquidity for operational purposes, affecting cash flow management and liquidity planning. The inefficiency in fund availability can hinder business operations, potentially leading to missed opportunities or increased borrowing costs to cover immediate financial needs.

5. Distributed Ledger Technology (DLT)

Blockchain technology, initially developed to facilitate Bitcoin transactions, provides a decentralized, secure, and transparent structure for managing digital transactions (Brauneis et al., 2022). Its primary innovation lies in achieving consensus within a trustless environment, eliminating the need for intermediaries and central authorities, thus making it particularly appealing for financial market clearing and settlement (Bothra et al., 2023).

At its core, blockchain technology utilizes distributed ledgers, which are secure, tamper-proof, sequential transaction records distributed across a computers network. Each participant in the network possesses a copy of the ledger, ensuring transparency and minimizing fraud risk (Gourisetti et al., 2021; Bhaskar et al., 2015). Transactions are validated and recorded through consensus mechanisms like proof of work (PoW) or proof of stake (PoS), ensuring ledger integrity and preventing unauthorized changes (Oprea & Bâra, 2021; Benedetti & Nikbakht, 2021). These transactions are secured by advanced cryptographic techniques, thus making it very difficult for malicious parties to alter data or violate the network (Yin et al., 2023; Birch, 2015). Additionally, smart contracts—self-executing contracts with terms embedded in code—facilitate the automation of complex financial operations, including clearing and settlement (Zhang et al., 2023).

Distributed ledger technology (DLT), as exemplified by blockchain, was introduced by Satoshi Nakamoto in response to the 2008 financial crisis, serving as the foundational technology for Bitcoin (Nakamoto, 2009). Nakamoto's white paper described Bitcoin as a peer-to-peer electronic cash system that facilitates secure transfers of money, assets, and data directly between parties over the internet, eliminating the need for a third party or central authority (Swan, 2015). This is accomplished through decentralized data storage, point-to-point transmission, consensus mechanisms, and cryptographic techniques.

Blockchain technology differs from traditional distributed databases in three key ways:

- Decentralization, a trust-free system, and cryptographic encryption. Decentralization allows control and access to be performed by multiple network participants, with transactions executed between peers without requiring central authority authentication. This reduces server and operational costs while alleviating performance constraints at the central server (Zheng, 2018).
- The trust-free system employs consensus mechanisms to validate each transaction record in the digital ledger, ensuring database integrity without requiring the parties to trust each other (Benos et al., 2017).
- Cryptographic encryption ensures that data is securely stored and accessible only to authorized parties, enhancing system security (Krishnan et al., 2020).

The main goal of integrating blockchain into securities clearing and settlement is to enhance efficiency and liquidity, rather than to completely replace trusted intermediaries such as central securities depositories (CSDs) (Priem, 2020). The potential advantages include streamlined processes, lower costs, and improved efficiency and security. Traditional equity trading systems often struggle with low operational efficiency and lack of diversity, issues that blockchain technology is well-positioned to resolve (Peng, 2021).

The adoption of blockchain technology offers potential benefits across various industries due to its ability to record and share transactional data, automate supply chain processes efficiently, and enhance transparency throughout value chains (Al-Jaroodi & Mohamed, 2019). Blockchain is particularly valuable for sectors that rely on information and benefit from receiving fast and accurate data. It provides immediate, shared, and transparent information stored on an immutable ledger, enabling users to track orders, payments, accounts, and production (Dowelani et al., 2023). Network participants gain a unified view of the truth, facilitating end-to-end transaction visibility, boosting confidence, and generating new efficiencies and opportunities (Laurence, 2019).

6. Potential opportunities for DLT in payments, clearing & settlement

Since the emergence of Distributed Ledger Technology (DLT), particularly blockchain, its potential applications have extended far beyond its initial use in cryptocurrencies like Bitcoin. DLT platforms offer decentralized frameworks for storing and transferring digital assets, securities, or data across a shared ledger, presenting a compelling alternative to traditional centralized systems (Benos et al., 2019; Chiu & Koeppl, 2019).

The financial sector, characterized by its reliance on multiple ledgers to manage transactional information and balances, has been particularly drawn to the innovative capabilities of DLT. This technology promises transformative benefits in terms of recording, storing, and transferring digital assets efficiently and securely. According to Mills et al. (2016), key incentives driving businesses towards adopting DLT include enhanced transparency, reduced complexity in multiparty transactions, lowered operational and financial risks, minimized reconciliation needs, accelerated processing speeds, and improved network resiliency through distributed data management.

Despite advancements in financial technology, current post-trade settlement systems remain plagued by inefficiencies inherent in relying on designated third parties. The dispersed nature of information throughout the trading process and the compatibility issues between various back-office systems of intermediaries lead to significant costs and complexities in record-keeping and reconciliation (Benos et al., 2019). In fragmented securities markets, settlement cycles are often protracted and rigidly scheduled, such as T+2 or T+3, to coordinate actions among multiple intermediaries. Certain transactions, such as syndicated loans, can endure even longer settlement periods, occasionally stretching up to three weeks due to legal complexities (Benos et al., 2019).

Throughout this chapter, we will explore in depth the benefits of DLT and blockchain in payments, clearing, and settlement processes. We will examine how these technologies streamline operations, enhance transparency and security, reduce settlement times, and contribute to a more resilient financial ecosystem. By understanding these advancements, stakeholders can better appreciate the implications of adopting DLT in modern financial infrastructures.

6.1. Streamlined Post-Trade Processes and Cost Efficiency in Financial Markets

Distributed Ledger Technology (DLT), such as blockchain, has the potential to revolutionize post-trade processes in financial markets. By synchronizing ownership records across all participants, DLT automates and simplifies operations, significantly reducing reconciliation costs and eliminating the need for centralized backups (Bech & Garratt, 2017). This synchronized and transparent ledger enhances transparency and traceability, allowing for direct access to securities holdings and reducing intermediation costs and operational risks (Micheler, 2015).

Moreover, DLT introduces a single, shared ledger accessible to all participants, cutting down on information costs and offering flexibility in settlement timings and costs (Chiu & Koeppl, 2018). Smart contracts enable instant clearing and settlement, potentially transforming the current multi-day settlement cycles into near-instantaneous processes (Bech & Garratt, 2017). This not only improves operational efficiency but also mitigates settlement risks and enhances liquidity in financial markets (Burger et al., 2009; Aitken et al., 2004; Benos et al., 2017).

Overall, DLT provides a streamlined and cost-effective approach to post-trade activities in financial markets. By reducing manual processing and improving transparency, DLT enables faster and more secure transactions, benefiting market participants through enhanced efficiency and reduced operational complexities.

6.2.Transparency, Traceability, and Security

DLT significantly enhances transparency, traceability, and security in payment, clearing, and settlement systems. By synchronizing ownership records among all participants, DLT minimizes reconciliation costs and eliminates central backup systems (Bech & Garratt, 2017). The immutability of DLT records provides complete visibility into fund flows and securities history, ensuring traceability and preventing fraud (Benos et al., 2019).

Direct ownership of securities through DLT reduces intermediation costs and operational risks, enabling investors to access holdings directly while allowing issuers to track beneficial ownership efficiently (Micheler, 2015; Fiedler et al., 2018). DLT's potential for near-real-time settlement cycles mitigates transaction risks, supported by smart contracts that automate transaction execution based on predefined conditions (Bech & Garratt, 2017).

Enhanced security and resilience in DLT are achieved through its decentralized architecture, which eliminates single points of failure and enhances recovery from disruptions (Benos et al., 2019). Automated settlement processes and netting algorithms in DLT systems reduce the need for clearing agents, thereby lowering costs and operational risks (Benos et al., 2017).

In conclusion, DLT not only improves transparency, traceability, and security but also enhances operational efficiency and flexibility in settlement processes, making it a transformative technology for safer and more efficient financial ecosystems.

6.3.Enhancing Efficiency in Securities Settlement Processes

DLT offers significant potential for enhancing efficiency in securities settlement processes. One key advantage lies in its ability to provide flexible settlement times, potentially reducing the settlement cycle for securities transactions. Implementations like T+0 settlements significantly mitigate settlement risk by enabling transactions to be settled almost instantaneously (Bech & Garratt, 2017). This flexibility is facilitated by smart contracts, which automate transaction execution based on predefined conditions, thereby enhancing operational efficiency (Bech & Garratt, 2017).

Moreover, DLT facilitates instant clearing and settlement of securities, unlike traditional systems that involve multi-day delays. This capability not only reduces counterparty risk but also increases capital liquidity, fostering a more dynamic financial ecosystem (Fiedler et al., 2018). By integrating DLT solutions, direct ownership of securities becomes feasible, reducing intermediation costs and operational risks. Investors gain direct access to their holdings, while issuers can easily track beneficial ownership in a transparent manner (Micheler, 2015; Fiedler et al., 2018).

Furthermore, the simultaneous computation of obligations in DLT systems improves efficiency by automating the settlement process. Algorithms for netting reduce the need for clearing agents, lowering costs and operational risks associated with traditional clearing systems (Benos et al., 2017). This streamlined approach to settlement processes not only enhances efficiency but also reduces the complexity associated with multi-tier custody models. DLT's consensus-based settlement system maintains a unified master record on a blockchain, eliminating inefficiencies related to reconciling separate databases across the custody chain (Chiu & Koeppl, 2018).

6.4.Direct Ownership and Reduced Intermediation Costs

Blockchain technology offers significant potential to revolutionize securities markets by enabling direct ownership of assets, reducing intermediation costs, and enhancing transparency.

DLT facilitates direct ownership of securities, allowing investors to access their holdings directly without relying on intermediaries (Micheler, 2015). This direct access enhances transparency in ownership and reduces operational risks associated with intermediaries.
Smart contracts, integral to blockchain platforms, automate transaction execution based on predefined conditions, thereby reducing the need for traditional intermediaries in clearing and settlement (Wall & Malm, 2016). By eliminating intermediaries, blockchain lowers transaction costs and minimizes legal and operational risks associated with centralized systems (Fiedler et al., 2018).
Moreover, blockchain's decentralized ledger ensures a synchronized record of ownership across all participants, reducing reconciliation costs and eliminating the need for a central backup system (Bech & Garratt, 2017). This distributed ownership model enhances efficiency in post-trade processes by providing a common standard for ownership verification and transfer (Fiedler et al., 2018).

6.5.Risk Management and Resilience

Implementing distributed ledger technology (DLT) in securities clearing and settlement systems offers significant advantages in terms of risk management and resilience. Traditional systems often rely on centralized databases maintained by central securities depositories (CSDs), which pose a single point of failure risk. In contrast, DLT distributes ledger copies across a network of nodes, ensuring no single point of failure exists. This decentralized approach enhances security and resilience by making the system resistant to attacks and failures that could disrupt operations (Benos et al., 2019).
Smart contracts, integral to many DLT implementations, automate processes such as settlement through predefined rules and conditions. By utilizing smart contracts for automatic delivery versus payment (DvP), DLT reduces settlement risk without the need for a central authority. This automation minimizes the potential for errors and delays inherent in manual processing and traditional legal frameworks (Manning, 2016; Pop et al., 2018).
Moreover, the transparency inherent in DLT enhances risk management by providing real-time and auditable transaction records accessible to all network participants. This transparency not only improves regulatory compliance but also facilitates quicker identification and mitigation of operational risks. Each node in the DLT network maintains an identical copy of the ledger, ensuring data integrity and reducing the risk of fraudulent activities or unauthorized modifications (Lewis et al., 2017; Dowelani et al., 2023).
Furthermore, DLT mitigates custody risks associated with multi-tier custody models by eliminating the need for reconciliation across various intermediaries. A unified master record on the blockchain streamlines settlement processes, reducing the complexity and potential errors that arise from reconciling separate databases across the custody chain (Chen & Wang, 2020).

6.6.Enhanced Market Efficiency and Accessibility through Blockchain Technology

Blockchain technology enhances market efficiency and accessibility by revolutionizing securities settlement and asset trading. It facilitates real-time processing and settlement, significantly reducing transaction times and counterparty risks (Chiu & Koeppl, 2019). This capability not only increases capital liquidity but also fosters a more dynamic and resilient financial system.
DLT ensures transparent and verifiable asset ownership by decentralizing ledger copies across network participants (Benos et al., 2019). By maintaining a unified record on a blockchain, DLT reduces risks associated with multi-tier custody models, eliminating inefficiencies in reconciling separate databases across custody chains (Chiu & Koeppl, 2019). This enhances operational efficiency and improves transparency in asset transactions (Dowelani et al., 2023).

Blockchain's integration of trading, clearing, and settlement into a unified, real-time process minimizes the need for intermediaries, thereby reducing costs and enhancing operational efficiency, particularly in recordkeeping functions (Schmiedel et al., 2006). These advancements underscore blockchain's transformative potential in making financial markets more efficient, transparent, and accessible, contributing to a resilient global financial ecosystem (Avgouleas & Kiayias, 2019).

6.7.Process and Operational Efficiency in Blockchain-Based Securities Settlement

Blockchain technology offers significant improvements in process and operational efficiency within securities settlement systems. By leveraging distributed ledger technology (DLT), several key benefits can be realized, enhancing the overall efficiency of post-trade processes.

One major advantage is the automation and simplification of post-trade cycles through distributed ownership records. DLT enables a synchronized and distributed ledger of security ownership among all network participants, minimizing reconciliation costs and eliminating the need for central backup systems (Bech & Garratt, 2017; Benos et al., 2019). This unified record standardizes processes and enhances operational efficiency across the settlement ecosystem.

Moreover, DLT enhances transparency and traceability by ensuring the immutability of transaction records. Participants have real-time visibility into the entire history of securities and fund flows, ensuring complete traceability and transparency (Benos et al., 2019).

Direct ownership of securities is facilitated through DLT, reducing intermediation costs and operational risks. Investors can directly access and manage their securities holdings, while issuers can efficiently track beneficial owners, thereby enhancing transparency and reducing the complexities associated with multi-tiered custody models (Micheler, 2015).

Blockchain's ability to offer flexible settlement times and reduce settlement risks is another critical efficiency enhancement. Real-time settlement capabilities and potential for near-instantaneous transactions (T+0) significantly reduce settlement risks and increase capital liquidity (Bech & Garratt, 2017).

Security and resilience are bolstered through blockchain's decentralized architecture, which eliminates single points of failure and enhances resistance against cyberattacks. The use of cryptographic signatures and distributed storage ensures data integrity and strengthens overall system security (Benos et al., 2019).

By integrating trading, clearing, and settlement into a unified, real-time process, DLT reduces the need for intermediaries and simplifies the operational landscape. This integration streamlines processes, lowers costs, and reduces operational risks associated with multi-layered custody chains (Chiu & Koeppl, 2019).

Overall, blockchain technology in securities settlement systems improves process efficiency by automating workflows, enhancing transparency, reducing settlement times, and strengthening security measures. These advancements not only optimize operational workflows but also contribute to a more resilient and transparent financial ecosystem.

6.8.Simplified User Interface and Enhanced Security

Blockchain and distributed ledger technology (DLT) offer a transformative approach to financial transactions, combining transparency with enhanced security and resilience. Unlike traditional systems reliant on central databases prone to single points of failure, blockchain's decentralized ledger is replicated across multiple nodes, ensuring data integrity and reducing vulnerability to cyberattacks (Dowelani et al., 2023). This distributed architecture not only enhances system reliability but also mitigates risks associated with data manipulation, fostering trust and transparency among participants (Benos et al., 2019).

The user interface remains familiar to participants, accessible through standard electronic devices, while the backend infrastructure undergoes significant transformation. Instead of intermediaries managing fragmented records, blockchain provides a single, shared ledger accessible to all authorized parties (Chiu & Koeppl, 2019). This transparency minimizes discrepancies and facilitates real-time verification of asset ownership and transaction histories (Fiedler et al., 2018). Furthermore, cryptographic techniques secure data access and transaction integrity, ensuring that each node in the network maintains an identical, tamper-resistant record (Micheler, 2015).

In addition to security enhancements, blockchain's scalability supports efficient domestic and cross-border transactions, potentially streamlining global financial operations (Bech & Garratt, 2017). The technology's capability to integrate trading, clearing, and settlement into a unified, real-time process reduces complexity and operational costs associated with traditional intermediaries (Chen & Wang, 2020). This integration not only accelerates transaction processing but also lowers settlement risks by eliminating the need for reconciliation across multiple custodial layers (Burger et al., 2009).

Overall, blockchain and DLT promise a future where financial markets operate more efficiently and securely, leveraging decentralized architectures to enhance transparency, reduce costs, and mitigate operational risks (Chiu & Koeppl, 2018). As regulatory frameworks adapt to these technological advancements, blockchain's role in enhancing market integrity and investor confidence continues to evolve, paving the way for a more resilient and inclusive financial ecosystem.

6.9. Direct Access and Atomic Transactions

Blockchain technology offers substantial improvements in the efficiency and security of financial transactions, particularly in payments, clearing, and settlements. By utilizing distributed ledger technology (DLT), transactions can be processed in real-time without the need for intermediaries, such as banks or clearinghouses. This direct peer-to-peer interaction streamlines processes and reduces costs associated with traditional centralized systems.

The concept of atomic transactions ensures that transactions are settled immediately upon payment, unlike the traditional banking systems that settle transactions days after payment (Accenture, 2022). This capability significantly reduces the costs associated with maintaining a global network of correspondent banks and enhances transaction speed and efficiency.

6.10. Streamlined Settlement and Mitigation of Risks

Blockchain and Distributed Ledger Technology (DLT) implementations offer significant improvements in securities settlement processes, addressing various inefficiencies and risks present in traditional systems.

DLT simplifies settlement by consolidating transaction data onto a single, consensus-driven ledger. This eliminates the need for multiple reconciliations across custodians, reducing operational complexity and the likelihood of errors (Bech & Garratt, 2017; Chiu & Koeppl, 2019). Additionally, the transparency of blockchain enhances data integrity and accessibility throughout the custody chain, benefiting issuers, central securities depositories (CSDs), and regulators alike (Benos et al., 2019).

Furthermore, the implementation of blockchain enables real-time settlement capabilities, significantly reducing the time required to finalize transactions. This improvement not only lowers settlement risk but also enhances liquidity by accelerating capital availability (Chiu & Koeppl, 2019). By facilitating direct delivery versus payment (DvP) through smart contracts, blockchain minimizes intermediary involvement, thereby cutting costs associated with post-trade processes (Wall & Malm, 2016).

In terms of security, blockchain’s decentralized architecture and cryptographic protections enhance resilience against cyberattacks and system failures. Each node in the network maintains an identical ledger copy, ensuring data consistency and mitigating the risks of manipulation or unauthorized access (Benos et al., 2019; Dowelani et al., 2023).

Overall, the integration of DLT in securities clearing and settlement not only streamlines processes but also improves transparency, reduces operational risks, and enhances market efficiency, aligning with regulatory goals for market integrity and investor protection (Fiedler et al., 2018).

6.11. Alignment with Regulatory Frameworks

The transparency features of DLT align with evolving regulatory frameworks aimed at promoting market integrity and bolstering investor confidence. Initiatives focusing on beneficial ownership transparency and shareholder rights are complemented by DLT's capacity to provide auditable and transparent transaction records.

6.12. Reducing Processing Time and Costs

Typically, bank transfers take around three days to process, which is significantly slower than the current pace of our modern world. This delay is not only frustrating for customers but also for banks.
The lengthy processing time for bank transfers is largely due to the existing financial infrastructure. Transfers must pass through a network of intermediaries, including correspondent banks, custodians, and other financial institutions. A simple transfer from one account to another involves navigating through this complex intermediary system, resulting in added costs and risks due to the fees and potential errors introduced by each middleman. Additionally, the time each institution takes to process the transfer further delays the transaction.

7. Challenges to adoption of DLT in Payments, clearing & settlement

The application of DLT systems in clearing and settlements might provide various benefits, including reduced counterparty risk, lowering settlement costs, efficient operational procedures due to fewer intermediaries, and an enhanced level of transparency. Nonetheless, DL Technologies are still facing numerous challenges (Priem, 2020).

- **Considerations for cost-benefits of DLT adoption**

A key challenge is determining the relevant use cases in which the potential costs savings in financial and operational inefficiencies that justify the investment and the operational adjustments required for the DLT adoption. Furthermore, DLT's long-term operational costs must be lower than those of existing alternative technologies. Importantly, assessments of these case studies require a comparison of other potential alternatives to alleviate the frictions existing in the market in which DLT is being examined (Mills et al. 2016).

- **Privacy issues**

The complete transaction data in ledgers is typically accessible to all participants in the system and is duplicated in their individual ledgers to boost transparency and trust within the DLT system. However, in financial markets, this level of transparency can lead to privacy or competition issues, potentially breaching laws like the General Data Protection Regulation (Priem, 2020).
According to Deutsche Bundesbank (2017), DLTs pose privacy risks if current encryption technologies become vulnerable due to technological advancements. Additionally, networks consisting of various node types may be more susceptible to attacks, and connections to real assets represented on a DLT must be established via intermediaries.

- **Financial instruments and tokenization issues**

Financial securities can be issued in either electronic or paper form, and standard design options

apply to to both book-entry securities, which are "immobilized" or "dematerialized" through the employment of a securities custodian.
Over time, DLT may offer many opportunities to redefine traditional existing design options for issuing, holding, and transferring securities. We can cite "tokenization" as one of the new concepts that enable encoded data to represent security on a certain type of ledger and allow for a fast and easy transmission by the owner or their intermediaries, but it doesn't take the role of the security itself or the set of rights and obligations it represents. Securities remain to be the liabilities of the actual issuer of the security.
If systems were established in which tokens represent securities and the tokens are not intended to be securities, then concerns regarding the tokens status and their representation and how managed when transfers or hoding go wrong may emerge. The legal status of digital assets may also raise concerns (Mills et al. 2016).

- **Long-run changes of the role of financial intermediaries**

Another concern for both securities and monetary instruments is the type of institutions that have the permission to issue liabilities and operate as intermediaries. Institutions may be required to serve as custodians in some particular cases. As new entrants into these processes provide novel design concepts, these entrants may be required to address and review regulatory issues. Mills et al. (2016) explains that long-term shifts in the financial market intermediaries' roles and obligations, as well as demands for their services, cannot be denied. However, they perform a crucial role in the economy by connecting borrowers and savers, ensuring stable monetary instruments that serve as the foundation of the payments system. In addition, it is very unlikely that these functions will become outdated in the near future.

- **Standardization issues**

Due to the development of specialized Distributed Ledger Technology (DLT) systems by market participants, there is a risk of potential compatibility issues and fragmentation among these systems (Goldman Sachs, 2016). The primary goal of applying DLT is to streamline the custody chain by reducing layers. However, if each layer adopts its own customized DLT system, it could increase operational risks (Pinna and Ruttenberg, 2016).
This lack of standardization might require ongoing or increased human validation in post-trade activities, thus impeding efforts to eliminate intermediaries (Klimos, 2018). Nevertheless, various industry initiatives are currently underway to establish common standardized protocols and solutions for Distributed Ledger Technology (DLT). Examples of these initiatives include the HyperLedger project under the Linux Foundation, the R3 Consortium, the Post-Trade Distributed Ledger Group, and the CSD Working Group on DLT.
Many authors agree that fragmentation concerns do not represent serious barriers to the adoption of DLT (Priem, 2020).

- **Regulatory challenges**

The German Banking Industry Committee (2016) states that Distributed Ledger Technology (DLT) systems function fundamentally differently from traditional systems, and thus requiring the development of a distinct regulatory approach. If current clearing and settlement providers adopt DLT purely as technological advancement, the European Securities and Markets Authority (ESMA, 2017) foresees minor regulatory issues. However, if DLT were to operationally replace the existing market participants and market infrastructure, significant regulatory concerns could emerge.
According to Priem (2019), permissioned DLT systems would face two types of legal challenges:
a) Current post-trade regulations might be a barrier to the launch of this technology, and

b) If the implementation of this technology succeeds, it may present prudential and conduct risks that are not sufficiently addressed by the current regulatory framework.
Zetzsche et al. (2017), mentions in this context that DLT systems are secure from a technical standpoint, but from a legal/regulatory standpoint, they might be a source of risk by spreading risks amongst participants that were previously concentrated with a small number of central institutions
The Bank of International settlement (2017) agrees that new requirements should be set, emphasizing that a lot of work is required to ensure that the legal foundations of DLT arrangement are solid and their governance is robust and that adequate data measures are established.
Therefore, for this technology to be successfully employed, current regulations may need to be changed. At the moment it is unclear if operators of DLT systems which are unregulated will begin to provide clearing and settlement services.

8. Key Factors for Successful Implementation of DLT/Blockchain in Payments, Clearing, and Settlement

Examining and identifying the aspects that may impact the development and application of Distributed Ledger Technology (DLT) is crucial for its successful implementation in payments, clearing, and settlement processes. These factors encompass environmental, technological, and financial considerations, each playing a vital role in the adoption and efficiency of DLT-based systems.

- **Technological Maturity and Scalability**

The technology must be advanced enough to handle high transaction volumes efficiently. Issues such as scalability, interoperability, and latency must be addressed to meet the demands of high-frequency financial transactions. The technology's maturity and its ability to integrate seamlessly with current processes and systems are critical for its successful deployment (Agarwal et al., 2023; ESMA, 2017).

- **Regulatory and Legal Framework**

A clear and supportive regulatory framework is essential for the widespread adoption of DLT. Regulators need to provide comprehensive guidelines on how DLT can be integrated within existing financial systems. Regulatory bodies like the European Securities and Markets Authority (ESMA) and other international organizations are actively exploring the implications of DLT to ensure legal certainty and settlement finality (BIS, 2017; ESMA, 2017).

- **Security and Privacy**

Ensuring the security of the DLT network is critical due to the sensitive nature of financial data. Robust encryption, secure consensus mechanisms, and measures to prevent unauthorized access are essential. Addressing privacy concerns, especially in permissioned blockchains used by financial institutions, is also vital for maintaining trust among participants (Agarwal et al., 2023; ESMA, 2017).

- **Operational Efficiency and Cost Reduction**

One of the primary benefits of DLT is its potential to reduce costs associated with clearing and settlement by eliminating intermediaries and streamlining processes. However, achieving this requires significant initial investment and a clear understanding of the operational changes involved. The shift towards DLT should focus on enhancing operational efficiency and reducing transaction costs (Agarwal et al., 2023; BIS, 2017).

- **Industry Collaboration and Standards**

Collaboration among financial institutions, technology providers, and regulators is crucial for the success of DLT. Developing industry-wide standards and protocols can help achieve interoperability and wider adoption of DLT-based solutions. Collaborative efforts drive innovation, address common challenges, and ensure that the technology meets the needs of all stakeholders involved (BIS, 2017; ESMA, 2017).

- **Integration with Existing Systems**

Seamless integration with legacy financial systems is necessary to ensure continuity and reliability. Financial institutions need strategies for integrating DLT with existing infrastructure while minimizing disruptions. Ensuring compatibility with current systems and processes allows for a smooth transition to DLT-based operations (ESMA, 2017).

- **Pilot Projects and Testing**

Conducting pilot projects and real-world testing helps identify practical and ine and refine the technology. Many institutions have undertaken such initiatives to better understand the implications and benefits of DLT. Pilot projects provide valuable insights into the feasibility, performance, and potential issues of DLT systems in real-world scenarios, allowing for adjustments before full-scale implementation (Agarwal et al., 2023; ESMA, 2017).

- **Environmental, Technological, and Financial Factors**

According to the Bank for International Settlements (2017), several environmental, technological, and financial factors contribute to the implementation of DLT solutions:

- Environmental Factors: Organizational adoption of new technologies, market factors (e.g., structure, size, and practices), legal and regulatory framework, and industry's coordination level.
- Technological Factors: Issues related to the technology's maturity and interoperability with current processes and systems.
- Financial Considerations: Initiatives offering higher returns on investments through cost savings and revenue prospects have a great potential to be embraced by markets and institutions (BIS, 2017; ESMA, 2017).

Moreover, the implementation of DLT often requires widespread industry adoption to achieve potential efficiency gains, which can be network-dependent. A significant number of participants may be necessary before the industry perceives any substantial benefits. Additionally, effective adoption of DLT-based solutions in payments, clearing, and settlement processes necessitates fundamental and structural market changes, such as modifications to market norms and practices (BIS, 2017).

By addressing these factors, financial institutions can enhance the efficiency, transparency, and security of their payment, clearing, and settlement processes through the adoption of DLT and Blockchain technologies. These factors are crucial for the successful deployment of DLT, ensuring it meets the high standards required by financial markets and contributes to their modernization and improvement.

9. Conclusion

Blockchain technology is currently causing a disruptive phase in the digital era by enabling the transfer of digital property relations in decentralized transactions. Transaction data is distributed and validated through a decentralized network database, eliminating the requirement for a central entity. Deutsche Bundesbank (2017) states that DLTs have the potential to enhance transparency and immutability, increase operational efficiencies, improve security and resilience, promote independence from intermediaries, and reinforce automated contract processing. Several industry participants believe that DLT has considerable potential to minimize reconciliation costs and improve the efficiency in clearing and settlement of securities.

Many central banks and industry groups have undertaken experiments with DLT to test prototypes, assess their potential safety and efficiency implications, and investigate market opportunities to solve inefficiencies in the existing payments and settlement systems. Some global financial institutions have already launched innovation labs, partnerships, and DLT-related initiatives. In Morocco, notable initiatives include the Casablanca Stock Exchange's efforts to establish a new derivatives clearinghouse featuring a SPAN risk calculation module acquired from the CME (Chicago Mercantile Exchange). Maroclear, the Moroccan Central Securities Depository, plays a crucial role in ensuring the efficient functioning of post-market processes by offering services such as codification, custody, settlement, administration, and dematerialization of securities. These initiatives reflect Morocco's proactive stance in exploring DLT to enhance its financial market infrastructure.

Despite these advancements, current regulations were not developed with DLT in mind, and further requirements may be necessary to address prudential and/or conduct risks associated with this technology. Establishing partnerships between relevant startups and technology firms would mutually benefit startups by providing access to capital and expertise, while financial institutions would continue to embrace and benefit from innovative financial technology.

Distributed Ledger Technology (DLT) holds transformative potential for the financial industry, particularly in the realms of payments, clearing, and settlements. As this study has shown, DLT offers significant benefits, including enhanced transparency, increased efficiency, reduced costs, and improved security. By decentralizing transaction processing and eliminating the need for intermediaries, DLT can streamline financial operations and mitigate the inefficiencies inherent in current systems. Realizing the full potential of DLT requires addressing several key challenges. Technological barriers, such as scalability and interoperability, must be overcome to handle high transaction volumes efficiently. Privacy concerns and regulatory uncertainties also pose significant hurdles. To address these issues, it is imperative for financial institutions, regulators, and technology providers to collaborate closely. Establishing clear regulatory frameworks and industry standards will be crucial for fostering a conducive environment for DLT adoption.

Furthermore, pilot projects and real-world testing are essential for refining DLT applications and demonstrating their viability. These initiatives will provide valuable insights into the practical challenges and benefits of DLT, helping stakeholders make informed decisions about its implementation. As the financial sector continues to evolve, the integration of DLT promises to revolutionize traditional processes, paving the way for a more resilient, transparent, and efficient financial ecosystem. Continued exploration and innovation in this field will be key to unlocking the transformative potential of DLT, ultimately shaping the future of financial markets.

In conclusion, while DLT presents remarkable opportunities, its successful adoption hinges on overcoming significant obstacles through concerted efforts by all stakeholders. By addressing these challenges and leveraging the advantages of DLT, the financial industry can usher in a new era of efficiency, security, and innovation.

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