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Innovative Computational Frameworks for Secure Financial Ecosystems: Integrating Intelligent Automation, Risk Analytics, and Digital Infrastructure

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Abstract

A broad array of sophisticated and innovative algorithms is presented to effectively solve complex problems that arise in efficient and secure financial networks today. The specific problems we consider span several vital areas, including optimization techniques and algorithms specifically designed to operate in the presence of adversarial or corrupt data. Moreover, we delve into network security games and trustworthy recommendation settings. We also examine the significant consequences brought about by incidental and adversarial errors *during the critical training phase of learning algorithms, which can greatly affect their performance and reliability.*

To understand the emergent behaviors of a multitude of interacting agents within dynamic financial systems, we must draw upon disciplines and concepts from both game theory and economic theory. These theories provide fundamental insights critical for constructing such systems and for estimating the potential risks and losses they might encounter. In this context, we propose several characteristic frameworks that evolve in response to the inherent changes and challenges present in financial systems, and we discuss the various challenges that come along with these dynamic systems.

Furthermore, recommendations on the most plausible directions for future tutorials and comprehensive surveys in this rapidly advancing area are included, highlighting the importance of ongoing research and development in financial algorithms. We emphasize that keeping pace with the evolving nature of financial networks is crucial for building resilient systems capable of withstanding adversarial threats.

Keywords: Sophisticated Algorithms, Financial Networks, Optimization Techniques, Adversarial Data, Corrupt Data, Network Security Games, Trustworthy Recommendations, Learning Algorithms, Training Errors, Algorithmic Reliability, Game Theory, Economic Theory, Risk Estimation, Dynamic Systems, Financial System Challenges, Evolving Frameworks, Resilient Systems, Adversarial Threats, Future Research, Algorithmic Development.

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1. Introduction

With the proliferation of digitization, financial services play a pivotal role in economic growth and well-being and in creating a mechanism for competitiveness. One potential tool for maintaining the stability and growth of the contemporary financial network is the ability to detect uncertain or risky events, which has recently been getting increased attention in light of large fluctuations in the global financial market. Random or periodic uncertainties leading to an eventual crisis in present-day globally integrated financial markets could emanate from a plethora of potential factors such as geopolitics, complex behaviors of economic agents, and intricate multi-banking linkages among others. In any such case, quick detection and effective preventive measures could potentially mitigate the effects of the unfolding crisis. To achieve this a priori, an almost real-time condition monitoring and prediction tool that takes into consideration the complex, multi-layered interactions within and between coupled financial networks, as well as those that take into account various sources of uncertainty, would be essential.

With the revolutionary growth of data at our fingertips in the last two decades, data-driven methodologies could have a slight upper hand when combined with sufficiently powerful computing platforms. Traditionally, classes of data-driven predicting methodologies have been based on recognizable data patterns and learning, and have been referred to as machine learning methods. To effectively confront the challenges of predicting financial instability, one has to contemplate developing and formalizing a multitude of data-driven analytics frameworks. If one simply focuses on agents that are globally integrated in financial markets, it can be seen that the interaction at each level of the global financial market has different aspects or acknowledges the existence of linkages between the respective elements. The varying complexities at these levels may sometimes involve treating the relationships under different computational paradigms. In any data-driven application, where an ensemble includes learning or model training from a set of large and varied events, sometimes may involve inherently different learning and feedback frameworks.

1.1. Financial Landscape Insights

The global financial landscape contains a rich medley of complex, multi-dimensional interconnected economic networks that are not only spatially distributed but also functionally differentiated. These networks involve individuals, households, firms, and other financial institutions, as well as governments and many other non-governmental organizations. The interconnections that characterize these networks arise primarily because of the movement of funds across various entities in individuals' search for returns, firms' quest for building capital for production and consumption, governments' endeavors to deliver essential services and amenities, and non-governmental organizations' activities toward the fulfillment of their goals, be it charity, research, prevention, or national well-being that can include security, law, education, and health. Instead of being isolated, these networks are part of a larger intertwined financial architecture that identifies and maintains all the unique characteristics of a particular entity concerning its interaction with the other entities in the global computing mandate.

An explicit treatment of the global financial ecosystem as composed of interconnected economic networks presents several fascinating questions for the research community. These questions include coordinating diverse economic activities across several geographical, cultural, and legal domains, understanding trust among millions of people and institutions in an environment that is experiencing significant deregulation and liberalization of many constraints on national finance-based social institution behavior over the last two decades, recognizing that financial systems consist not only of key financial institutions but also of substantial social networks that are inseparable from the structure and behavior of the institutions themselves, and appreciating that contemporary payment systems are complex, evolving systems growing out of closely intertwined arrays of social, legal, and economic settlements.

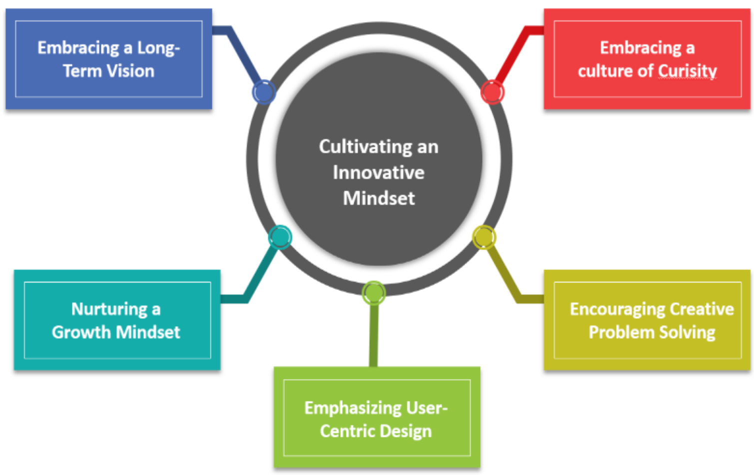

Fig 1 : AI-Powered Innovation in Digital Transformation

2. Background

During the 1990s, as a result of significant effort expended by the governments and industries in building e-infrastructure and associated frameworks for over 20 years, a level of trust began to emerge between various stakeholders such as governments, financial institutions, businesses, and citizens. Financial establishments across the world began offering a range of Internet-based services that enable businesses and consumers to carry out transactions over the Internet. The collapse of dot-coms, terrorist attacks, and corporate scandals led to renewed interest in web services that can (quasi-)automatically transform into documents required for satisfying specific policies and regulations designed to control behavior in organizations and markets. Financial organizations and businesses were and still are worried about external auditors analyzing their services concerning these documents.

Policies and regulations, unlike protocols, have been thought of as human-constructible. They are created at a much slower rate, exercised for longer periods, and are updated as society evolves. However, such documents must find proper expression in an organization's administrative framework, in its business applications, and in digital certificates that bind human attributes and organization titles to the soundness of specific public keys. Our interest is in representing in a secure and accessible way these ad hoc financial and IT organization policies, e.g., regulations and auditable standards that can be either obligations or goals and can be combined in unpredictable ways, and supporting document-to-policy mapping exercises that seek to establish or demonstrate specific policy compliance properties. We believe that our interests greatly differ from the others.

Equation 1 : Risk Propagation in Financial Networks

$$R_t = \sum_{i=1}^{n} P_i L_i$$

where

R_t = Total systemic risk,

P_i = Probability of failure for financial agent i,

L_i = Loss incurred by financial agent i,

n = Number of interacting agents.

2.1. Overview of Financial Ecosystems

Today's financial ecosystems comprise banks and non-banks that provide a wide array of services at the individual, corporate, national, and international levels. Individuals have choices for storing, borrowing, and investing in savings products. They need to trust qualifying, three-level regulated banks that are interlinked with the central bank and are eligible to use the interbank fund system overseen by central banks. Moreover, extracts from a report opine that, in addition to central banks, certain authorities are responsible for the oversight and resolution regimes of systemically important central counterparties.

More generally, the financial system includes interlocking balance sheets of numerous intermediaries, including shadow banks, savings institutions, insurance companies, mutual funds, pension funds, hedge funds, private equity funds, and factoring outfits. The size of the different components of the financial services industries varies by country and changes with business cycles, regulatory requirements, tax policies, and globalization trends. Therefore, measured and unobserved risks of different financial products are often amplified through the importance of inter-fund trading. Consequently, once a financial shock is intuited by potential buyers, there is a sudden, simultaneous withdrawal of funds from the various markets, followed by widened spread increases and trading halts.

2.2. Importance of Security in Financial Systems

In this paper, we adopt a mixed perspective, focusing on the financial systems and the derivation of powerful and innovative computational paradigms to finance security, derived from advances in the domain of security, and the concurrent design of scalable financial services supporting secure transactions. This is a challenging and interesting domain that, to the best of our knowledge, has not been deeply researched in the current security models or the financial community. Creating open, scalable secure ecosystems for financial services is a high-priority problem, with a broad reach in both financial institutions and corporations but also involving final users and households. We argue in this paper that businesses are moving away from traditional, closed financial ecosystems to demand more dynamic and personalized, open and flexible, support in the computation of their own, complex financial models representing a richer set of financial profiles. In this context, computing will become an essential (and hence very critical) infrastructure, hosted at any and every business site and institutional building, as well as being deeply interwoven in all family and personal financial decisions. To date, a capillary software infrastructure and a reliable set of financial services and tools do not guarantee adequate and required security services which are critical in both institutional as well as personal financial services. It is now well known that the current situation is not satisfactory, but even at a recent workshop, there was a widespread conviction in the plenary meeting that current security solutions are broken and/or that businesses do not deliver the appropriate level of financial security awareness.

2.3. Emerging Technologies in Finance

Financial technology, or fintech, is a rapidly growing field that is transforming the face of finance and many areas of economic life. This transformation is driven by a new wave of technological innovations including blockchain and distributed ledger technologies, quantum computers, smart contracts, cross-border networks, financial marketplaces, decentralized autonomous organizations, initial coin offerings, data analytics, machine learning, artificial intelligence, and telecommunications. These technologies challenge traditional economic and regulatory models, with significant consequences for intermediation, globalization, and international relations, and a need to update regulatory models across all areas.

The pace and extent of fintech innovation are driven by rapid advances across several technology platforms, applications, and enabler domains, each focused on the specific technical requirements of the financial sector. Since all four classes of technology generate periods of rapid advancement, increase a critical mass of innovation-creating agents, and provide the elements required for all technological breakthroughs, they are generally considered drivers of technological change. Financial technology is evolving to encompass new services and programs that help consumers and business owners manage their financial operations more effectively and efficiently. Therefore, financial technology provides a distinct field for studying disruptions and complements historical understandings of financial crises and instabilities. Fintech represents a microcosm of the broader economy, offering critical insights into how firms, industries, and public policies adapt to new technological possibilities.

3. Intelligent Automation in Financial Services

Intelligent automation in financial services integrates advanced analytical methods and distributed machine learning algorithms and provides increased operating efficiency, especially for back- and middle-office support functions. This autonomy allows both vertical integration and widening of fintech functions, facilitates more nuanced regulatory strategies, including cumulative systemic risk, and minimizes information disruptions. AI also facilitates the creation of ever more powerful and precise heuristics, including selective use of overlay rules for moral sentiments, achieving a consistent regulatory and supervisory framework for financial services. Consequently, intelligent automation stimulates the dematerialization of the economy, reducing the impact of exchanges on both the natural and monetary systems, and accelerating economic dynamism. This discussion covers the main structural and regulatory reconfigurations needed to ensure the effective fulfillment of intelligent automation's potential for economic progress, for which SMEs, direct finance for risk-taking, and targeted social assistance programs play a fundamental role.

Regulation technology, or simply regtech, is a promising field for intelligent automation in financial services. It leverages distributed techniques to democratize the generation of finance rules, allowing convergence and specialization of predefined blocks, thus achieving a consistent mixed regulatory and contractual supervisory regime. These new informational capabilities, which rewrite the rule that trust collapses, also promote progressive dematerialization of the monetary economy. With the help of intelligent automation, not only profitable companies but those financed by speculative capital are benefiting from equity incentives to finance the future. SMEs also witness a rise in the number and investment decisions of risk-seeking investors. Finally, intelligent automation has been promoting stability in unstable trajectories, as the impact of exchanges on both the natural and monetary systems is reduced, and low real activity growth rates are decoupled from high stock market infrastructure asset prices. That infrastructure, which is embodied in increasingly virtual valuable organizational innovations, accelerates economic dynamism.

Fig 2 : Intelligent Automation in Financial Services

3.1. Definition and Scope

Security of electronic transactions is one of the most important issues to ensure the future success of worldwide electronic commerce. Existing electronic commerce and payment schemes typically require the real-time participation of at least one trusted third party, such as banks or clearing houses. This does not provide efficient real-time transaction processing and introduces additional costs and dependencies on specific hardware and human operators. We suggest a new way of handling the real-time performance of financial services and payment clearing and settlement. We exploit techniques and methods developed within the fields of game theory, control, and distributed computing. These techniques have been known for some time and are specifically well-suited for providing security, confidentiality, and real-time computational performance. We also address some known issues and purposes of security of the underlying information and cash transfer protocols.

The wish to enhance information and transfer protocols introduces some performance problems due to the incurred computational costs. Note, however, that traditional computation structures, such as those based on predetermined sensing, communication, and computation schedules of a central processing unit located at the center of the computational network, are not only computationally heavy and prone to attacks but also do not provide the required real-time service. We anticipate the end of predetermined sensing and computations based on the assumption of data collected and processed by specially designed number crunchers located at the center of the network and assume that all agents can collectively calibrate their computation approaches.

3.2. Benefits of Automation

Automation of computational components brings many well-established benefits to security services. These include the speed of detection and reaction, consistency of protection measures, extended monitoring and analysis far beyond human capacity, and the contribution to the security of a consistent response under pressure when under attack. One of the most powerful knowledge management capabilities is to be able to capture the key expertise of the human intervention analysts who have become classic hackers of their systems in defense of the enemy. This is a form of a human 'tunnel' for the seamless integration of human and computer components of the cyberspace security systems to defeat the enemies' more powerful tunnel capabilities. In the constantly changing cyber-risk and attack landscapes, the ability to react at modern digital speeds across the extended digital enterprise that allows the combination of unique business capabilities is a key business survival factor.

Off-line systems - including CMDBs, configuration comparators, risk and compliance assessments, and test and certification of cyber attack and catastrophe defenses - can improve preparedness and reduce active and passive response times, risk costs, and attack impacts. A classic example is the test of new patch-level configurations in the operational environment. The ability to automate and accelerate the testing of individual patches and combined packages in a range of business and defense contexts offers the capability for faster, safer patching of vulnerabilities. The result is fewer and less severe security events and simpler support processes. Similarly, extending security protection to changing enabled configurations and business activity to be able to operate successfully and effectively in emerging environments helps with the business innovation of a secure ecosystem.

3.3. Challenges and Considerations

Financial systems address a broad set of economic entities including individuals, corporations, and governments. As a central component of the broader societal ecosystem, the security and functionality of financial systems and their associated infrastructural and social fabric are vital to the operation of world economies. Historically, however, both financial institutions and policymakers have been much more concerned about the functionality of these systems – for example, making sure that, as the global economy digitalizes, online transactions can be completed quickly and efficiently – while relegating security issues to second-tier status. This has changed over the last two decades with the recognition that within the largely digitized global financial sector, a system where significant fractions of the transactions that occur in cyberspace are not secure is a brittle system. Attacks need not cause the entire ecosystem to fail to cause significant disruptions; even attacks that move individual components out of their complex dynamic equilibria can be costly, due to negative effects on consumer and investor confidence in financial institutions and products.

The list of challenges that must be overcome to secure the financial system is long. Some of these challenges are in areas that will be covered in this report, like the structural and functional characteristics of the underlying networks. Other challenges include the need to understand both the microstructure and generic macro dynamics of the various systems to allow for the meaningful development of models. Finally, even with the best data and tools, understanding the full set of security and robustness concerns is a hard problem that will not be fully solved in the foreseeable future. More practically, security measures must be developed and implemented in the face of this uncertainty. This is sometimes called the "move forward even if you are only 90% correct" problem, as doing nothing is the surest path to costly financial disruptions. We organize our discussion of these challenges in a fashion that reflects the broader examination we carried out when drafting this section, paying special attention to challenges that have not yet received significant attention from the modeling and simulation communities.

4. Risk Analytics and Management

Financial risk analysis, especially credit risk analysis, is essential to the productivity of the financial system. In recent years, there has been a paradigm shift in credit risk assessment fueled by developments in computational frameworks over large-scale online financial transaction systems. These computational frameworks, in conjunction with data-driven analytics that employ big data-centric methods for profiling, leveraging comprehensive feature sets, model building, and interpreting results, lead to insights superior to those achievable using traditional methods of risk assessment. In this chapter, we first provide a high-level conceptual view of the modeling process. We then describe conceptually the major components in the process of setting a modeling standard for assessing loans, debt offerings, and other forms of risk. As we examine the utility of these models, we want to consider whether the variables in the models are sufficient to represent important concepts and whether the models help us to better understand mechanisms of observed behavior. We also talk about how to use data and why traditional data exploration and feature reduction on large data sets cannot accommodate big data problems in lending. In the following sections, we will describe in more detail various methodological challenges in modeling. Next, we discuss the application of big data methods to develop loan evaluation models. In the final section, we present some concluding comments and possibilities for future research.

4.1. Frameworks for Risk Assessment

The stochastic filtration spaces provide a means to describe uncertainty at the most general and abstract level. For example, the rich theory of Brownian stochastic reference models in financial mathematics. Filtering processes conceptually represent the open-loop risk assessment methodologies. Usually, these are assumed to be carried out by the market participants individually in an independent and idiosyncratic way. Statistical models of financial markets, through the use of complete parameterizations or, in the multivariate context of option pricing, with a separate parameter working as a formula input for each asset, completely overlook dependence and correlation structures intrinsic in the complex structure of the markets. We argue that closed-loop risk assessment processes are based on dependence and correlation structures and propose an alternative, new framework deeply rooted in statistical physics and information measures.

We postulate that, in large financial markets at least, these closed-loop risk monitoring and assessment processes could and indeed do take place at the systemic level in a process resembling the statistical-mechanical order-disorder transitions in physics and information measure-based phase transitions in science defined through the unique distribution norms. In our theory, the depth and the structure of the inherent market dynamics information and value being encoded determine the phase of the financial risk being addressed, and the response to any risk event affects changes in the shape of the market dynamics, decoding the information backward quickly. The proposed economic enticement function links the financial regulations and the uncertainties associated with economic agents. The financial-economic systems are modeled as collective systems characterized by stable probability distributions that reflect social interactions in which agents adopt strategies with the objective of maximizing their divergent interests.

4.2. Data-Driven Risk Analytics

An important area within the purview of machine learning (ML) is risk analytics, which centers around the assessment and active management of the risks to which financial institutions are exposed. The continual generation and accumulation of data by financial institutions provide an extraordinary opportunity to apply state-of-the-art data-driven risk analytics as a tool to provide valuable insights, help align business operational strategies, and drive profitable growth within these institutions. This paper describes several modern-day, innovative approaches for addressing the many opportunities that are associated with data-driven risk analytics. The methods and examples that are in this paper have been specifically designed to meet the unique needs of risk analytics in financial services. Throughout the paper, we discuss various categories of ML innovations and what they imply for the enhancement of a financial institution's risk management capabilities.

Today, the field of machine learning (ML) has the potential to revolutionize the practice of risk analytics. Some may view this statement to be hyperbolic given that statistical models have long been associated, albeit often indirectly, with the work done within the risk management field. However, as compared to traditional statistical techniques that are employed within the risk management realm — such as linear or logistic regression and time series analysis with respect to forecasting models — state-of-the-art ML methods offer many dimensions of capability that make them especially compelling for risk management.

4.3. Case Studies in Risk Management

We will illustrate a framework for risk management using cases selected from the large bodies of work in VaR, ES, and EVT. When dealing with operational risk involving the entire firm, we need to consider many more variables than market risk and credit risk. Data that reflect these various operational risks are extracted and processed before we apply the graphical framework. The VaR and EVT methods use the final investment values, and the ES approach involves loss. The risk is managed by exploring the interactions regarding fat tails, path dependence, and optimization severity. Because of financial innovation and the integration of financial services globally, the actual financial data are very complicated and may not be properly captured by the underlying pricing models. Thus, new and more refined risk measures and risk management tools are constantly being developed. We have the choice to use the methods that capture the dynamics of the actual data as closely as possible or to use the streamlined methods that generate one-size-fits-all results.

At the back-test stage, almost all of the proposed new VaRs at the targeted sides of the distribution, at 1%–10% probability levels, can pass the standard tests. Analyzing the kickback phenomenon of the potential advantages of the daily reevaluation of the delta change pair of interest rates, it is revealed that the proposed VaR passes the rigorous test which can handle large rebalancing jumps much more easily. During the crisis period from 2008 to 2011, except for the area under the curve, all of the performance measures of the proposed VaR are consistently greater than those of the other popular VaRs under study. With a close look at the tails and the dynamic temporal correlation, a simple yet effective option valuation toolkit for derivatives whose payoffs are path-dependent with an underlying asset indexed by an L1 path variable is provided. The proposed toolkit focuses on economic cycle synchronization, the centered limit process for the partial sum per path regulation of the order filter-based distribution, and the random projection margin along the congruence dimension. The Advanced marginal quantile aggregation becomes highly useful for personalized risk management in the Internet financial age. Due to the presentation issue, the risk measure formulas are not shown in this abstract.

5. Digital Infrastructure for Financial Security

Alongside trusted customer relationships, the efficient design and management of robust digital infrastructure is essential for ensuring cyber-secure, real-time retail payments across jurisdictions. From payment networks to credit card networks and ACH networks, financial service providers like banks, card issuers, merchants, and payment processors are competing to provide public and private innovation for near real-time fund mobility convenience where customers live, work, and play. Yet with every story of mobile payments, there is also a story of money laundering, terrorist financing, insider fraud, and credit and debit card identity fraud. In all payment stories, privacy and data breaches are also never far behind. This section will discuss the role of big data in payment system analytics that offer banks, merchants, and payment processors the needed intelligence and agility for keeping just ahead of fraud, money laundering, cybercrime, and data breaches that make real-time retail payments and faster payments so expensive and vulnerable to maintain.

But big data, even with speed analytics, is not enough to provide security by design. A more refined measurement perspective is needed for payment systems analytics. Such analytics need to reinforce secure architecture principles in networks of network models where the nodes are legal entities and the edges are the data and privacy interfaces between the legal entities. In such payer, payer intermediary, and payee networks of the rightful sending or receiving of legal tender, except for immediate withdrawal or use by the rightful payer, payer intermediary, or payee, that is guided by the law and informed and restrained by the rule of law, the digital durable medium of exchange could be used within and across not only the jurisdiction and sector silos of domestic and international payments but the independent and local retail-to-corporate-to-corporate-to-retail payments could also be securely used as a value-added innovation for practically enabling the micro-to-macro financial ecosystem.

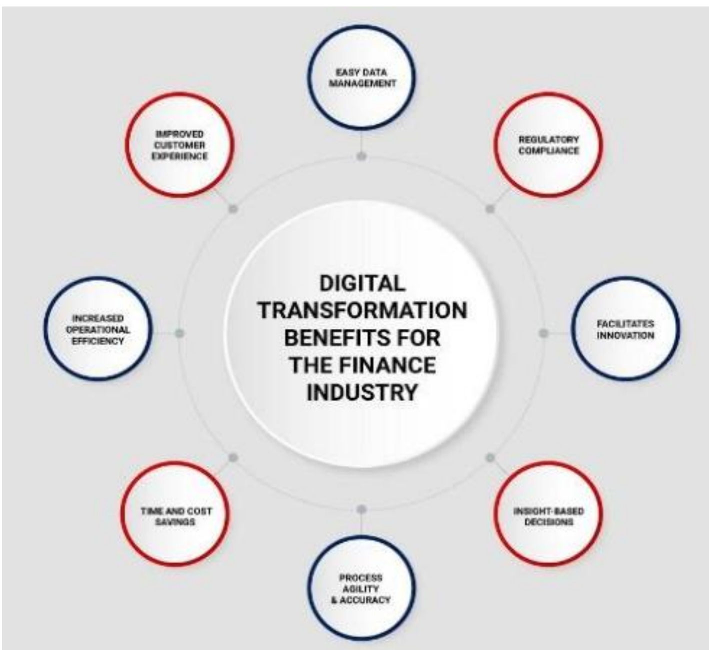

Fig 3 : Digital Transformation in Finance Industry

5.1. Cloud Computing and Financial Services

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. There are several important considerations for financial service and market regulators to deploy. These include organizational structure and governance, vulnerability, security certifications and safeguards, technology architecture, technological practices, and solutions for protecting sensitive information against unauthorized users. These concerns necessitate a comprehensive overhaul of the existing regulatory and supervisory perspectives governing the rapidly expanding and evolving financial services value chain exploiting the benefits of cloud computing. The current paper provides imperatives to be addressed by participating or intending stakeholders within the financial markets value chain to deliver their services and remain secure in the cloud.

Cloud computing adoption among financial industry firms has been cautious partly due to challenges in relegating operational, legal, and/or regulatory responsibility to a third party. The concept of financial institutions outsourcing business or service-related processes or activities to third parties and cloud computing's on-demand characteristics and virtual separation features have regulatory and supervisory implications. These features could transform financial regulation. The model is used to implement and/or host a broad array of financial solutions, including electronic securities trade execution, and operational and risk management monitoring systems. Additionally, an increasing category of players within the U.S. financial services supply chain has begun shifting command and control of some of their critical elements to their cloud provider. This situation is particularly so with an edge or smaller and non-U.S. banking institutions. The movement is into infrastructure, platform, software, and also fintech developers and cloud vendors.

Equation 2 : Nash Equilibrium in Financial Decision-Making

$$U_i(s_i^*, s_{-i}^*) \geq U_i(s_i, s_{-i}^*) \quad \forall s_i \neq s_i^*$$

where

U_i = Utility function of agent i,

s_i^* = Optimal strategy of agent i,

s_{-i}^* = Optimal strategies of all other agents.

5.2. Blockchain Technology in Finance

Blockchain is a distributed ledger that contains a list of time-stamped data. This technology provides transparency, security, and integrity. In cryptocurrencies, Bitcoin, which is an open-source project and a peer-to-peer network, is rapidly gaining acceptance for online shopping and other services. Blockchain is building trust in the modified version of Bitcoin by using the similar concept of a new company called Ethereum. An infinite number of cloud-based applications can be built using smart contracts. Blockchain is a very beneficial technology for personal, business, and government-based applications. Many financial companies are using a decentralized, secure, and transparent online transaction service using blockchain smart contracts.

A scalable architecture of the blockchain contains creator, consensus, and relayer layers. The creator layer is to create tokens, the consensus layer is to use the optimistic roll-up to write the data on the chain, and the relayer layer is to validate the off-chain transactions present in the same roll-up. The architecture is useful for scalability in Ethereum transactions because it reduces the number of users who have to validate the transactions, and an account state, and provides fast-performing transactions. The concept of scalable, trustless proof of replication is based on the replication of the data on the storage. The concept is secure, and the miner can prove that the data is stored. It can manage arbitrary blockchains such as Bitcoin and Ethereum. The main advantage of the proposed framework is that it is efficient and publicly verifiable.

5.3. Cybersecurity Measures and Protocols

The modern financial sector essentially operates in a digitized, networked environment that has several advantages in terms of efficiency, real-time risk assessment, wide distribution, and access to a large pool of customers across the globe. At the same time, this environment also has several challenges and vulnerabilities. Three of the primary sources of these vulnerabilities include social engineering attacks targeting ignorance or complacency, software or systems misconfiguration, and the intrinsic complexity in the functioning of systems. These potential 'holes' often translate to perfect opportunities for cybercriminals. Most often, cybercriminals are motivated by monetary interests and are backed by sufficient resources, tools, technologies, capabilities, and sophistication to execute their ulterior motives at will.

Several best practices, standards, and protocols are currently available to prevent or reduce the volume of cyber crimes, as well as to mitigate the impact of breaches. Standard practices are available in areas including confidentiality, integrity, availability of information, access control mechanisms, cryptography, intrusion detection and response, incident handling, and recovery planning and processes, to name a few. The need for industry-wide sharing of information around threats, vulnerabilities, practices, and breaches is critical. The challenges in ensuring and enforcing non-technical processes such as awareness, compliance, and enforcement are often underestimated, and many financial institutions are found to have weaknesses in these areas. Key areas where users are found wanting include password management, software update and patch management, awareness around social engineering attacks, awareness around phishing and pharming, identity theft protection, employee access to personal information, consumer training, and business participation in an information-sharing program. Engaging and sharing information and best practices from various institutions can significantly help.

6. Integration of Technologies

The theme of this book is about bringing the unique characteristics of some digital technologies together to develop secure financial cyber-ecosystems. The technologies underlying the proposed framework include machine learning, cryptography, and blockchain-based identity management. It is important to understand that while bringing cutting-edge technologies together, we add expertise from domain knowledge as well. To perform these tasks, knowledge is added with business insights into financial transactions. Both technologies and expertise facilitate legal and regulatory compliance analyses, which are particularly important in the financial sector. Below, we detail the integration of these digital technologies, which form the advanced cyber-infrastructure for secure financial ecosystems. A unique feature of the proposed solution is that models embrace the responsible AI theme. These models will likely be dealing with societally sensitive data, which calls for additional data privacy and security techniques to be included in the designed systems. It is also important that these unique features are highlighted.

In this chapter, we provide details on how expertise is added by enhancing high-fidelity digital models with business insights to develop efficient financial transactions. The strength of the combined digital technologies is enhanced through the models in this multidisciplinary approach. The proposed framework is validated towards two high-impact applications. These applications detail how regulators can use responsible AI models to enforce business conduct regulations. The first application identifies undue commercial benefits in various transactions at the country level and the bank level. The second application assists in identifying potentially fraudulent transactions across countries. In future practice, these techniques can be extended to address additional entity identification problems.

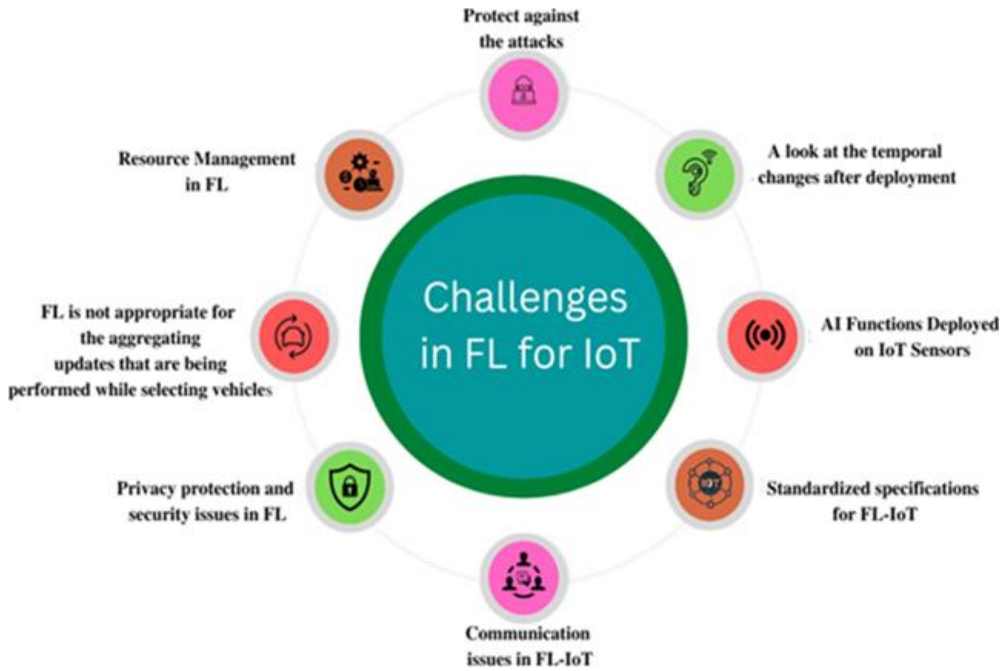

Fig 4 : Integration of federated learning with IoT for smart cities applications,

6.1. Combining Intelligent Automation and Risk Analytics

While digitization increased process velocity and expanded boundaries of growth opportunities, it has little impact on how an institution assesses the risk inherent in financial activities. The risk technology is deeply embedded in bank vaults - such metrics are at a basic level, made to monitor side threats that fluctuate in modest amounts compared to the bank reserve. As leverage increases, as most businesses nowadays have capital markets embedded in their operating models, this risk metric is insufficient. The main questions that financial institutions should address are: is risk understanding and related decision-making automated and fed by continuous big data flows? While middle office technology has embedded up-to-date market information in VaR technologies, does it digitize clients, market understanding, and depositor communities? Can we create a secure cyber environment to bring clients ever closer to the institution?

We are not asking for small things. The essential risk management challenge is combining intelligent robotics with professional insight. It needs to embed the envisioned fast frontier on functionalities, uses, and pay-offs of big data in advanced simulation models to visualize risk, and expose tail exposures, with an emerging front office that is continuously interested in clients' business and knows all operational risks behind the digits. The combined approach can transform financial institutions into respected pillars of society, leveraging dichotomous risk for profits, rather than mortgaging the future for bad risks. Good quality data, combined with powerful computing may not bestow omniscience but sharpen judgment skills. It demands organizational skills to break departmental divisions, consider the strategic implications of client relationships, and incorporate risk evaluation in operational tasks. The industry fuels a financial system that creates exponentially expanding, converging, and accelerating returns on investment measures computation performance not in terms of clock speed but by applying advanced risk analytics on advanced data flows generated by crowd-oriented business models embedded in digital and physical economies.

6.2. Building a Cohesive Digital Infrastructure

Financial systems globally have evolved from traditional paper-based platforms to highly sophisticated digital domains. The main motive behind turning bank accounts and transactions digital is to target the benefits of progress and wealth while empowering ecosystems, including developing underserved populations as well as the international financial network. Nevertheless, harnessing the advantages of a digital-based financial system heavily depends on its underlying foundation, including robust and secure digital architecture. Several countries have begun forming a cohesive digital infrastructure for financial services and have incorporated policies as well as guidance to progress. The innovative computational approaches can bolster together a unified and robust digital architecture for financial systems by demonstrating various scenarios in which they could be used to support policies.

The digital ecosystem is finding its footing in the form of a distributed ledger carried out by blockchain technology, moving into rapid transaction technologies that rely upon data-driven electronic financial services with constant assessment and analysis. The digital ecosystem can be configured to scale and meet both economic and user goals through genetic optimization, best models, and transforming classic systems to include feedback loops, machine learning, data validation techniques, and policies and strategies that help to improve data security and create refinable results. Such tools can help existing financial systems to deliver digital solutions by supporting access to markets and revenue systems and help to implement efficient infrastructure projects based on regional ecosystems' potential growth. Digital services can also be stratified into basic services for digital economies transformation as well as financial systems by promoting digital identity practices and cost-effective knowledge management services, intelligent data extraction and technique management, frameworks designed to value and prevent threats, distributed control solutions for complex smart contract management, digital techniques to help bring creditors and financial planning closer to optimized security design goals, and interoperable gateway services.

6.3. Interoperability Challenges

Efficient communication and coordination across different service providers and intermediaries can significantly improve the speed and scale of financial transactions. With the advancement of modern banking technology, crucial aspects of the financial ecosystem such as online payments, loan origination systems, customer onboarding processes, etc., are handled by service providers, partly external to the bank. To maximize the use of digital tools for financial access, fintech tools must provide APIs that facilitate rich two-way communication with banks. However, current methods for integration can be cumbersome and expensive. Implementing custom interfaces for service providers for every product becomes inherently difficult due to the long tail of products and the limitations of integration. New tools and frameworks are needed to make it easier for a service provider to work with a bank and for the bank to work with many service providers. Given the data privacy and protection of customer information, the financial ecosystem has inherent interoperability challenges, otherwise called "trust" challenges. How can inter-banking technological solutions be developed in a way that the necessary data are shared and information systems cooperate without creating vulnerabilities or privacy infringements?

7. Regulatory and Compliance Issues

The disillusion of financial regulations happens after financial institutions discover that creative ways can abate regulatory impositions. The total impact of information technology in the financial sector is currently being felt as it has achieved significant strides in enhancing operational transparency. This has severe regulatory and legal ramifications. Thus, current financial regulations and disclosure systems are woefully inadequate to regulate the sector. Current state, federal, and reviews revealed regulators' difficulties in overseeing: (i) inconsistencies in systemic vulnerabilities across global entities; (ii) conflicts of interest of institutions, their clients, and affiliates; (iii) non-reporting and under-representation of claims against fraud loss, loans, and troubled countries evaluation. In sum, the goal is to predict and correct, since countering a financial crisis is costly.

International financial portfolio management, payment systems, settlement, clearing, and financial advice leading sectors have become hedged by innovative techniques that can ill-define the scope of intervention strategies available to institutions and governments in the event of a financial crisis. These activities make it difficult to determine the boundary between permissible financial institutions' reform of trading, payments, and consultative services, operations, and the speculative and proprietary risks portfolio limits that alter financial and economic conditions and align banks with stock market risk movements. Awareness of loss data and portfolio interlink validation supports the institution's ability to meet the liabilities of the industry's participants, countering the observation that continuously monitors and/or absorbs market shocks.

7.1. Understanding Financial Regulations

It is difficult to overstate the critical importance of financial regulations in the global financial system. Financial regulations are being used by countries across the world to protect investors, ensure the stability of global financial institutions, and safeguard the entire global economy. This need is not surprising given the periodic financial crises that have beset the global financial system in the late 20th and early 21st centuries. These financial crises can have disastrous effects that reverberate across the entire global economy as, for example, subprime mortgage defaults in the United States unleashed the worst global financial crisis since the 1930s. Consequently, financial regulations will always be an active area of academic research and the subject of much media attention as they are constantly being updated in response to innovations in financial markets made possible by technological advances. Indeed, a recent analysis examined numerous financial regulations, including various pairs of value-at-risk thresholds, refinements of the regulatory calculations, and lines of regulatory text from the Basel III regulatory framework governing banks around the world; other innovative work on the complex interactions between financial regulations and cryptocurrencies has been published in just the past few months.

The existence of a large, complex web of financial regulations is well-known across the financial services industry. For example, the risk management division of virtually every financial institution is responsible for ensuring that the institution complies with a complex, ever-changing set of regulations that includes rules about acceptable risk metrics, transparent risk reporting, and reporting horizon. Financial professionals frequently mention compliance as the greatest cost of the division, which a large financial institution can expect to incur shortly. Claims about the importance of regulatory compliance are reinforced by the size of the fines that have been imposed on financial institutions in the recent past: significant fines have been imposed on financial institutions. Since regulations are a prominent part of the financial services industry, it should come as no surprise that this area of work has been a popular area for quantitative analysts. Indeed, sophisticated quantitative analysis of regulations predates the arrival of Bitcoin; to give just one example, a prescient piece of minimalist analysis about potential detrimental conditions from layering and spoofing was released in March 2009. Since the arrival of Bitcoin, the area of regulation where there has been the most innovative quantitative work focuses on cryptocurrencies.

7.2. Impact of Compliance on Innovation

It is a commonly held belief that the banking industry is not innovative because regulations hinder innovation. However, the only area where regulations hinder innovation is in relying on care and compliance. It is often the case that compliance is seen as a necessary checkbox or a hindrance to be minimized. This view has the effect of making the firm take non-compliance risks since compliance becomes a cost attached to an idea, not a fundamental part of it. However, business ideas should be brought in such a way that respect for rules is not seen as an external constraint that limits growth. This is possible through experience, learning, collaboration, communication, and change in mindsets. Today, compliance technology investment serves not only the need to maximize the speeding up of processes, reduce costs, optimize resources, and minimize the operational risks related to quality, production, and use of reports and related analysis models. Compliance through technology has become an exceptional exponential factor for growth, giving the ability to enter new areas and create new services and products, optimize ongoing operations, and remove profit containment factors. At the same time, the development has changed the approach to non-financial surveillance of credit institutions, risking diverting them from their core business, complicating their organizational structure, and extending the decision-making and verification process.

Compliance is a regulatory cooperative problem to be distinguished by controls, which are instead control and certification methods inherent in an administrative review system that veers on the judgment of deliberative acts and more generally on the governance of the company, which must minimize its risk profile. The design and management of compliance technologies and the technologies that affect compliance have today acquired central importance in the banking sector. Compliance technology investments also serve not only the need to maximize the speeding up of processes, reduce costs, optimize resources, and minimize the operational risks related to quality, production, and use of reports and related consulting and auditing analysis models. Compliance has become an exceptional exponential factor of growth, which gives the ability to enter new market areas and create new services and products, optimizing ongoing operations and removing profit-containment factors. At the same time, the development has changed the approach to non-compliance surveillance of credit institutions, complicating their organizational structure in creating satellite companies or purchasing external services, thus extending the decision-making and verification process.

7.3. Future Trends in Regulation

Regulatory monitoring and security enforcement of the implementations will be the subsequent stage of FinTech regulation. Regulators facing these changes should be innovative and follow new and improved policy models: simplified policy directives, generalized, not specific, legal frameworks, real-time value reviewing, and automated adjustments to these frameworks. Engagement with the practitioners will be a common iterative procedure for both the FinTech industry and the regulators. FinTech disruptions in financial services challenge the existing banking business model. Regulators, on their part, need to find a balance between their role as a safety net provider with responsibility for financial stability on the one hand, and their duty to facilitate a more competitive environment and cheaper solutions for banking users. This analysis provides a brief overview of these trade-offs and offers numerous examples from different jurisdictions as illustrative case studies. These show how new legislative efforts, often carefully intertwined with novel licensing approaches, are necessary to support the dynamics of the FinTech world and address the specific requirements that apply in cases of extreme openness in core services.

8. Case Studies of Innovative Frameworks

The purpose of the framework is to combine optimization and statistical modeling to predict both the need for and the optimal level of intervention using central bank digital currency in a liquidity crisis epidemic. A central motivation is that a central bank digital currency can be viewed as a hyper-liquid financial asset. By its unique design, it can be reallocated in real-time, without counterparty risk, at minimal transaction cost. The value added to the central bank's digital currency is limited by the visible technological capacity for instantaneous transactions. The central bank's digital currency, therefore, can be directly and instantly allocated to needy financial institutions and instill market stability. Using network theory, systems dynamics, and an epidemiologic approach, we design an effective early warning model for the threat to market stability induced by thrombosis of the interbank market. We develop a central bank digital currency framework with a novel approach. In addition to the rapid reallocation of liquidity, central bank digital currency can inject equity into the system.

The combination of stablecoins, with hedging of systemic interbank risk, can amplify the system response to thrombosis of the banking sector. The analysis shows a structure involving hub-and-spokes, where a group of a few very large banks formed the core of the network. Prior works have found other network shapes as well as interbank asset and liability contagion. The difference is informative. The neurological, flow and systemic risk models can identify and predict the impacts associated with liquidity problems. However, our work finds that system illiquidity is not independently predictable from other indicators—with the exception that chronic undercapitalization can suggest that the impact of systemic risk is heavy. The immediate lesson is that there is no way to predict or change the direction of financial market stabilization. Investors should acknowledge the maximum impacted value by the microscopic behavior of the whole system and expect to react rather than predict in real-time.

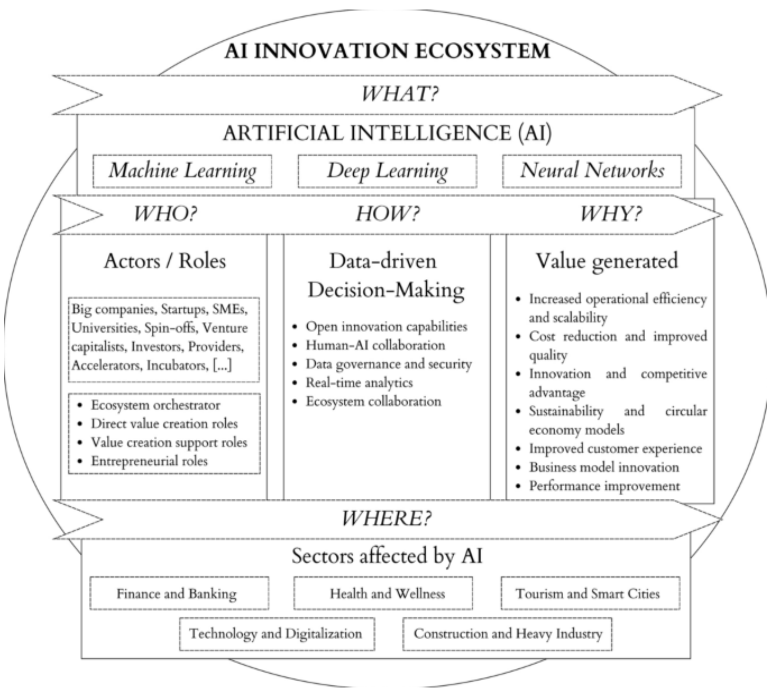

Fig 5 : Artificial intelligence within innovation ecosystems

8.1. Successful Implementations

The feasibility and discoverability of the methodology are twofold important objectives. No model is successful unless it is applied to real problems in complex systems. Early success in the application of a specific model can lead to the discoverability of multiple computational models that share certain characteristics. Such a discovery allows practitioners to set better expectations about the input data, the output resolution, and the runtime complexity. From the perspective of researchers, the application leads to unlikely sources of computational difficulty and tractability whose study can enrich the way to view the application itself. The success can also lead to the discovery of connections to other topics where the decision problems considered here remain open. Successful implementations of the Decision-Theoretic Game-Theoretic methodology illustrate that it provides a principled approach to trust management that can be applied to a wide class of security games in financial applications. Our implementation test also demonstrates the practical importance of the model-free multi-stage methodology.

In the first implementation of our methodology, we introduce a general framework for studying a wide range of applicable machine learning trust management problems, referred to as information privacy and trust management challenges in our case studies, by formulating them as two-stage sequential stochastic games. We provide two algorithms for the corresponding challenges. In the second implementation of our methodology, we focus on the model-free and multi-stage decision-theoretic and game-theoretic analysis of zero-sum and security games. Instead of focusing on solving the D-SG or SG directly, we provide algorithmic and complexity results that directly reveal the multi-stage and model-free structure of zero-sum and security games. This approach provides a practical justification of the methodology by placing a high computational cost on the assumption of a game model being known or approximated well. In such scenarios, the fact that attackers may adapt and exploit deviations from the model reduces the validity of the approximated game.

8.2. Lessons Learned from Failures

The study of innovations and the outcome of the attempt to launch innovative offerings uncovers that innovation outcomes occur within a context, which is host to failures as well as successes. Specifically, we learned that failures mostly result from applying an idea at the wrong time, in the wrong context, by the wrong person, or with the wrong strategy, or with the right strategy but the wrong execution. The identification of the context in which to push the digital agenda might constitute the most important lesson learned in the course of several studies dedicated to financial ecosystem innovation. The second most important lesson learned is that, to date, the failure of Fintech innovation seems to depend more on external factors than on firm-specific aspects. This is a strong underestimate of the critical role that the selection, institution, and training of employees during the preparation stage, as well as the organizational ability to handle the change during the incubation and seeding stage, might play. We will call this an opportunity for exploiting the company perspective paradigm corroborated by valuable contributions in the supply chain management and relationship marketing literature. In conclusion, every stakeholder in financial innovation, from the educational organization to the single financial operator, needs to be aware that the appearance of opportunities passes through a perspective, either company-related or industry-related. Furthermore, small companies have special abilities to anticipate, exploit, and manage a perspective or to lean on narratives to encrypt unusual business opportunities and convert them into innovations.

9. Future Directions

There are several areas of future research in finance, risk management, intelligent systems, and network security. Several future directions of intelligent systems, including emerging topics, are presented, such as ambiguity, monetary grammar systems, net intention sets, ontologies, ontology engineering, the semantic web, power interval sets, consensus fusion, expert wisdom, and geometric programming. Future research includes integrating dimension reduction, consensus fusion, various risk measures, and compliance with diverse approaches, such as disclosure accounting, out-of-sample variance, stochastic differential games, stochastic differential equations, financial performance, financial statement analysis, knowledge, and network security, to study risk betas, risk tolerance, algorithms, and data analytics, such as big data, further development of a novel neural network-based communication model, expert systems, intelligent workflow, emotion recognition, new accounting rules, neural networks, likelihood region classifiers, probabilistic FSM, regression analysis, uncertainty interval networks, and services.

9.1. Trends in Financial Technology

Financial technology is the marriage between finance and technology. Simply put, fintech spans a myriad of services and technology platforms that employ machine learning, natural language processing, blockchains, and associated capabilities to disintermediate traditional finance actors, offering better access and value to customers. Holding product enabler and cost efficiency vendor status, financial entities are partnering with fintechs to help them with customer identification, money laundering monitoring, credit capabilities, trading measures, portfolio balances, risk management, compliance, fraud exposure, and technological innovative solutions. Categorized as P2P lending, crowdfunding, robo-advisors, trading platforms, insurance, portfolio advisory, payment gateways, identity services, and financial solution providers, among others, fintechs face operational challenges. Fragmented markets, lack of security standards, explosive growth demands, and lack of interoperability across providers and platforms together propel a ripe environment for multiple financial frauds. Risks to financial stability and macroprudential surveillance are unilateral, where contracting and leading banking service provision is a reactant to mitigate platform risks with hindsight bias. Regulatory gaps create weakened praxis and cross-country coordination on how financial regulators design and manage platform-based service provision is lacking. Platform conflicts of interest are delayed by a lack of consumer privacy, service access controls, and value propositions aggregated at layered ecosystem levels where financial institutions, technology service providers, and service users do not align incentives.

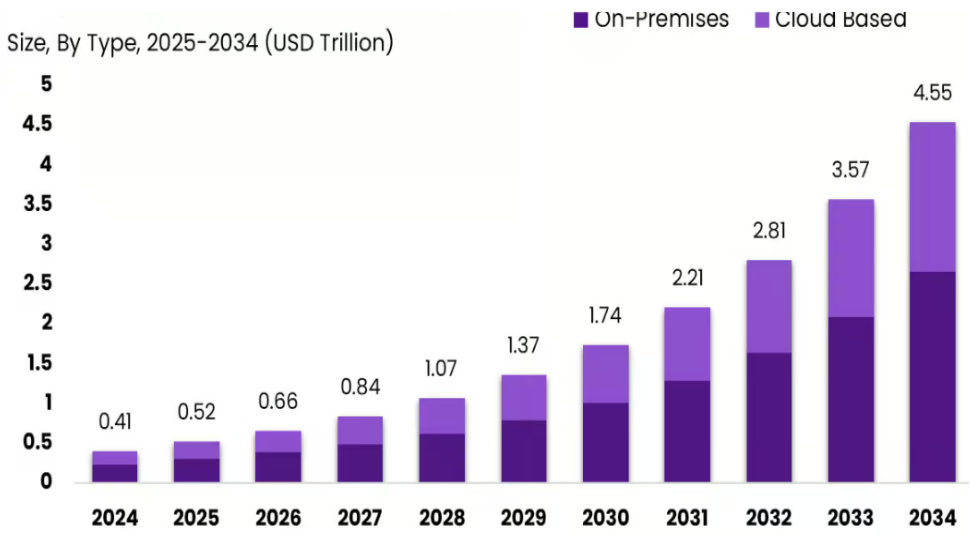

Fig 6: Digital Infrastructure Market Size

9.2. Potential Research Areas

It is clear from the previous discussions on innovative computational frameworks for secure financial ecosystems that this vibrant area offers several opportunities and potential research challenges. We present below several potential research directions including advanced generic security services, privacy-friendly models, protection of big financial data, and blockchain-based secure financial transactions. Dynamic, adaptive, and hybrid cryptographic services needed for secure financial clouds must be designed and developed. The dynamic adjustments can be based on changing characteristics of financial data as well as user businesses, and the adaptive tools must consider specific user contexts and operational requirements. Hybrid architectures need to be developed to enable hybrid asymmetric and symmetric encryption, key agreement using public and private keys, key updating, key rotation and re-keying, and threshold signature and encryption schemes. Homomorphic encryption needs to be made practical, group distribution and registration of secret keys based on nonpublic distribution models and methods, time-polynomial secure coding in a large non intersecting pool of participants with a constant composition of participants in each period, and probabilistic identity-based encryption have to be developed for big data services in secure financial clouds. Data hiding, watermarking, and side-channel cryptanalytic techniques for financial analysis must be enhanced. Statistical systems and probability models must be developed for cyber risk assessments needed for financial ecosystems. Inspection rules and regulations, detection strategies, and control measures are required for big data markets with online auctions and competition authority intervention markets.

9.3. Long-term Impact on Financial Ecosystems

Static regulations can often serve as a deterring force against cyber hacking. In a rapidly changing digital environment, stronghold regulations may harm progress. For instance, although EMV cards may be effective for some time in Europe and the US, the imposition of responsibility on the weaker party and benefiting banks over payment services can serve as a deterrent to liability rules. Regulatory burdens can thus constitute an artificial entry barrier in the digital world by stifling innovation. But it is also important to account for the demand side's decreased innovation: excessive regulations are likely to reduce ex-post experimentation and learning and encourage path dependence. Consequently, finding the right balance becomes important.

It may appear that being risk-averse and overprotective protects the financial system. There is a trade-off; digital security and growth lie along the riverbanks, but not on the same side of the river. To implement static stopgap solutions because optimal policy is politically and intellectually difficult is to act like the simple-minded man who searches under the streetlight for his key, because that is where the light is. The many advantages of innovation through openness and scale in highly connected digital platforms must be met with public policies to moderate the downsides. Our purpose in this book is to supply such public policies, summarize the results and establish a blueprint for effective innovation policy for financial technology.

Equation 3 : Algorithmic Risk Management Efficiency

$$E_r = \frac{D_c}{T_a}$$

where

E_r = Risk management efficiency,

D_c = Correctly detected anomalies,

T_a = Total analyzed transactions.

10. Conclusion

The constant increase in the complexity and diversity of financial ecosystems is an indication of the constant growth of these systems. With this growth, new and more complex vulnerabilities and threats appear at each moment since the monetary gains associated with these types of activities are very attractive to criminals. It is known that the development of security frameworks can contribute to mitigating these threats; however, the level of complexity and diversity of systems has been challenging even the most up-to-date models. In this chapter, four innovative computational frameworks were analyzed in which the authors holistically approached the financial ecosystems, subdividing them into levels recognized in the literature of complexity and diversity.

It is concluded that the models and frameworks analyzed have the potential to contribute to the solution to the problem, and new versions and adaptations will improve these frameworks. An early version of homogeneous, modular, and integrated security can already be implemented through the adaptation of these new security models and frameworks, with an inherent level of complexity adaptation, instead of the adaptation of the reality of integrated systems to existing models and frameworks of known and outdated low complexity. Data security and the functionality of financial service providers are essential for the existence and maintenance of any financial ecosystem. It is essential that, for the survival of these systems, increasingly sophisticated and efficient methods and models for guaranteeing this essential security, in ever-growing and highly interdependent systems, may be developed. The computational frameworks used can attract the economic and social value of the financial ecosystems analyzed, in particular, and of the existing ones. The application of the financial ecosystems analyzed has economic potential in the various sectors with an effect on the general population. This conclusion allows for wide use in many technological sectors, with applicability in various sectors of society.

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