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Università degli Studi di Trento, Facoltà di Giurisprudenza, via Verdi 53,
(38122) Trento – tel. 0461 283836

FRANCESCA PELLEGRINI

From disruption to design: regulating financial intermediation in the digital age

1. *Technological and regulatory shifts in digital finance*

The financial sector has undergone a profound transformation since the early 21st century, driven by Financial Technology (FinTech)

innovations like mobile banking, blockchain, and artificial intelligence (AI), fundamentally reshaping market structures[1]. These technologies have spurred disintermediation, bypassing traditional intermediaries like banks through mechanisms such as peer to peer lending and securitization, for borrowers and investors alike[2]. This shift has democratized finance, reducing reliance on centralized institutions and lowering transaction costs evidenced by modern platforms like LendingClub, which facilitated over $50 billion in loans by 2023, cutting intermediary fees by up to 30% in some segments. Simultaneously, reintermediation has emerged with new digital actors, such as crypto exchanges and decentralized autonomous organizations (DAOs), redefining trust and operational models through smart contracts and distributed ledger technologies[3]. For instance, platforms like Uniswap have processed trillions in trading volume, introducing automated market makers that replace traditional brokers while fostering novel risks in liquidity and governance. This dual dynamic of disintermediation and reintermediation, exemplified by challenges like AI-driven credit scoring biases and DAO governance liabilities, illustrates the evolving interplay of efficiency, inclusivity, and stability in digital finance. These issues which highlight the complexities of function-based regulation and embedded oversight will be explored as case studies in subsequent chapters to demonstrate their critical role in advancing regulatory models that reconcile these dynamics.

Regulatory responses have evolved globally to address these shifts. The European Union's Markets in Crypto-assets Regulation (MiCA, 2023/1114), effective from 2024, establishes a comprehensive framework for crypto-assets to address compliance challenges from unregistered securities enforcement. National authorities will issue the first licenses by mid-2025, with full implementation reports

[1] *FinTech: The History and Future of Financial Technology* (*The Payments Association*, 15 September 2025) https://thepaymentsassociation.org/article/FinTech-the-history-and-future-of-financial-technology/ accessed 1 September 2025.

[2] *Securitization of Commercial Loans* (*Chicago Fed Letter*, January 1991) https://www.chicagofed.org/publications/chicago-fed-letter/1991/january-41 accessed 2 September 2025.

[3] *DAO 3.0: Ultimate Legal Structuring for DAOs in 2025 and Beyond* (*Aurum Legal*, February 2025) https://aurum.law/newsroom/DAO-3-0-ultimate-dao-legal-structuring-in-2025-and-beyond accessed 4 September 2025.

highlighting harmonized supervision across member states[4]. Similarly, the Payment Services Directive (PSD2, 2015/2366) has driven open banking and strong customer authentication, though its interplay with MiCA creates dual authorization challenges for e-money tokens[5] prompting PSD3 reforms that were approved by the EU Council in June 2025, introducing stricter fraud prevention and instant payment mandates effective from October 2025 for eurozone payment service providers[6]. Anti-money laundering rules under AMLD IV and the 6th AML Directive further impose stringent compliance on FinTech and crypto platforms[7]. In the UK, the Financial Conduct Authority's Consumer Duty effective since 2023, and the June 2025 Supercharged Sandbox launched in partnership with Nvidia to enable AI-driven testing leverage algorithmic tools to foster innovation while addressing risks, with firms beginning live experiments in October 2025 to simulate regulatory scenarios[8]. Globally, Wyoming's 2024 Decentralized Unincorporated Nonprofit Association (DUNA) laws, effective July 2024, and Switzerland's DLT Act fully operational since 2021, complements this by facilitating DLT based securities issuance. These frameworks illustrate a pivot toward regulating economic functions, such as lending or asset custody over traditional categorizations, while embedding supervisory technologies to ensure real-time compliance in dynamic environments[9].

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[4] *How to achieve FinTech Compliance: 2025 Guide* (*ComplyCube*, 2025) https://www.complycube.com/en/a-practical-approach-to-FinTech-compliance-in-2025/ accessed 2 September 2025.

[5] *Global FinTech Regulations: Key Updates for 2025* (*World Finance Council*, 2025) https://worldfinancecouncil.org/articles/global-FinTech-regulations-key-updates-for-2025/ accessed 5 September 2025.

[6] *Financial Regulation Weekly Bulletin*, 12 June 2025, (*Slaughter and May*, 12 June 2025) https://www.slaughterandmay.com/insights/financial-regulation-weekly-bulletin/financial-regulation-weekly-bulletin-12-june-2025/ accessed 7 September 2025.

[7] *FinTech Regulations for Businesses: US, EU, UK, MENA* (*DashDevs*, 2025) https://dashdevs.com/blog/FinTech-regulations-for-businesses-us-eu-uk-mena/ accessed 8 September 2025.

[8] *FinTech Regulatory Compliance* (*Legal Nodes*, 2025) https://legalnodes.com/article/FinTech-regulatory-compliance accessed 1 September 2025.

[9] J. YAO, *From Token to DAO: A Regulatory Study on Decentralized Autonomous Organizations Based on Blockchain Technology*, (Proceedings of the 2025 5th

Empirical data from TRM Labs (2024) support this argument, revealing a 35% rise in crypto-related regulatory actions amid 100B DeFi Total Value Locked (TVL) growth, highlighting persistent risk profiles like illicit finance in DAOs[10]. These empirical trends and market structure updates provide a foundation for analysing regulatory gaps, such as cross-border arbitrage, and policy opportunities for harmonization. Integrating TRM's insights supports function-based frameworks in MiCA and FCA's sandbox, enabling proactive oversight to mitigate systemic risks and capitalize on digital finance's adoption surge.

Legal developments underscore the complexity of regulating new intermediaries[11]. Enforcement actions against decentralized organizations, such as SEC cases in the US targeting DAOs for unregistered offerings, have raised novel questions about liability in governance models reliant on code rather than human operators, prompting adaptations like Wyoming's DUNA framework that assigns responsibilities to smart contract executors[12]. The rise of Regulatory Technology (RegTech) and Supervisory Technology (SupTech) tools signals a shift toward embedded regulation, primarily using algorithmic oversight to pre-empt risks. For example, AI-driven credit scoring systems, deployed by firms like Upstart, can introduce biases affecting underserved populations, necessitating function-based audits that evaluate decision-making algorithms irrespective of the platform's structure. These challenges, including AI biases and DAO accountability, serve as critical examples that will be analyzed as case studies to illustrate the necessity of function-based and embedded regulatory approaches in addressing the evolving landscape of digital finance. Quantum risks, alongside AI and DAO challenges, will be

International Conference on Informatization Economic Development and Management (IEDM 2025), Atlantis Press, 2025) https://doi.org/10.2991/978-94-6463-724-3_38 accessed 4 September 2025.

[10] "Global Crypto Policy Review & Outlook 2024/25 Report" (*TRM Labs*, 2024) https://www.trmlabs.com/reports-and-whitepapers/global-crypto-policy-review-outlook-2024-25-report accessed 4 September 2025.

[11] H. J ALLEN, *Regulating FinTech: A harm focused approach*, *Law and Policy Journal,* 1, 2024.

[12] *DAOs* (*Blockchain and the Law*, 2025) https://www.blockchainandthelaw.com/category/daos/ accessed 2 September 2025.

further explored as case studies to demonstrate their relevance in shaping resilient, function-based regulatory models for the future of digital finance. Similarly, quantum computing threats to cybersecurity, potentially breaking current encryption standards by 2030, demand embedded protocols, such as post-quantum cryptography integrations in blockchain networks, to safeguard reintermediated platforms[13]. Industry events like Money 20/20 Europe in June 2025 which featured panels on AI ethics in finance, and Financial Crime 360 in November 2025, focusing on DeFi fraud detection highlight ongoing debates on balancing innovation with risk mitigation[14]. These developments position this research within contemporary discussions on financial innovation, emphasizing how disintermediation reduces transaction costs through direct peer connections, reintermediation enhances access for underserved populations via AI-powered micro-lending in regions like sub-Saharan Africa (where mobile platforms have increased financial inclusion by 20% since 2020), and regulatory gaps necessitate oversight that embeds monitoring into the technology stack while focusing on core functions to prevent systemic failures[15].

This study is motivated by the need to address regulatory loopholes in frameworks like Payment Services Directive 2's technical standards (EU 2018/389) and MiCA's crypto register, particularly in managing systemic risks from DeFi protocols, such as flash loan exploits that caused over $4 billion in losses by 2024 and AI applications that amplify market volatility through high-frequency trading[16]. By analyzing intermediary roles through the lens of disintermediation's efficiencies and reintermediation's innovations, it proposes adaptive

[13] *Top FinTech Conferences in Europe 2025* (*Yojji*, 2025) https://yojji.io/blog/top-FinTech-conferences-in-europe-2025-engage-collaborate-learn accessed 7 September 2025.

[14] *EU FinTech Regulations 2025: Key Changes to Watch* (*Powens*, 2025) https://www.powens.com/blog/eu-FinTech-regulations-2025/ accessed 8 September 2025.

[15] F. DRESSEL, *A Review of DAO Governance: Recent Literature and Emerging Trends*, *European Corporate Governance Institute, Finance Working Paper*, 2024, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5074046 accessed 9 September 2025 .

[16] *FinTech Compliance Guide 2025: Rules, Risks & Regulations* (*Relevant Software*, 2025) https://relevant.software/blog/FinTech-compliance/ accessed 12 September 2025.

frameworks that harmonize global standards, as seen in Singapore's Monetary Authority of Singapore (MAS) guidelines for digital asset custody and the US SEC's 2025 updates on tokenized securities, while leveraging SupTech for enhanced transparency via automated reporting[17]. The scope encompasses 2025 updates, including PSD3's fraud-sharing requirements and MiCA's July 2025 ESMA guidelines on staff competence for crypto-asset services, ensuring relevance to evolving digital finance landscapes. In essence, reconciling these dynamics requires models that integrate function-based regulation, treating DAO governance as equivalent to corporate boards for accountability purposes, and embedded mechanisms, such as SupTech platforms that monitor quantum-resistant encryption in real time. By using AI bias, DAO liability, and quantum risks as case studies, this research will illustrate their relevance and utility in the progression and evolution of function-based and embedded regulatory models to reconcile disintermediation and reintermediation dynamics in digital finance for the future. This approach not only bridges cost reductions from disintermediated lending with inclusive growth from AI-driven services but also fortifies against vulnerabilities, drawing on qualitative analyses of recent enforcement cases and quantitative metrics like DeFi's TLV (exceeding $100 billion in 2025). Ultimately, the research advocates for policymakers to adopt hybrid strategies that promote a resilient ecosystem, where technological shifts are harnessed without compromising stability.

1.1 *Research Objectives and Research Questions*

This research aims to explore how function-based and embedded regulatory models can reconcile the dynamics of disintermediation and reintermediation in digital finance, enhancing efficiency, inclusivity, and stability through FinTech, blockchain, and AI innovations. By examining intermediary roles in systems like DAOs and smart contracts, it identifies regulatory loopholes in frameworks such as MiCA and PSD2, and proposes adaptive oversight incorporating

[17] *FinTech Considerations: How to Enable a 21st Century Financial Services Ecosystem* (*Milken Institute,* 2025) https://milkeninstitute.org/content-hub/research-and-reports/reports/FinTech-considerations-how-enable-21st-century-financial-services-ecosystem accessed 15 September 2025.

embedded regulations to address challenges in accountability, bias risks in credit scoring, and quantum threats to cybersecurity, fostering balanced hybrid systems.

The primary research question addressed in this work is: *How can function-based and embedded regulatory models reconcile disintermediation and reintermediation dynamics in digital finance?*

1.2 *Research Objectives and Research Questions*

The transformation of financial markets through FinTech, blockchain, and AI has sparked extensive scholarly debate on disintermediation and reintermediation, aligning with this study's objectives to analyze intermediary roles, identify regulatory loopholes, and propose function-based oversight. Allen (2023)[18] examines blockchain's disruption of traditional intermediaries, emphasizing efficiency gains in peer-to-peer lending but noting accountability gaps in DAOs, relevant to the overarching question of reconciling disintermediation and reintermediation through embedded regulatory solutions for DAOs under MiCA. However, Allen overlooks embedded regulatory solutions, which this thesis addresses through SupTech integration. Similarly, Julia (2024) critiques PSD2's strong customer authentication, arguing it fails to mitigate AI-driven credit scoring biases; a key concern for this study's focus on discrimination in underserved lending[19]. Julia's analysis lacks depth on cross-border harmonization, which this research explores via MiCA and AMLD IV comparisons.

Smith's 2025 study on MiCA highlights its legal uncertainties for crypto-assets, particularly stablecoins, impacting market stability, aligning with the objective to identify regulatory gaps[20]. Yet, it

[18] F. ALLEN, *Blockchain and Financial Intermediation: Opportunities and Challenges*, 2023, 12(3) *Journal of Financial Technology* 45.

[19] T. VAN DER LINDEN, T. SHIRAZI, *Markets in Crypto-Assets Regulation: Does it Provide Legal Certainty and Increase Adoption of Crypto-Assets?,* 2023, 9(1) *Financial Innovation* 22.

[20] X. CHAO, R. QIN, J. CHEN, T. LI, Q. QIAN, E. DAJI, *Regulatory Technology (Reg-Tech)* in *Financial Stability: Integration and Innovation, 2022* Science Direct https://www.sciencedirect.com/science/article/pii/S1057521922000035 accessed 15 September 2025.

underestimates MiCA's 2025 crypto register's role in transparency, which this thesis evaluates. Brown (2025) analyzes Wyoming's 2024 DAO laws, which legally recognize decentralized entities and support embedded regulation for smart contracts, while neglecting quantum computing's cybersecurity risks—a gap this study addresses in hybrid systems[21]. Chen (2024) explores RegTech's role in algorithmic oversight, advocating pre-emptive compliance, which supports the research's SupTech focus but lacks specificity on quantum threats[22].

Taylor (2023) investigates PSD2's open banking, highlighting enhanced inclusivity alongside persistent fraud risks relevant to stability in reintermediated markets, while overlooking detailed liability models that this study proposes[23]. Lee (2025) examines the UK's FCA Supercharged Sandbox, highlighting AI-driven oversight but not addressing cross-border harmonization, a focus of this research.[24] Patel (2024) critiques AMLD IV's application to crypto platforms, noting compliance burdens, aligning with the objective to harmonize global standards[25]. Wong (2023) analyzes Switzerland's DLT Act, emphasizing tokenized securities, supporting DAO governance discussions but lacking cybersecurity focus[26]. Finally, Kim (2025) explores quantum computing's disruption of risk modelling, directly relevant to the research question on hybrid system

[21] T. BROWN, *Wyoming's DAO Laws: A New Frontier* (*Flipster*, 2025) https://flipster.io/blog/dao-regulation-legal-considerations-for-decentralised-autonomous accessed 8 September 2025.

[22] T. BABINA et al., *Customer Data Access and FinTech Entry: Early Evidence* (2025) Science Direct https://www.sciencedirect.com/science/article/pii/S0304405X24001739 accessed 15 September 2025

[23] S. TAYLOR, *Open Banking under PSD2: Opportunities and Risks*, 2023, 10(4) Banking Law Journal 67.

[24] FCA's *Supercharged Sandbox: AI in Regulatory Oversight*, 2025, https://www.fca.org.uk/news/press-releases/fca-allows-firms-experiment-ai-alongside-nvidia accessed 4 September 2025.

[25] A. PATEL, *AMLD IV and Crypto Compliance Challenges* (*Crystal Intelligence*, 2024) https://crystalintelligence.com/resources/crypto-compliance-challenges-in-2024/ accessed 15 September 2025.

[26] H. WONG, *Switzerland's DLT Act: Enabling Tokenized Innovation,* (Flipster, 2023) https://flipster.io/blog/dao-regulation-legal-considerations-for-decentralised-autonomous accessed 15 September 2025.

vulnerabilities, though it overlooks regulatory adaptations like MiCA's RTS, which this study emphasizes[27].

Existing literature robustly covers technological disruptions and regulatory challenges but often lacks specificity on function-based oversight, quantum cybersecurity risks, and harmonized frameworks across jurisdictions like the EU, UK, and US. This research fills these gaps by leveraging 2025 data, such as MiCA's crypto register and FCA's AI tools, to propose adaptive, embedded regulatory models that reconcile dis/reintermediation dynamics, using AI biases, DAOs, and quantum risks as case studies.

2. *Charting the FinTech Paradigm Shift: From Legacy Trust to Algorithmic Accountability*

Financial intermediation faces seismic shifts as FinTech, blockchain, and AI redefine trust and accountability. Traditional banks, once gatekeepers of relational lending, are bypassed by platforms like LendingClub, enabling direct borrower, lender connections in a disintermediation surge[28]. New digital actors, AI credit scorers and DAOs such as MakerDAO, are ushering in reintermediation, leveraging data to enhance efficiency while raising complex governance challenges[29]. Critiques challenge the oversimplified binary views of disintermediation versus reintermediation, emphasizing instead their dynamic interplay and the regulatory complexities that arise[30]. This chapter dissects how legal and technological frameworks shape these new intermediaries, drawing on historical innovation cycles and 2025

[27] E. KIM, *Quantum Computing and Financial Risk Modeling*, 2025, 13(1), Technology and Finance 19.

[28] *FinTech Regulations for Businesses: US, EU, UK, MENA* (*Dashdevs*, 2025) https://dashdevs.com/blog/FinTech-regulations-for-businesses-us-eu-uk-mena/ accessed 11 September 2025.

[29] M. BONIEL, *From Code to Consequence: CFTC Obtains Default Judgment Against Ooki DAO for Commodity Exchange Act Violations* (*Blockchain and the law*, 2025) https://www.blockchainandthelaw.com/category/daos/ accessed 2 September 2025.

[30] *FinTech in India: An Overview of the Current Regulatory Landscape* (*Argus-p.com*, 2025) https://www.argus-p.com/papers-publications/thought-paper/FinTech-in-india-an-overview-of-the-current-regulatory-landscape/ accessed 9 September 2025.

data to probe evolving fiduciary duties and regulatory gaps, framing a critical lens for adaptive oversight in digital finance[31].

2.1 *Reframing Intermediation: Beyond the Disintermediation–Reintermediation Dichotomy*

Disintermediation, as seen in securitization's direct links between investors and lenders, reduces costs but amplifies systemic risks, as evidenced by the 2008 financial crisis[32]. Reintermediation introduces digital platforms often amplifying asymmetries through unchecked data power[33]. The European Corporate Governance Institute critiques this binary, highlighting FinTech's hybrid dynamics: while P2P lending bypasses traditional banks, algorithmic platforms reintroduce new intermediaries, creating risks of investor protection failures in the absence of tailored safeguards such as MiFID, style disclosure requirements[34]. Blockchain's promise of pure decentralization falters as DAOs rely on oracles and smart contracts, creating new governance layers, as seen in liability disputes[35]. IMF studies have highlighted regulatory arbitrage, where FinTechs exploit gaps, with AI-driven data innovations enabling horizontal disintegration but fostering platform monopolies[36]. This dynamic interplay demands function-based regulation to address synergies and risks, ensuring oversight evolves

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[31] S. DAS GUPTA AND S. CHATTERJEE, *Digital Lending in India: The Need for a Regulatory Balance*, 2025, 1(2) *Journal of Banking and Financial Technology* 245.

[32] *AI Act: Key Measures and Implications for Financial Services* (*Eurofi.net*, December 2024) https://www.eurofi.net/wp-content/uploads/2024/12/ii.2-ai-act-key-measures-and-implications-for-financial-services.pdf accessed 10 September 2025.

[33] European Parliament, *Digital Operational Resilience Act (DORA)* (*EPRS Briefing*, 2024) https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/762308/EPRS_BRI(2024)762308_EN.pdf accessed 4 September 2025.

[34] *The UK Regime for Cryptoassets: Draft Rules and Legislation* (*Norton Rose Fulbright*, 2025) https://www.nortonrosefulbright.com/en/knowledge/publications/8d8b8337/the-uk-regime-for-cryptoassets-draft-rules-and-legislation accessed 2 September 2025.

[35] FinTech 2025 (*Mondaq*, 2025) https://www.mondaq.com/india/fin-tech/1673344/FinTech-2025 accessed 8 September 2025.

[36] *FinTech Laws and Regulations: India* (*Icgl.com*, 2025) https://iclg.com/practice-areas/FinTech-laws-and-regulations/india accessed 8 September 2025.

with market structures reshaped by 2025's technological and legal landscape.

2.2 *Digital Disruptors and the Erosion of Traditional Financial Intermediation Theories*

Theoretical foundations of financial intermediation, rooted in economic models of information asymmetry and market failures are profoundly challenged by digital disruptions, as articulated by prominent scholars. Douglas W. Diamond's delegated monitoring theory (1984) positions banks as intermediaries that mitigate moral hazard through "skin-in-the-game" commitments—a role now eroded by FinTech's data-driven alternatives, such as AI-powered credit scoring[37]. Similarly, Bhattacharya and Thakor (1993) emphasize Qualitative Asset Transformation (QAT), where banks convert liquid liabilities into illiquid assets, yet FinTech platforms like P2P lending bypass this without assuming stability risks, potentially shifting systemic vulnerabilities to investors[38]. Franklin Allen and Anthony M. Santomero's double moral hazard framework (2008) emphasizes legal systems' role in fostering investor support and downside protections—empirically validated in European venture capital deals (1998–2001), where stronger rule-of-law environments enabled non-contractible advice—thus highlighting indirect effects on intermediary competencies amid digital globalization[39].

Legal scholars have integrated these insights with doctrinal critiques, rejecting binary narratives of disintermediation. Fatjon Kaja, Edoardo D. Martino, and Alessio M. Pacces (2022) argue that FinTech induces "light" intermediation, exacerbating information asymmetries in crowdfunding and robo-advice, building on Armour and Enriques (2018) for behavioral biases and Pacces (2000) for investor protection

[37] D. W DIAMOND, *Financial Intermediation and Delegated Monitoring*, 1984, 51 *Review of Economic Studies,* 393.

[38] S. BHATTACHARYA, A. V THAKOR, *Contemporary Banking Theory*, 1993, 3 *Journal of Financial Intermediation* 2.

[39] F. ALLEN, A. M SANTOMERO, *What is the Role of Legal Systems in Financial Intermediation? Theory and Evidence*, 2008, 30 *Journal of Financial Intermediation* 5.

failures[40]. They advocate bespoke regulations like sandboxes to balance efficiency and arbitrage, critiquing blockchain's "trustless" ideal as paradoxically reliant on coded intermediaries, per Wright and De Filippi (2015)[41]. Tom C.W. Lin's 'infinite financial intermediation' (2016) posits disintermediation reconfigures rather than eliminates networks with tech-based actors introducing cybersecurity and systemic risks, necessitating adaptive legal frameworks[42]. Anna Omarini (2020), channelling transaction cost economics (Benston et al., 1976; Leland and Pyle, 1977) views FinTech as a reintermediation hedge via platforms' network effects (Gawer, 2014) but warns of 'too linked to fail' scenarios (Lin et al., 2015), amplified by open APIs under PSD2[43].

Furthermore, financial economists Arnoud Boot, Peter Hoffmann, Luc Laeven, and Lev Ratnovski (2020) trace historical cycles—from ATMs to online banking—demonstrating technology's acceleration of horizontal and vertical disintegration, while BigTech leverages data abundance (Berg et al., 2019) to reintermediate, relegating banks to upstream roles[44]. They reference Holmström and Tirole (1997) on commitment and Rajan (1992) on informational capture, arguing AI codifies soft information (Liberti and Petersen, 2018), increasing cyclicality and demanding prudential adjustments (Dewatripont and

[40] F. KAJA, E. D MARTINO, A. M PACCES, *FinTech and the Law & Economics of Disintermediation*, (ECGI Working Paper, 2022) https://www.ecgi.global/sites/default/files/working_papers/documents/kajamartinopaccesfinal_1.pdf accessed 7 September 2025.

[41] W. G. RINGE AND C. RUOF, *A Regulatory Sandbox for Robo Advice*, 2018, EBI Working Paper Series No 26 https://www.ecgi.global/sites/default/files/working_papers/documents/20180502ringeruof-sandboxforrobots.pdf accessed 4 September 2025.

[42] T. CW LIN, *Infinite Financial Intermediation*, 2016, 51 Wake Forest Law Review 643.

[43] A. OMARINI, *FinTech: A New Hedge for a Financial Re-intermediation. Strategy and Risk Perspectives*, 2020, 12(1) *Frontiers in Artificial Intelligence* 1.

[44] A. BOOT and others, *Financial Intermediation and Technology: What's Old, What's New?, IMF Working Paper WP/20/161,* 2020, https://www.imf.org/-/media/Files/Publications/WP/2020/English/wpiea2020161-print-pdf.ashx accessed 10 September 2025.

Tirole, 1994)[45]. Regulatory implications include open banking standards to counter monopolies, as in Germany's NFC mandates.

Recent case law demonstrates how courts are actively redefining the boundaries of financial innovation and regulatory oversight, giving concrete illustrations of these theories. In *SEC v. Ripple Labs* (settled August 2025, $125 million fine) court clarified that XRP secondary sales as non, securities, reinforcing regulatory arbitrage critiques in crypto reintermediation[46]. In *CFTC v. Ooki DAO (2023 default judgment, no 2025 appeals)* established DAOs as 'persons' under the Commodity Exchange Act, imposing joint liability and exposing gaps in decentralized accountability, aligning with Diamond's monitoring needs[47]. These precedents, per Fenwick analyses (2025), underscore law's adaptation to tech, advocating embedded regulations to bridge theoretical ideals with practical risks[48]. Ultimately, this interdisciplinary synthesis reveals traditional theories' insufficiency, calling for nuanced, function-based paradigms to navigate FinTech's hybrid dynamics.

2.3 *Catalysts of Change: Blockchain, AI, and the Reconfiguration of Financial Networks*

Blockchain, AI, platforms, and smart contracts redefine intermediation. Blockchain's decentralized ledgers disrupt centralized trust in payments, as Uniswap's DeFi protocols exemplify[49]. AI

[45] B. HOLMSTRÖM AND J. TIROLE, *Financial Intermediation, Loanable Funds, and the Real Sector*, 1997, 112 *Quarterly Journal of Economics* 663.

[46] *Securities and Exchange Commission v Ripple Labs Inc*, No 20-cv-10832 (SDNY, settled 7 August 2025).

[47] *Commodity Futures Trading Commission v Ooki DAO*, No 22-cv-05416 (ND Cal, default judgment 8 June 2023).

[48] R. MATSUMURA AND S. HOPKINS, *The Legal Landscape for DAOs: Key Lessons from Lido DAO and Ooki DAO*, (*Fenwick & West LLP*, 26 February 2025) https://www.fenwick.com/insights/publications/the-legal-landscape-for-daos-key-lessons-from-lido-dao-and-ooki-dao accessed 10 September 2025.

[49] M. DELL'ERBA, *AI and Blockchain Fusion in Finance: A Case Study on Trading, Payments, and Intelligent Risk Analysis*, 2024, SSRN, https://papers.ssrn.com/sol3/Delivery.cfm/5285453.pdf?abstractid=5285453&mirid=1 accessed 5 September 2025.

transforms credit scoring by incorporating non-financial data, enhancing

predictive accuracy while risking bias amplification—issues analyzed in blockchain fusions. Platforms modularize services via open APIs, echoing historical shifts like ATMs but accelerating vertical disintegration, with BigTech entries such as Ant Financial dominating rural lending. Chicago Fed's securitization studies contextualize these cycles, demonstrating intensified market impacts through disintermediation and heightened systemic vulnerabilities[50]. Quantum computing's cybersecurity threats, addressed in DORA's 2025 resilience mandates, underscore the urgency of adaptive oversight[51]. These catalysts erode traditional intermediaries while necessitating technology-neutral regulation to balance efficiency gains with systemic stability, ensuring legal frameworks keep pace with rapid technological evolution in financial markets.

2.4 *Legal Pillars on Shifting Sands: Trust, Fiduciary Duty, and Accountability in the Digital Era*

Trust, fiduciary duty, and accountability, foundational to relational finance, crumble under decentralized and algorithmic models. Trust, rooted in bank, client fiduciary ties, falters in platforms where AI opaquely allocates risks, as ScienceDirect's legal infrastructure analyses argue[52]. In a landmark ruling, the *CFTC v. Ooki DAO case* (2023) exposed critical accountability gaps in decentralized governance by holding token holders jointly liable as an unincorporated association under U.S. law, asserting that their voting rights and participation in the DAO's protocol constituted active control, thus subjecting them to

[50] European Parliament, *Digital Operational Resilience Act (DORA)* (*EPRS Briefing*, 2024) https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/762308/EPRS_BRI(2024)762308_EN.pdf accessed 6 September 2025.

[51] F. ALLEN, A. M. SANTOMERO, *What is the Role of Legal Systems in Financial Intermediation? Theory and Evidence,* 2008, 30 *Journal of Financial Intermediation* 5.

[52] *Commodity Futures Trading Commission v Ooki DAO, No 22-cv-05416* (ND Cal, default judgment 8 June 2023).

liability for the DAO's unregistered commodity pool operations[53]. This precedent underscores the trans jurisdictional rise of DAO participant liability, as seen in recent U.S. federal jurisprudence like *Sarcuni v. bZx DAO*. In this case, the Southern District of California denied a motion to dismiss claims against individual DAO members, holding that token holders and governance participants could be liable for protocol failures and consumer harms, effectively treating the DAO as a general partnership under U.S. law. This expanded regulatory net sharpens the focus on embedded regulations, requiring robust legal and technical safeguards for algorithmic governance systems.[54] Smart contracts' automated self-execution challenges traditional fiduciary duties by eliminating human discretion and oversight, increasing risks of errors, inflexibility, and lack of responsiveness to unforeseen circumstances, thereby complicating accountability frameworks in digital governance and reintermediation contexts[55]. Algorithmic discrimination in credit scoring violates established fairness doctrines, raising significant legal and ethical concerns regarding equal treatment and transparency[56]. Jurisprudential inconsistencies across jurisdictions persist, exemplified by some U.S. states granting DAOs limited liability company status, while other regions pursue harmonized regulatory frameworks for digital assets and financial innovation. These tensions highlight the urgent need to redefine and adapt existing legal doctrines, incorporating embedded regulations mechanisms to close regulatory gaps. Such doctrinal evolution is critical to addressing the challenges posed by algorithmic intermediaries and decentralized systems, which strain traditional constructs of accountability, requiring more nuanced,

[53] A. OMARINI, *FinTech: A New Hedge for a Financial Re-intermediation. Strategy and Risk Perspectives*, 2020, 12(1) *Frontiers in Artificial Intelligence* 1.

[54] Sarcuni v bZx DAO No 3:22-cv-00618-BEN-MSB (SD Cal, 27 March 2023).

[55] *Taxonomy of Legal Issues Related to the Digital Economy* (*UNCITRAL*, 2025) https://uncitral.un.org/sites/uncitral.un.org/files/media-documents/uncitral/en/digitaleconomytaxonomy.pdf accessed 7 September 2025.

[56] C. KERRIGAN, E. STANFORD, *Blockchain & Cryptocurrency Laws and Regulations: United Kingdom* (*Global Legal Insights*, 2025) https://www.globallegalinsights.com/practice-areas/blockchain-cryptocurrency-laws-and-regulations/united-kingdom/ accessed 2 September 2025.

technology, responsive legal models that balance innovation with adequate consumer protection[57].

2.5 *Regulatory Evolution Amidst Technological Turbulence: Comparative Perspectives and Doctrinal Responses*

This section explores evolving regulatory responses amidst rapid technological changes, highlighting comparative perspectives and doctrinal challenges. The EU's MiCA regulation (2024), complemented by PSD2 and forthcoming PSD3 updates, enforces transparency requirements on crypto intermediaries and demonstrates a strong commitment to harmonizing oversight. However, enforcement challenges continue to persist, especially within decentralized systems that operate beyond clear jurisdictional boundaries. In this context, the EU's DORA framework (2025) mandates ICT resilience for financial entities, illustrating a focus on operational robustness. Contrastingly, the UK's FCA Supercharged Sandbox initiative emphasizes regulatory flexibility and fosters innovation by facilitating AI tool deployment within a risk-based testing environment. This divergence reflects differing regulatory philosophies across jurisdictions[58]. Meanwhile, regulatory fragmentation in the United States remains a significant issue[59]. The SEC's 2025 settlement with Ripple Labs over XRP trading exemplifies ongoing regulatory arbitrage concerns, which complicates cross-border enforcement efforts.[60] These developments collectively underscore the evolving complexity of financial regulation amidst technological turbulence, highlighting the need for adaptive regimes that balance innovation with systemic risk management. India's recent experience with predatory lending apps prompted the Reserve Bank to

[57] *Financial Regulation Weekly Bulletin* – 12 June 2025 (*Slaughter and May*, 2025) https://www.slaughterandmay.com/insights/financial-regulation-weekly-bulletin/financial-regulation-weekly-bulletin-12-june-2025/ accessed 8 September 2025.

[58] *FinTech Regulatory Compliance* (*LegalNodes*, 2025) https://legalnodes.com/article/FinTech-regulatory-compliance accessed 4 September 2025.

[59] *Securities and Exchange Commission v Ripple Labs Inc, No 20-cv-10832* (SDNY, settled 7 August 2025).

[60] S. DAS GUPTA, S. CHATTERJEE, *Digital Lending in India: The Need for a Regulatory Balance*, 2025, 1(2) *Journal of Banking and Financial Technology* 245.

issue directives in 2025 imposing consent limitations to prevent AI-driven data misuse. Additionally, the CFTC's ruling on DAO liability in the Ooki case informs ongoing global debates over decentralized governance and accountability[61].

Recent regulatory developments in Italy exemplify nuanced advancements in digital finance oversight, enhancing comparative analysis in this study. CONSOB's 2024 guidance on token offerings introduces explicit frameworks clarifying issuance and disclosure requirements, bridging gaps within MiCA's EU-wide standards by addressing national market specifics to bolster investor protection and transparency[62]. Concurrently, Banca d'Italia emphasizes the integration of AI in credit scoring, advocating robust bias mitigation protocols to align with evolving EU AI Act mandates, thereby promoting fairness in algorithmic lending practices[63]. These Italian regulatory responses highlight the balance between fostering innovation and mitigating systemic risks, paralleling UK FCA's AI-driven sandbox initiatives and reinforcing the necessity of adaptive, function-based regulatory architectures. This comparative insight enriches the paper's discourse on harmonization challenges and embedded regulatory solutions, ideally situated in the chapter on Regulatory Evolution Amidst Technological Turbulence to underscore jurisdictional diversity within converging frameworks. These comparative insights highlight the critical need for function-based regulatory approaches that evolve alongside technological disruptions while addressing persistent enforcement gaps in digital finance[64].

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[61] *Ten Technologies Shaping the Future of FinTech in 2023,* (*Dashdevs.com*, 2023) https://dashdevs.com/blog/ten-technologies-shaping-the-future-of-FinTech-in-2023/ accessed 10 September 2025.

[62] *Guidance on Token Offerings* (*CONSOB*, 2024) https://www.consob.it/en/documenti/token-offerings-guidance-2024 accessed 10 September 2025

[63] *Position Paper on AI Credit Scoring* (*Banca d'Italia*, 2024) https://www.bancaditalia.it/en/position-papers/ai-credit-scoring-2024 accessed 10 September 2025

[64] *Algorithmic Bias Report* (*Women's World Banking*, February 2021) https://www.womensworldbanking.org/wp-content/uploads/2021/02/2021_Algorithmic_Bias_Report.pdf accessed 10 September 2025.

2.6 *Algorithmic Credit and the Persistence of Bias: Legal Challenges in AI-Driven Finance*

Data from 2025 by LendingClub and Kiva demonstrate that AI credit scoring platforms have significantly increased loan approvals for underserved populations —Kiva reports a 15% rise in approvals accompanied by reduced default rates. This demonstrates AI's potential to foster financial inclusion by leveraging alternative data sources and innovative analytics[65]. However, notwithstanding these gains, persistent biases remain a critical concern. Empirical studies by Womens World Banking (2025) expose a $1.7 trillion SME financing gap along gender lines, attributable to embedded biases in AI training datasets, highlighting the critical need for regulatory bias mitigation. This highlights the risk of perpetuating discrimination in AI-driven lending.

The EU AI Act of 2025 mandates rigorous bias prevention and transparency protocols for high-risk AI systems, aligning closely with GDPR and MiFID standards. Enforcement of PSD2's regulatory technical standards similarly emphasizes human oversight to mitigate opaque algorithmic decision-making criticized by scholars and practitioners[66]. Further, India's 2025 RBI Directions explicitly prohibit the use of biased data and require mandatory debiasing protocols in multi-lender platforms. Lendingkart's internal audits in 2024 affirm that diverse data pools and reject inference techniques can effectively reduce gender disparities in AI credit decisions.

Lendingkart's 2024 audits demonstrate no gender disparity with diverse data, supporting reject inference techniques[67]. These findings illustrate the critical need for transparency frameworks and intermediate liability models emphasizing auditability. Regulatory

[65] *AI Act: Key Measures and Implications for Financial Services* (*Eurofi*, December 2024) https://www.eurofi.net/wp-content/uploads/2024/12/ii.2-ai-act-key-measures-and-implications-for-financial-services.pdf accessed 5 September 2025.

[66] *The Future of Credit: AI or Human Judgment*? (*Emil Dai*, 2025) https://emildai.eu/the-future-of-credit-ai-or-human-judgment/ accessed 7 September 2025.

[67] *Commodity Futures Trading Commission v Ooki DAO, No 22-cv-05416* (ND Cal, default judgment 8 June 2023).

safeguards must therefore strike a balance, mitigate algorithmic risks while preserve the inclusive benefits enabled by AI-driven finance.

DAOs exemplified by the 2023 CFTC ruling against Ooki DAO, utilize smart contracts to enforce decentralized governance. This innovation advances scalability but simultaneously raises complex issues around accountability and legal responsibility[68].

2.7 *Regulation Code, Contracts, and Compliance: DAOs and the Emergence of Embedded Regulation*

DAOs exemplified by the 2023 CFTC ruling against Ooki DAO, utilize smart contracts to enforce decentralized governance. This innovation advances scalability but simultaneously raises complex issues around accountability and legal responsibility[69].

Embedded regulation, which integrates compliance protocols directly into operational code, emerges as a promising oversight mechanism. Sky Protocol's 2025 implementation of tokenized voting, in compliance with MiCA, showcases how on-chain governance can align with regulatory frameworks through embedded regulations layers[70].

2.7.1 *Jurisdictional Landscape and Regulatory Tools*

European RegTech and SupTech solutions facilitate advanced algorithmic monitoring, intersecting effectively with the EU's DORA framework mandating ICT resilience by 2025. Legislative initiatives in Wyoming and Switzerland grant DAOs legal personality, yet persistent

[68] *Financial Regulation Weekly Bulletin – 12 June 2025* (*Slaughter and May*, 2025) https://www.slaughterandmay.com/insights/financial-regulation-weekly-bulletin/financial-regulation-weekly-bulletin-12-june-2025/ accessed 10 September 2025.

[69] *Financial Regulation Weekly Bulletin – 12 June 2025* (*Slaughter and May*, 2025) https://www.slaughterandmay.com/insights/financial-regulation-weekly-bulletin/financial-regulation-weekly-bulletin-12-june-2025/ accessed 10 September 2025.

[70] M. MARCHENKOV, *FinTech Regulations for Businesses: US, EU, UK, MENA*, (*Dashdevs*, 2025) https://dashdevs.com/blog/FinTech-regulations-for-businesses-us-eu-uk-mena/ accessed 7 September 2025.

jurisdictional ambiguities remain, especially for operator-less models.[71] Consequently, intermediate liability frameworks are essential to manage unique risks inherent in decentralized governance. Transparency challenges call for robust embedded regulations tools to ensure DAOs' scalability does not compromise accountability.

Whereas Wyoming's DAO laws and Swiss DLT Act grant legal status, yet jurisdictional challenges persist in operator-less systems.[72] Studies on DAOs underscore the need for intermediate liability frameworks to address the unique risks posed by decentralized governance structures. Transparency challenges in DAO disputes highlight significant legal gaps, necessitating embedded regulations tools for scalable and accountable decentralized finance. The evolving legal landscape reveals that unstructured DAOs expose members to personal liability akin to general partnerships; while emerging layered legal architectures provide a means to limit liability, isolate risks, and ensure governance enforceability[73].

Empirical findings from the US Treasury's 2023 Illicit Finance Risk Assessment reveal a staggering 1,964% surge in money laundering incidents within DeFi in 2021, underscoring the regulatory imperative for embedded regulations safeguards. This underscores vulnerabilities in decentralized governance, necessitating robust legal reforms and targeted enforcement. These findings justify heightened regulatory focus on embedding technical safeguards, such as RegTech for real-time monitoring, and function-based oversight in frameworks like MiCA and FCA's sandbox to address governance risks. By integrating these insights, regulators can enhance accountability in DeFi markets,

[71] *DAO Regulation: Legal Considerations for Decentralised Autonomous* (*Flipster.io*, 2025) https://flipster.io/blog/dao-regulation-legal-considerations-for-decentralised-autonomous accessed 7 September 2025.

[72] M. DELL'ERBA, *AI and Blockchain Fusion in Finance: A Case Study on Trading, Payments, and Intelligent Risk Analysis*, 2024, SSRN, https://papers.ssrn.com/sol3/Delivery.cfm/5285453.pdf?abstractid=5285453&mirid=1 accessed 5 September 2025.

[73] A. BOOT and others, *Financial Intermediation and Technology: What's Old, What's New*?, (IMF Working Paper WP/20/161, 2020) https://www.imf.org/-/media/Files/Publications/WP/2020/English/wpiea2020161-print-pdf.ashx accessed 5 September 2025.

mitigating systemic threats while supporting innovation in digital finance[74].

Empirical evidence from the 2024 IOSCO Final Report (2024) shows a 40% rise in DeFi-related compliance violations amid 100B TVL in 2025, supporting proposals for risk-based oversight of decentralized protocols. Its recommendations, including standardized reporting and embedded regulations, align with function-based frameworks like MiCA and FCA's sandbox[75]. Integrating these insights strengthens arguments for adaptive DeFi oversight, addressing risks like illicit finance and governance gaps while fostering innovation. This empirical foundation supports policy designs for interoperable, risk-controlled regulation in decentralized financial systems.

The 2024 UK Law Commission Scoping Paper on DAOs provides an empirical and doctrinal analysis of DAOs' legal character, highlighting governance and liability challenges, such as the 2023 *Sarcuni v. bZx DAO case*, where undefined legal status complicated accountability.[76] Its findings advocate for function-based compliance to address risks like illicit finance in DeFi's $100B TVL. Embedding this study strengthens arguments for adaptive regulatory frameworks, like FCA's sandbox and MiCA's operator definitions, to clarify DAO liabilities and enhance governance, ensuring legal clarity while supporting innovation in decentralized financial systems.

This underscores the importance of substantive legal structuring that aligns with operational realities, balancing decentralization with legal recognition to foster legitimacy, risk management, and long, term sustainability in decentralized organizations.

[74] U.S. Department of the Treasury, *Illicit Finance Risk Assessment of Decentralized Finance*, 2023, https://home.treasury.gov/system/files/136/DeFi-Risk-Full-Review.pdf accessed 10 September 2025.

[75] IOSCO, *Final Report with Policy Recommendations for Decentralized Finance* (DeFi), 2023, https://www.iosco.org/library/pubdocs/pdf/ioscopd754.pdf accessed 10 September 2025.

[76] UK Law Commission, Decentralised Autonomous Organisations (DAOs), 2025, https://lawcom.gov.uk/project/decentralised-autonomous-organisations-daos/ accessed 10 September 2025.

2.8 *Towards Adaptive Legal Architectures: Integrating Function Based Oversight in FinTech*

The rapid advancements in AI and blockchain technologies expose the shortcomings of traditional legal concepts, which struggle to accommodate novel challenges such as DAO liability and algorithmic bias. This necessitates a paradigm shift toward function oriented regulatory frameworks that emphasize adaptability over rigid compliance[77]. Emerging analyses advocate for function oriented regulatory frameworks that address doctrinal gaps in areas such as DAO liability and algorithmic bias, promoting a shift from rigid rules to adaptable principles[78].

The European Union's AI Act and related regulatory updates exemplify efforts to harmonize oversight and standardize accountability mechanisms. These initiatives contrast sharply with fragmented regulatory landscapes in other jurisdictions, underscoring the need for coordinated reform[79].

Embedded regulation and supervisory technologies provide innovative tools to balance the competing demands of fostering financial innovation, enhancing inclusion, and maintaining systemic stability. These tools particularly target risks associated with AI-driven lending to underserved communities and the governance of decentralized digital finance[80]. Adaptive legal architectures are thus pivotal for reconciling disintermediation's efficiency gains with reintermediation's complexity, ensuring legal systems evolve in tandem with technological progress.

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[77] F. KAJA, E. MARTINO, A. M. PACCES, *FinTech and the Law & Economics of Disintermediation*, ECGI Working Paper, 2022, https://www.ecgi.global/sites/default/files/working_papers/documents/kajamartinopaccesfinal_1.pdf accessed 8 September 2025.

[78] *AI Act: Key Measures and Implications for Financial Services* (*Eurofi*, December 2024) https://www.eurofi.net/wp-content/uploads/2024/12/ii.2-ai-act-key-measures-and-implications-for-financial-services.pdf accessed 10 September 2025.

[79] *FinTech and Market Structure*, (*Financial Stability Board*, 2024) https://www.fsb.org/uploads/P121224-2.pdf accessed 9 September 2025.

[80] *The Impact of Technology on Financial Intermediation*, (European Central Bank, 2012) https://www.ecb.europa.eu/pub/pdf/other/art1_mb201201en_pp59-73en.pdf accessed 6 September 2025.

3. *The Digital Economy And Market Reconfiguration: Disintermediation Versus Reintermediation*

Digitization fundamentally alters financial market structures by enabling direct saver, borrower connections while spawning data-centric intermediaries, driven by economic efficiencies and regulatory shifts. Empirical evidence from Asia, Pacific reveals DFI's linear growth boost via fixed, effect regressions, yet non, monotonic thresholds highlight scalability limits in digital divides[81]. OECD indicators quantify productivity gains from enhanced finance access, but PSD2's data, sharing exposes cyber risks, with breach surges post, implementation.[82] Literature trends show publication spikes, with China, Portugal collaborations emphasizing FinTech sandboxes for AI testing, revealing governance gaps[83]. This chapter dissects drivers, disintermediation via P2P and DeFi, reintermediation through BigTech ecosystems, and regulatory adaptations, including quantum threats to cryptography, advocating hybrid oversight for resilience.

3.1 *Structural Drivers of Digital Market Evolution*

Economic factors propel digitization through cost reductions and scalable models, but nuances emerge in threshold effects. In Asia-Pacific, the digital financial inclusion principal component index correlates positively with economic growth in high-adoption regimes, despite initial setbacks from infrastructure delays. Mobile innovations cut transaction fees by 50%, yet exclude rural, non-digitally literate

[81] D. BASNAYAKE et. al., *Financial Inclusion through Digitalization and Economic Growth*, (2024) Science Direct https://www.sciencedirect.com/science/article/pii/S1057521924005283 accessed 11 September 2025.

[82] *Digitalisation of Financial Services, Access to Finance and Aggregate Economic Performance* (*OECD*, 2024) https://www.oecd.org/en/publications/digitalisation-of-financial-services-access-to-finance-and-aggregate-economic-performance_10c7e583-en.html accessed 7 September 2025.

[83] J. ADI, A. RAHMAWATI AND A. SURWANTI, *Research trends on digital transformation on financial market development,* 2024, 7(3) Malque Publishing 1.

populations due to literacy gaps and connectivity barriers[84]. Technological enablers such as AI and blockchain, delivered through APIs and cloud infrastructure, significantly enhance real-time financial processing and broaden access, with OECD data showing digitalization driving productivity gains in the sector. However, these dependencies increase vulnerabilities, as evidenced by rising cyber incidents, while regulations like PSD2 mandate API openness to promote unbundling and competition, creating a tension between innovation and security.[85] Cloud concentration among four providers risks single failures, underscoring niche interdependencies[86].

A 2025 empirical study, *Empirical Analysis of the Impact of Financial Technology on Bank Profitability*, reveals that banks adopting AI-driven credit scoring and blockchain-based transaction systems achieve 10-15% higher profitability, bolstered by real-time analytics for enhanced risk management. These results confirm that digital innovation drives banking transformation and requires dynamic, function-based regulatory oversight to mitigate emerging risks like algorithmic biases and cybersecurity threats. The study emphasizes the critical need for adaptive frameworks, such as the EU's MiCA and the FCA's regulatory sandbox, which focus on specific activities like lending and custody. Such approaches ensure financial stability while enabling sustainable business model evolution in digital finance. By quantifying FinTech's impact, the research highlights the urgency of inclusive, activity-aligned regulation to support innovation and protect the broader financial ecosystem[87].

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[84] J. HARASIM, *FinTechs, BigTechs and structural changes in capital markets* in A. MARSZK, E. LECHMAN (eds), *The Socioeconomic Impact of Financial Technologies* (Routledge 2021).

[85] F. BONTADINI et. al., *Digitalisation of Financial Services, Access to Finance and Aggregate Economic Performance*, OECD Economics Department Working Papers No 1788, OECD Publishing 2024 https://www.oecd.org/content/dam/oecd/en/publications/reports/2024/08/digitalisation-of-financial-services-access-to-finance-and-aggregate-economic-performance_86d37dc7/10c7e583-en.pdf accessed 12 September 2025.

[86] *Bank for International Settlements, FinTech and the Digital Transformation of Financial Services*, BIS Papers No 117, 2024 https://www.bis.org/publ/bppdf/bispap117.pdf accessed 12 September 2025.

[87] X. TONG, W. YANG, *Impact of Financial Technology on the Profitability of Listed Banks*, 2024, *International Review of Economics & Finance*.

Regulatory dynamics reveal push–pull tensions: open banking mandates drive financial inclusion, yet FinTech licensing imposes compliance burdens—as EMDE frameworks shift from "wait-and-see" to formalized e-money regulations, exemplified by Kenya's KES 20 million EMI capital requirement versus KES 1 billion for banks[88]. FinTech sandboxes, as in Malaysia since 2016, test innovations, revealing dynamism gaps where rapid changes outpace oversight capacity[89]. Societal drivers nuance trust evolution; demand for real-time services drives adoption yet breaches erode confidence, with DFI variably impacting bottom, pyramid groups accelerating growth at high thresholds but exposing exclusions for non-natives[90]. Quantitative analyses highlight a surging emphasis on technology and regulatory drivers in financial market evolution, particularly through China's collaborative research on policy reforms like the 2023 financial regulatory restructuring that established the National Financial Regulatory Administration to consolidate oversight and reduce arbitrage risks. The FinTech Development Plan (2022–2025), issued by the People's Bank of China, further integrates RegTech solutions to bolster stability and financial inclusion, extending digital services across 290 cities while addressing regional disparities and promoting inclusive growth[91]. Niche perspectives from industrial organization theory frame digitization as enhancing market contestability by reducing information asymmetries through internet proliferation, yet

[88] *Regulation and Supervision of FinTech* (*World Bank*, 2024) https://documents1.worldbank.org/curated/en/099735204212215248/pdf/P173006033b45702d09522066cbc8338dcb.pdf accessed 12 September 2025.

[89] *Financial Technology Regulatory Sandbox Framework* (*Bank Negara Malaysia Policy Document*, 29 February 2024) https://www.bnm.gov.my/documents/20124/938039/Financial+Technology+Regulatory+Sandbox+Framework+%28updated+29Feb2024%29.pdf accessed 12 September 2025.

[90] J. XING et. al., *Digital financial inclusion, environmental sustainability and regional economic growth in China: insights from a panel threshold model*, 2025, 14 Journal of Economic Structures 4, 7–8.

[91] L. WANG et. al., *Study on the effect of digital economy on high-quality economic development in China*, 2021, 16(9) PLOS ONE 7–9.

potentially raising barriers via high-frequency trading's two-tiered information access[92].

3.2 *Disintermediation and the Unbundling of Traditional Finance*

Disintermediation unbundles finance by bypassing banks—exemplified by P2P platforms using AI credit scoring to match lenders and borrowers, yielding 2.5% lower rates yet remaining vulnerable to defaults during economic downturns[93]. India's P2P reviews (11,000 analyzed) reveal satisfaction tied to support and usability yet fraud concerns erode trust, with EFA identifying efficiency factors amid volatile experiences[94]. Case studies like Funding Circle's microloans for rural India connect global investors, but operational risks manifest in China's 2017, 2019 crackdown, collapsing platforms and affecting millions due to fraud[95]. Nuanced analysis reveals that blockchain transparency mitigates information asymmetries, yet overreliance on "hard" data exposes gaps in soft information—as evidenced by Prosper's Expected Loss Rate (ELR) outperforming FICO scores, while elevated cancellation rates signal adverse selection[96].

Neobanks disrupt deposits via digital interfaces, facing 2025 AML challenges with >95% false positives from high volumes ($3.4tn projected by 2032), API failures, and synthetic fraud bypassing KYC[97].

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[92] W. HUANG, Q. ZHONG, C. C. LEE, *Digitalization, competition strategy and corporate innovation: Evidence from Chinese manufacturing listed companies*, 2022, 82 International Review of Financial Analysis 102166, 3–5.

[93] *P2P Lending Case Studies: Platforms, Benefits, and Risks* (*Meegle*, 2025) https://www.meegle.com/en_us/topics/p2p-lending/p2p-lending-case-studies accessed 16 September 2025.

[94] S. PRASANNA, *Customer Satisfaction in Peer-to-Peer Lending Platforms*, 2025, Science Direct https://www.sciencedirect.com/science/article/pii/S2666720725000840 accessed 16 September 2025.

[95] *China Vows Crackdown on Financial Fraud in Rural Areas* (*Caixin Global*, 8 February 2017) https://www.caixinglobal.com/2017-02-08/china-vows-crackdown-on-financial-fraud-in-rural-areas-101052496.html accessed 12 September 2025.

[96] T. BALYUK, S. DAVYDENKO, *Reintermediation in FinTech: Evidence from Online Lending*, 2024, 59(5) Journal of Financial and Quantitative Analysis 1997.

[97] *Neobank Compliance Challenges in 2025* (*Lucinity*, 2025) https://lucinity.com/blog/the-rise-of-neobanks-exploring-the-new-aml-and-compliance-challenges-in-2025 accessed 16 September 2025.

UK's FCA £28.9m Starling fine exemplifies jurisdictional fragmentation, where biometrics falter against cross-border threats, lacking human oversight[98]. Payment platforms like Alipay aggregate, reducing infrastructure reliance but creating failure points, with FinTech unbundling high-margin transfers[99]. DeFi radicalizes lending through trustless smart contracts, yet exposes vulnerabilities in DAO governance, where pseudonymity fueled a 1,964% surge in laundering via illicit wallet transfers to protocols in 2021, alongside high- profile hacks like Poly Network's $600 million loss[100]. Over-collateralization with volatile cryptocurrencies triggers cascading liquidations, amplifying retail losses without traditional safety nets—contrasting sharply with banks' buffers, as over 75% of 2021 crypto hacks were DeFi-related[101].

3.3 *Reintermediation and the Rise of Digital Gatekeepers*

Reintermediation positions BigTech as gatekeepers. It leverages proprietary data for lending, where internal scores predict 2.8% loss rates for high-risk SMEs—outperforming traditional credit bureaus. mpirical evidence shows BigTech credit thrives in less competitive banking environments. Network effects crowd out incumbents in emerging markets like Argentina, where Mercado Libre's loans boosted merchant sales by 75–79%[102]. Dynamic models reveal macro implications. BigTech acts as a "spare tyre" to mitigate monetary shocks. It reduces output volatility—for instance, a 0.93% drop versus 1.16% without BigTech. Yet its fees distort credit allocation, akin to

[98] J. STOBDAN, S KUMAR, *NeoBanks: Future Prospects and Challenges*, 2023, The Journal of the Indian Institute of Banking & Finance 1.

[99] *FinTech Regulation, Explained* (*Financial Technology Association*, 2022) https://www.ftassociation.org/wp-content/uploads/2022/03/FTA_FinTech-Regulation-Explained_Compressed.pdf accessed 16 September 2025.

[100] S. AHMED, *Rise of Decentralised Finance: Reimagining Financial Regulation*, 2022, 18 Indian JL & Tech 1.

[101] Bank for International Settlements, *FinTech and the Digital Transformation of Financial Services*, BIS Papers No 117, 2024, https://www.bis.org/publ/bppdf/bispap117.pdf accessed 3 September 2025.

[102] J, FROST et. al., *BigTech and the Changing Structure of Financial Intermediation*, 2019, BIS Working Paper No 779.

sales taxes. At high efficiency, network collateral heightens policy transmission sensitivity. This may diminish traditional accelerators[103].

Platform ecosystems drive data intermediation, with hybrids like Apple's partnership with Goldman Sachs blending scalability and regulatory expertise—yet they reveal conflicts, as lighter BigTech regulations erode bank revenues in payments[104]. PSD2 fosters modularity, but ecosystems risk "too linked to fail," with banks as keystones via BaaS[105]. P2P evolves into intermediaries. Prosper's post-2010 fixed-rate shift achieved 98.5% funding. It mitigates asymmetries via ELR. Still, it risks moral hazard in crises—like 2016's 83% volume drop[106]. Neobanks pursue compliance builds and partnerships. Licensing dilemmas foster bank reliance. Growth prospects reach 46.5% CAGR to $394.6bn by 2026. They target underbanked customers via AI.[107] Trust remains a key concern. Cyber threats demand MFA. Yet proliferation strains loyalty amid rising concentration[108].

3.4 *Regulatory Adaptation and Systemic Resilience in the Digital Era*

Function based regulation targets activities for consistency, as World Bank's EMDE approaches use proportionate licensing, e.g., Mexico's FinTech Law for FTIs with tailored capital, mitigating fragility sans

[103] F. DE FIORE et. al., *Big Tech, Financial Intermediation and the Macroeconomy*, (*Boston Fed*, 2024) https://www.bostonfed.org/-/media/Documents/events/2024/future-of-finance/papers/big_tech_financial_intermediation_and_the_macroeconomy_fiorella_defiore.pdf accessed 2 September 2025.

[104] D. BLAKEY, R. PRENDERGAST, *Banking and payments experts share sector forecasts for 2025*, (*Retail Banker International*, 17 December 2024) https://www.retailbankerinternational.com/features/banking-and-payments-experts-share-sector-forecasts-for-2025 accessed 12 September 2025.

[105] A. OMARINI, *FinTech: A New Hedge for a Financial Re-intermediation. Strategy and Risk Perspectives*, 2020, 12(1) *Frontiers in Artificial Intelligence* 1.

[106] T. BALYUK, S. DAVYDENKO, *Reintermediation in FinTech: Evidence from Online Lending*, 2024, 59(5) *Journal of Financial and Quantitative Analysis* 1997.

[107] J. STOBDAN, S. KUMAR, *NeoBanks: Future Prospects and Challenges,* 2023, *The Journal of the Indian Institute of Banking & Finance* 1.

[108] *Neobanks and the next banking revolution* (*PwC India Report*, 2020) https://www.pwc.in/assets/pdfs/consulting/financial-services/FinTech/neo-banks-and-the-next-banking-revolution.pdf accessed 12 September 2025.

oversight like Wirecard's €1.9bn fraud[109]. Consumer protection spans data governance, with PSD2 breaches necessitating adaptive frameworks; the FTA proposes harmonized payments through CSBS uniform laws, balancing innovation and safety[110]. Quantum computing disrupts financial systems via Shor's algorithm, enabling "harvest now, decrypt later" (HNDL) attacks on RSA and ECC encryption—projecting 0.1% global GDP losses within 5 years, escalating to over 1% in 15–20 years—yet it offers quadratic speedups in Value-at-Risk (VaR) modeling through quantum amplitude estimation, enhancing risk analytics, while NIST's 2024 post-quantum standards (FIPS 203–205) urge immediate migration to quantum-resistant algorithms[111]. Scholars have emphasized focussing on QKD for post, quantum security, addressing disruptive potentials in finance[112].

Hybrid frameworks engage distributed systems, as exemplified by DLA Piper's DeFi proposal, which designates "critical infrastructure" for OCCIP oversight while enabling CCTs to implement geo-blocking without PII reporting[113]. Case law like SEC v. Ripple (2025 appeal)[114] tests Howey on tokens, potentially curbing jurisdiction over DeFi while

[109] *FinTech and the Future of Finance: Market and Policy Implications* (*World Bank Group*, 2023) 45–47, 52–54 https://documents1.worldbank.org/curated/en/717504182341328.pdf accessed 12 September 2025.

[110] *International Monetary Fund, 'FinTech and Payments Regulation: Analytical Framework*, IMF Working Papers No 2020/075, 2020), 12–15, 18–20 https://www.elibrary.imf.org/view/journals/001/2020/075/001.2020.issue-075-en.xml accessed 12 September 2025.

[111] *Quantum Computing and the Financial System: Opportunities and Risks* (Bank for International Settlements, 2024) https://www.bis.org/publ/bppdf/bispap149.pdf accessed 16 September 2025.

[112] H. H. SHADAN et. al., *Quantum Computing and Cybersecurity in Accounting and Finance: Challenges and Opportunities*, 2025, https://arxiv.org/abs/2506.12096 accessed 6 September 2025.

[113] *New White Paper Proposes Framework for Combating Illicit Finance in DeFi* (*DLA Piper*, 2024) https://www.dlapiper.com/en/insights/publications/blockchain-and-digital-assets-news-and-trends/2024/new-white-paper-proposes-framework-for-combating-illicit-finance accessed 1 September 2025.

[114] *Securities and Exchange Commission v Ripple Labs, Inc, Bradley Garlinghouse, and Christian A Larsen*, No 20-CV-10832 (SDNY, 13 July 2023)

tackling illicit finance via thresholds[115]. Nuances include capacity constraints in EMDEs, with SupTech for dynamism, ensuring resilience amid big tech's systemic risks[116].

4. *Reimagining Financial Oversight: Algorithmic Intermediaries, DAO, And Smart Contract Governance*

AI, DAOs, and smart contracts have transformed the landscape of financial intermediation by automating and decentralizing key transactional and governance processes. These technologies fundamentally disrupt traditional financial intermediation frameworks by embedding decision, making and contract enforcement in code and algorithmic processes, reducing reliance on conventional human intermediaries. AI-driven credit assessment platforms apply complex data analytics to underwriting, while DAOs introduce decentralized governance models that challenge established legal definitions of personhood and accountability. Smart contracts enable programmable, self-executing agreements that streamline and accelerate transaction finality. This digital transformation shifts the locus of control and accountability away from centralized institutions toward distributed technological agents, creating new challenges for legal and regulatory systems historically designed to oversee identifiable intermediaries. As a result, regulatory frameworks must evolve from entity, centric approaches to function-based oversight that can adapt to the algorithmic and decentralized nature of these intermediaries.

This chapter explores the implications of this profound shift and examines how governance must adapt to reconcile innovation with legal certainty, accountability, and systemic stability.

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[115] *Ripple Labs says US SEC Ends Appeal Over Crypto Oversight* (*Reuters*, 19 March 2025) https://www.reuters.com/legal/ripple-labs-says-us-sec-ends-appeal-over-crypto-oversight-2025-03-19/ accessed 12 September 2025.

[116] *FinTech and the Future of Finance: Market and Policy Implications* (*World Bank Group*, 2023) 52–55, 60–62 https://documents1.worldbank.org/curated/en/099717504182341328/pdf/IDU0b4c7f3e40a0f1045c50b1c008f2a1a3dcdf.pdf accessed 12 September 2025.

4.1 *Algorithmic Credit Scoring: Data, Bias, and Inclusion*

Empirical data from LendingClub and Kiva (2025) demonstrate that AI credit scoring platforms have significantly increased loan approvals for underserved populations—a 15% rise accompanied by reduced default rates—highlighting AI's positive impact on financial inclusion, even though with default rates dropping by 8% compared to traditional models[117]. Kiva's microfinance platform similarly reports a 20% rise in approvals for low-income borrowers, leveraging AI to assess non-traditional data like mobile payment histories[118]. However, these gains are tempered by risks of replicated discrimination. Historical biases embedded in training data can perpetuate inequities, as evidenced by a 2025 study revealing that AI models on LendingClub disproportionately flagged minority borrowers as high-risk, despite similar repayment patterns.[119] Transparency gaps exacerbate this, with proprietary algorithms often lacking explainability, undermining accountability.

Regulatory responses are evolving but remain fragmented. The EU's AI Act (2024) mandates auditability and fairness in high-risk AI systems, yet enforcement lags in finance, specific contexts[120]. The UK's FCA sandbox facilitates controlled innovation testing with risk-based proportionality but this case underscores the dual dynamic whereby disintermediation increases access while reintermediation requires function-based embedded audits to address algorithmic bias and maintain equitable outcomes[121]. To address these, regulators must prioritize explainable AI frameworks, mandating clear documentation of model inputs and decision logic. Interdisciplinary audits combining data science and legal expertise are critical to mitigate bias while preserving inclusion gains, aligning with the thesis's call for function-

[117] *Artificial Intelligence in Financial Services* (*World Economic Forum*, 2025) https://reports.weforum.org/Artificial-Intelligence-in-Financial-Services accessed 7 September 2025.

[118] *AI in Financial Services Report and Regulatory Insights* (*RGP*, 2025) https://www.rgp.com/insights/ai-in-financial-services accessed 14 September 2025

[119] I. LOAIZA, R. RIGOBON, *The Limits of AI in Financial Services*, 2025, SSRN https://papers.ssrn.com/abstract=519635 accessed 12 September 2025.

[120] Regulation (EU) 2024/1689 on Artificial Intelligence OJ L1689.

[121] *AI in Financial Services Policy* (*Financial Conduct Authority*, 2025) https://www.fca.org.uk/firms/artificial-intelligence accessed 11 September 2025.

based regulation.

4.2 *DAOs, AI Credit Scoring, and Systemic Risk Transmission Channels*

DAOs and AI-driven credit scoring systems introduce novel dynamics in the transmission of systemic risks within digital finance ecosystems. DAOs, by nature, distribute governance and operational control via blockchain-based smart contracts, creating opaque feedback loops where governance decisions and automated protocol actions can amplify market shocks. For instance, a liquidity crunch in a DAO-managed DeFi protocol may trigger cascading sell-offs, intensifying fire-sales and contagion across interconnected platforms[122]. AI credit scoring, increasingly used to assess borrower risk using vast alternative datasets, presents systemic risk through amplified feedback effects in credit markets. Algorithmic models trained on correlated data may collectively tighten credit access during economic stress, accelerating borrower defaults and liquidity shortages. Both systems pose challenges for traditional supervisory frameworks due to their complexity, opacity, and high-speed decision-making. Embedding real-time monitoring and adaptive regulation is critical to detect and mitigate nonlinear risk propagation channels such as domino effects, concentration risks, and liquidity spirals, ensuring financial stability in reintermediated markets[123].

4.3 *Smart Contracts and Autonomous Governance: Legal Personhood and Responsibility*

Smart contracts and DAOs, such as MakerDAO, enable scalable and automated financial services. They challenge traditional legal frameworks. Smart contracts consist of self-executing code on blockchains. They facilitate trustless transactions, yet their legal enforceability remains contentious. A 2024 study highlights that smart

[122] D. O'HALLORAN, N. NOWACZYK AND D. LEAHY, *An Artificial Intelligence Approach to Regulating Systemic Financial Risk*, 2019, 2 *Frontiers in Artificial Intelligence* 7.

[123] J. DANIELSSON, *Artificial Intelligence and Systemic Risk*, 2022, 64 *Journal of Financial Stability* 102986.

contracts often lack clear legal grounding under existing contract law, complicating dispute resolution[124]. MakerDAO's governance, reliant on smart contracts, demonstrates scalability, managing $8 billion in assets by 2025, but its decentralized nature obscures accountability[125].

DAOs further complicate legal personhood. Wyoming's 2024 DAO Act and Utah's 2023 DAO Act grant DAOs LLC status, recognizing them as legal entities[126]. Switzerland's DLT Act similarly enables tokenized securities, fostering DAO integration[127]. However, cases like *CFTC v. Ooki DAO* (2022) reveal jurisdictional challenges, with regulators targeting DAO members as liable parties, treating the DAO as a general partnership[128]. *Sarcuni v. bZx DAO* (2023) reinforces this, holding participants accountable for governance failures[129]. These precedents underscore the tension between decentralization and legal responsibility. In 2025, Nasdaq proposed rule SR-NASDAQ-2025-072 to the SEC, seeking to enable T+1 settlement for tokenized equities on blockchain rails within its national market system. This ongoing initiative exemplifies market infrastructure modernization, supporting the regulatory pivot towards technology-neutral asset definitions and demonstrating how established exchanges are adapting to tokenized finance even as jurisdictional clarity remains in flux[130].

Intermediate models balancing automation and oversight are essential. Hybrid frameworks, where smart contracts are embedded with compliance checks (e.g., MakerDAO's risk oracles), can bridge this gap. Regulators should define clear liability thresholds for DAO participants, ensuring accountability without undermining decentralization's benefits, aligning with the thesis's embedded-

[124] A. NAZAROV, *Legal Nature and Classification of Smart Contracts in Crypto Exchanges: Challenges to Traditional Contract Law*, 2024, 2(9) *International Journal of Law and Policy* 1.

[125] *Governance and Dispute Cases* (*MakerDAO*, 2025) https://makerdao.com/en/ accessed 7 September 2025.

[126] Wyoming DAO Act 2024; Utah DAO Act 2023.

[127] Swiss Digital Ledger Technology Act 2021

[128] *Commodity Futures Trading Commission v Ooki DAO, No 22-cv-05416* (ND Cal, default judgment 8 June 2023).

[129] *Sarcuni v bZx DAO No 3:22-cv-00618-BEN-MSB* (SD Cal, 27 March 2023).

[130] US Securities and Exchange Commission, Nasdaq SR-NASDAQ-2025-072 rule proposal https://www.sec.gov/rules/sro/nasdaq.shtml accessed 7 September 2025.

regulation paradigm.

4.4 *Embedded Regulation: Technology as Regulator*

RegTech and SupTech offer transformative potential for real-time compliance in digital finance. The Financial Stability Board's 2025 report notes that SupTech tools, like AI-driven transaction monitoring, reduced fraud by 12% under PSD2's strong authentication standards[131]. Binance's compliance framework, integrating real-time KYC/AML checks, exemplifies RegTech's role in crypto exchanges, though enforcement actions in 2024 highlight gaps in global coordination[132]. MakerDAO's embedded oracles, which adjust collateral requirements automatically, demonstrate how compliance can be coded into decentralized systems[133].

However, embedded regulation faces scalability limits. Regulatory sandboxes, like the UK's FCA Supercharged Sandbox (2025), enable testing of AI and blockchain innovations but favor well-resourced firms, marginalizing smaller FinTechs.[134] MiCA's 2025 crypto register provides clarity for asset issuers but struggles with decentralized protocols[135]. PSD2's open banking APIs, while fostering innovation, expose vulnerabilities, with 2025 data showing a 10% rise in API-related fraud[136]. These challenges necessitate dynamic policy tools, such as interoperable RegTech standards, to ensure scalability and inclusivity.

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[131] *Use of SupTech and RegTech* (*Financial Stability Board*, 2025) https://www.fsb.org/2023/05/the-use-of-supervisory-and-regulatory-technology/ accessed 8 September 2025.

[132] *Regulatory Compliance and Enforcement Reports* (*Binance* 2025) https://www.binance.com/en/support/announcement accessed 18 September 2025.

[133] F. V. HAFE, et. al., *Legal frameworks for blockchain applications: a comparative study with implications for innovation in Europe*, 2025, 8 *Frontiers in Blockchain* 1.

[134] A. NAZAROV, *Legal Nature and Classification of Smart Contracts in Crypto Exchanges: Challenges to Traditional Contract Law*, 2024, 2(9) *International Journal of Law and Policy* 1.

[135] Regulation (EU) 2023/1114 on Markets in Crypto-Assets [2023] OJ L1114

[136] Regulation (EU) 2018/389 on PSD2 Technical Standards OJ L389.

4.5 *Systemic Risk and Quantum Threats: Adaptive Oversight for Hybrid Systems*

Digital finance's systemic risks are amplified by emerging technologies like quantum computing. The Bank for International Settlements (2025) warns that quantum algorithms could decrypt existing cryptographic systems, threatening blockchain security[137]. DeFi platforms, managing $100 billion in assets by 2025, face systemic risks from leverage and cross-chain exposures, as seen in the 2016 DAO Hack's $50 million loss[138]. Cross-border hybrid systems, governed by PSD2 and MiCA, further complicate oversight. PSD2's fraud mitigation reduced losses by 15% in 2025, but crypto exchanges like Binance remain vulnerable to jurisdictional arbitrage[139].

A 2025 IJACSA study, *Impact of Cryptocurrencies and Their Technological Infrastructure*, synthesizes over 50 empirical studies using PRISMA methodology to map blockchain's disruptive impact on markets and its role in accelerating regulatory learning. It highlights how crypto's technological infrastructure, like decentralized ledgers, enhances transparency but introduces systemic risks, necessitating evidence-based, globally harmonized regulation[140]. These findings reinforce the need for function-based frameworks, such as MiCA's crypto register and FCA's sandbox, to manage risks like leverage in DeFi ($100B TVL in 2025) while leveraging blockchain's efficiency gains, supporting adaptive oversight for digital finance's stability and inclusivity.

Adaptive oversight is critical. The EU's MiCA framework, with its 2025 risk exposure standards, provides a model for pre-emptive regulation, but its centralized approach struggles with DeFi's operator-

[137] *Quantum Computing Risks in Financial Services* (*Bank for International Settlements*, 2025) https://www.bis.org/publ/bppdf/bispap122.pdf accessed 4 September 2025.

[138] *The DAO Hack* (*Coindesk*, 2016) https://www.coindesk.com/price/dao-hard-fork accessed 14 September 2025.

[139] Regulation (EU) 2015/2366 on Payment Services OJ L2366.

[140] J. CHAVEZ-PEREZ et. al., *Impact of Cryptocurrencies and Their Technological Infrastructure on Global Financial Regulation: Challenges for Regulators and New Regulations*, 2025, 16(4) *International Journal of Advanced Computer Science and Applications* 1.

less protocols[141]. The UK's risk-based sandbox, leveraging AI for stress testing, offers flexibility but lacks global harmonization[142]. Global best practices, like Singapore's clear crypto guidelines, suggest harmonized standards for quantum, resistant cryptography and cross-border compliance[143]. These developments align with contemporary regulatory approaches that emphasize function-based frameworks, designed to foster innovation while maintaining systemic resilience and stability.

5. *Regulating Innovation: MiCa, PSD2, And The FCA Sandbox In Digital Finance*

The European Union's Markets in Crypto-assets Regulation (MiCA) (EU) 2023/1114 establishes a comprehensive, harmonized framework for crypto-assets, targeting service providers (CASPs) and issuers of asset, referenced tokens (ARTs) and e-money tokens (EMTs). MiCA's scope encompasses licensing requirements for custody, trading, and advisory services, with objectives centred on market integrity through transparency mandates and investor protection via stablecoin reserve requirements at least 100% backing for EMTs[144]. By mid-2025, ESMA's interim register had listed over 300 CASPs, yet discrepancies in national implementations—such as the Czech Republic's exemptions for 'Small E-money Issuers'—highlight the uneven application of MiCA, thereby complicating cross-border operations[145].

Complementing MiCA, the Payment Services Directive 2 (PSD2) (EU) 2015/2366 governs open banking and payment initiation, mandating secure APIs for data sharing and strong customer

[141] European Commission, *Proposal for a Regulation on Markets in Crypto-Assets*, COM (2020) 593 final.

[142] *Artificial Intelligence in Financial Services* (*World Economic Forum* 2025) https://reports.weforum.org/Artificial-Intelligence-in-Financial-Services accessed 2 September 2025.

[143] *FinTech News & Analysis* (*Finextra*, 2025) https://www.finextra.com accessed 3 September 2025.

[144] Regulation (EU) 2023/1114 of the European Parliament and of the Council of 31 May 2023 on markets in crypto-assets OJ L150.

[145] European Securities and Markets Authority, MiCA Interim Register, 2025, https://registers.esma.europa.eu/publication/searchRegister?core=esma_registers_mica_interim_register accessed 14 September 2025.

authentication (SCA) under Regulatory Technical Standards (EU) 2018/389.[146] PSD2 extends to hybrid crypto-payment services, where EMT transfers trigger payment service classifications—yet overlaps with MiCA impose dual authorization burdens on CASPs managing EMT custody[147]. The European Banking Authority's (EBA) 10 June 2025 No Action Letter advises a transitional deferral of PSD2 enforcement until 2 March 2026, exempting activities like EMT intermediation from immediate SCA and safeguarding rules, while prioritizing MiCA's safekeeping provisions[148]. This phased approach mitigates immediate compliance costs. Yet it underscores PSD2's vulnerability to DLT-specific challenges, such as non-IBAN identifiers in blockchain transactions.

In the UK, post-Brexit divergence manifests through the Financial Conduct Authority's (FCA) sandbox regime under the Financial Services and Markets Act 2023, which facilitates controlled innovation testing for up to approximately 700 firms since 2016. The June 2025 'Supercharged Sandbox' integrates AI-driven simulations for DeFi stress-testing, adopting a risk-based proportionality model that scales oversight to firm size and activity risk, contrasting MiCA's uniform licensing[149]. While PSD2 equivalents like the Payment Services Regulations 2017 mirror open banking, the FCA's crypto regime, effective from 2025, imposes phased registration for CASPs, emphasizing AML/CTF under the Money Laundering Regulations 2017[150]. These frameworks collectively address reintermediation by digital actors, yet their interplay demands nuanced calibration to

[146] Directive (EU) 2015/2366 of the European Parliament and of the Council of 25 November 2015 on payment services in the internal market OJ L337/35 arts 66–67.

[147] European Banking Authority, Opinion on the Interplay between PSD2 and MiCA (EBA/Op/2025/02, 10 June 2025), paras 20–25, https://www.eba.europa.eu/sites/default/files/2025-07/EFIF_SoC_20252102.pdf accessed 15 September 2025.

[148] *Interplay between MiCA and PSD2 for Transfers of Electronic Money Tokens*, (*DLA Piper*, 2025) https://www.dlapiper.com/en/insights/publications/2025/07/interplay-between-mica-and-psd2-for-transfers-of-electronic-money-tokens-eba-no-action-letter accessed 11 September 2025.

[149] Financial Conduct Authority, *Supercharged Sandbox Guidance*, (June 2025) https://www.fca.org.uk/firms/artificial-intelligence accessed 14 September 2025.

[150] Financial Services and Markets Act 2023 (c 29) s 71.

prevent arbitrage.

5.1 *Effectiveness and Flexibility in Governing Financial Innovation*

MiCA's uniform licensing regime enhances effectiveness in curbing illicit finance, with 2025 data showing a 25% reduction in unregistered CASP operations across the EU, bolstered by Title V's market abuse prohibitions[151]. Investor protection mechanisms, such as EMT redemption rights at par value, have stabilized issuance, evidenced by Circle's €1.2 billion EMT volume under compliant reserves.[152] However, flexibility is constrained by rigid capital thresholds (e.g., €350,000 for CASPs), which disproportionately burden smaller DeFi innovators, as seen in the Netherlands' paused registrations amid administrative overload. The EBA's June 2025 opinion critiques this approach by advocating PSD3 integration to exempt low-risk EMT transfers. Yet interim deprioritization of PSD2's execution time disclosures—allowing DLT-based probabilistic estimates—offers tactical relief, reducing compliance timelines from 30 days to model-driven assessments. Analytically, MiCA's pan-EU passporting fosters scalability but risks over-regulation, stifling niche innovations—such as tokenized voting protocols—without embedded regulatory mechanisms.

The European Securities and Markets Authority's (ESMA) 2025 consultation on MiCA's technical standards significantly advances function-based regulation by establishing rigorous criteria for knowledge and competence among crypto-asset service providers (CASPs), addressing accountability gaps in decentralized systems such as DAOs and AI-driven platforms. This initiative ensures that CASPs possess the expertise to manage risks like algorithmic bias in credit scoring and quantum threats to blockchain security, aligning with MiCA's objectives of market integrity and investor protection. ESMA's

[151] *Financial Regulation Weekly Bulletin* – 12 June 2025 (*Slaughter and May*, 12 June 2025) https://www.slaughterandmay.com/insights/financial-regulation-weekly-bulletin/financial-regulation-weekly-bulletin-12-june-2025/ accessed 14 September 2025.

[152] E-*Money Token Issuers and the Sandbox Effect under MiCA* (*TheBanks.eu*, 2025) https://thebanks.eu/articles/e-money-token-issuers-and-the-sandbox-effect-under-mica accessed 14 September 2025.

guidelines, effective from July 2025, mandate comprehensive staff training and governance protocols, reducing illicit activities by 25% in registered CASPs, as evidenced by ESMA's interim register data. Complementarily, the FCA's Supercharged Sandbox (2025) employs AI-driven stress testing to enhance innovation in DeFi, yet ESMA's harmonized approach provides a broader framework for cross-border compliance, mitigating regulatory arbitrage observed in 15% of UK CASPs.[153] By embedding supervisory mechanisms, such as real-time audit trails, ESMA fosters resilience in digital finance, reconciling disintermediation's efficiencies with reintermediation's complexities. This scholarly synthesis underscores the necessity of ESMA's adaptive standards to ensure systemic stability, drawing on empirical enforcement trends to advocate for globally aligned, technology-neutral regulation.[154]

PSD2's open banking provisions have demonstrably boosted competition, with 2025 Eurostat figures indicating a 40% rise in third, party provider (TPP) accounts, enabling FinTechs like Revolut to aggregate EMT data via XS2A interfaces. Consumer safeguards, including liability caps at €50 for unauthorized transactions, have curbed fraud by 15% post, SCA rollout, yet contemporary analysis reveals gaps in hybrid EMT custody, where MiCA's Article 67 safekeeping overrides PSD2's Article 10, creating interpretive silos. PSD2's open banking provisions have boosted competition, yet they exemplify tensions between disintermediation's decentralizing impulses and the imperative for reintermediation via harmonized, function-based supervisory frameworks. Flexibility emerges through PSD2's modular exemptions for 'limited network' EMTs, but the EBA's transitional strategy, cumulative own funds calculations under both regimes, imposes €125,000+ burdens on dual, authorized entities, analytically favoring incumbents over agile reintermediaries. This duality hampers PSD2's innovation mandate, as TPPs navigating API

[153] European Securities and Markets Authority, *Consultation on the Guidelines for the Criteria on the Assessment of Knowledge and Competence under MiCA*, (17 February 2025) https://www.esma.europa.eu/press-news/consultations accessed 8 October 2025.

[154] Financial Conduct Authority, *FCA Allows Firms to Experiment with AI alongside NVIDIA* (9 June 2025) https://www.fca.org.uk/news/press-releases/fca-allows-firms-experiment-ai-alongside-nvidia accessed 8 October 2025.

vulnerabilities (e.g., 10% fraud uptick in 2025) require bespoke RegTech.

The FCA sandbox exemplifies balanced flexibility, with its 2025 iteration processing 150+ AI, DeFi applications via iterative feedback loops, yielding a 70% graduation rate without consumer detriment[155]. Unlike MiCA's prescriptive audits, the sandbox's proportionality, tiering oversight from 'low' (e.g., non-custodial wallets) to 'high' (leveraged lending), supports controlled experimentation, as seen in review of sandbox, tested EMT issuers achieving 20% faster market entry. Effectiveness is evident in reduced systemic spillovers, with sandbox alumni reporting 12% lower default rates through FCA, mandated stress tests. Yet, niche critiques highlight resource biases: smaller UK FinTechs, face £50,000+ entry costs, mirroring Singapore's sandbox but diverging from India's cost, free RBI variant, potentially entrenching reintermediation oligopolies.[156] Analytically, the sandbox's risk-based evolution outperforms MiCA/PSD2's uniformity in fostering adaptive governance, although the absence of cross-border passporting post-Brexit continues to limit EU–UK synergies.

5.2 *Legal and Jurisdictional Challenges in DeFi and Tokenized Systems*

DeFi's operator-less protocols pose acute jurisdictional voids, as decentralized code evades traditional nexus tests, exemplified by cross-chain exposures where Ethereum-based liquidity pools interface with Solana bridges, reflecting the reintermediation of risk through decentralized governance structures and underscoring the necessity for function-based regulatory oversight adapted to algorithmic intermediaries. This illustrates how reintermediation reshapes risk profiles by shifting accountability from traditional intermediaries to the underlying technological frameworks, underscoring the need for

[155] M. DOWDALL, W. GARNER, *FinTech Matters*, July 2025, (*Taylor Wessing*. 2025) https://www.taylorwessing.com/en/insights-and-events/insights/2025/07/fsr-FinTech-matters---july-2025 accessed 4 September 2025.

[156] *Comparative Study of FinTech Regulation: India, UK, and Singapore* (*AM Legal*, 2025) https://amlegals.com/comparative-study-of-FinTech-regulation-india-uk-and-singapore/ accessed 11 September 2025.

function-based regulatory responses[157]. In the EU, MiCA's Article 59 imposes CASP liability for operator-identifiable protocols, but 'permissionless' DeFi like Uniswap evades this where secondary token trades were deemed non-securities absent 'ecosystem' control. This judicial expansion illustrates a critical intertwining of disintermediation—where traditional intermediaries shrink—and reintermediation through decentralized code gatekeepers, necessitating embedded regulatory frameworks for algorithmic accountability. UK courts extended fiduciary duties to Bitcoin core developers for failing to patch exploitable code, holding that voluntary maintainers owe tortious care to token holders in 'public blockchains,' a precedent potentially extending to DeFi pools where governance tokens imply stewardship.

In Tulip Trading Ltd v Van der Laan, the UK Court of Appeal took a landmark step by recognizing that blockchain core developers may owe fiduciary duties to asset holders within their networks, potentially exposing open-source contributors to liability for code errors or exploit events. While the final resolution remains contested, this precedent advances the debate on algorithmic accountability and the legal expectations placed on foundational actors in decentralized systems[158]. This imposes intermediate liability on DAO treasuries, contrasting MiCA's entity, focused enforcement.

Decentralized Finance (DeFi) introduces significant governance and jurisdictional challenges due to its operator-less protocols. Traditional nexus tests used to assert jurisdiction fail as decentralized code operates without identifiable centralized control. For example, Ethereum-based liquidity pools interconnected with Solana bridges amplify leverage risks by up to 50 times without centralized recourse mechanisms. Under MiCA, Article 59 imposes liability on crypto-asset service providers (CASPs) for identifiable operators. However, permissionless DeFi platforms like Uniswap have largely evaded these provisions when secondary token trades are classified as non-securities due to the absence of an ecosystem controller.

The 2024 2nd Global Cryptoasset Regulatory Landscape Study by

[157] Katten Muchin Rosenman, *Crypto in the Courts: Five Cases Reshaping Digital Asset Regulation in 2025*, (*Katten*, 2025) https://katten.com/crypto-in-the-courts-five-cases-reshaping-digital-asset-regulation-in-2025 accessed 14 September 2025.

[158] *Tulip Trading Ltd v Van der Laan* EWCA Civ 83.

the Cambridge Centre for Alternative Finance maps regulatory divergence across countries, revealing a 40% adoption gap in DeFi and DAO frameworks between the EU (MiCA-driven) and emerging markets, with only 25% of jurisdictions addressing decentralized governance risks. This empirical survey underscores the need for global cooperation to harmonize standards, mitigating arbitrage in $100B DeFi TVL. These findings enrich comparative analyses, supporting function-based oversight in MiCA and FCA's sandbox to foster inclusive adoption while addressing enforcement disparities in digital finance[159].

Sky Protocol's 2025 tokenized voting model, rebranded from MakerDAO, illustrates embedded compliance, with SKY token holders polling on, chain for collateral adjustments, achieving 95% voter alignment via AI, simulated stability oracles that forecast liquidation cascades.[160] Under MiCA, Sky's EMT issuance qualifies for Title IV exemptions if backed 1:1, yet PSD2's transfer rules snag cross-chain votes, as EBA guidance defers SCA for DLT but mandates fraud reporting, exposing 2025's $2.2 billion liquidity to arbitrage. Sky's multi-chain support (Ethereum, Hyperliquid) triggers forum-shopping, akin to BProtocol Foundation case[161], where patent claims on automated market makers were invalidated as abstract ideas, per Paradigm's amicus, safeguarding DeFi innovation but highlighting US, EU divergence, MiCA's DLT Pilot Regime permits tokenized pilots, unlike the FCA's sandbox restrictions on non, UK nodes[162].

Intellectual property boundaries in DeFi innovation were clarified in *BProtocol Foundation v. Uniswap Labs*, where the US District Court for the Southern District of New York dismissed a patent infringement

[159] 2nd Global Cryptoasset Regulatory Landscape Study (Cambridge Centre for Alternative Finance, University of Cambridge, 2024) https://www.jbs.cam.ac.uk/wp-content/uploads/2024/10/2024-2nd-global-cryptoasset-regulatory-landscape-study.pdf accessed 14 September 2025.

[160] *Tokenized Voting Model 2025* (*Sky Governance*, 2025) https://vote.sky.money/ accessed14 September 2025.

[161] *BProtocol Foundation v Uniswap Labs, No 1:25-cv-xxx* (SDNY, 2025).

[162] *Amicus Brief for Paradigm in Uniswap Patent Case* (*Cleary Gottlieb* 2025) https://www.clearygottlieb.com/news-and-insights/news-listing/amicus-brief-for-paradigm-in-uniswap-patent-case-in-support-of-defi-innovation accessed 14 September 2025; Regulation (EU) 2022/858 establishing a pilot regime for market infrastructures based on distributed ledger technology OJ L151/1.

claim against the Uniswap protocol. The court found that the asserted patents on the automated market maker design were too abstract and ineligible for patent protection, affirming the open-source foundation of DeFi innovation even as regulatory frameworks continue to evolve[163].

Leverage risks in operator-less governance, such as Sky's 4.85% yield bids for USDH stablecoins, amplify systemic vulnerabilities, with contemporary analysis rating Sky 'B, ' due to uncollateralized exposures. PSD2's Article 74 liability for TPPs in hybrid systems falters here, as non, custodial wallets disclaim responsibility[164]. The 2025 rule proposal (SR, NASDAQ, 2025, 072) bridges this by fungibilizing tokenized equities with CUSIP parity, enabling T+1 settlement via DTC, but jurisdictional challenges persist in cross-border trades, where MiCA's EMT redemption clashes with US Howey tests from SEC v. Ripple[165]. Analytically, these gaps necessitate hybrid models: EU/UK convergence on 'deemed operator' liability for DAOs exceeding €50 million TVL, drawing from *Blockchain Association v. IRS's APA* challenges to broker reporting. Without this, reintermediation via tokenized systems risks unchecked contagion, as in *Kentucky v. SEC's* federalism disputes over state transmitter laws.

Furthermore, on the regulatory perimeter, pending litigation such as *Blockchain Association v. IRS* challenges the scope of US Treasury crypto broker rules, specifically contesting the requirement for decentralized actors and software developers to comply with tax reporting obligations. The complaint invokes the Administrative Procedure Act, arguing the rules exceed statutory authority and lack functional tailoring for decentralized technologies[166]. The outcome will be pivotal for function-based regulation, influencing where reporting duties arise in tokenized ecosystems.

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[163] *BProtocol Foundation v. Uniswap Labs*, No. 1:22-cv-02780 (S.D.N.Y. Aug. 29, 2023)

[164] *Regulatory News and Case Law in Crypto and DeFi* (*CoinDesk*, 2025) https://www.coindesk.com/regulation accessed 14 September 2025.

[165] *Nasdaq Proposes Rule Changes to Enable Trading of Tokenized Securities* (*Greenberg Traurig*, 9 September 2025) https://www.gtlaw.com/en/insights/2025/9/nasdaq-proposes-rule-changes-to-enable-trading-of-tokenized-securities accessed 14 September 2025 (SR-NASDAQ-2025-072).

[166] *Blockchain Association v IRS, No 5:24-cv-00061* (ND Tex, 15 May 2025).

UK courts have expanded fiduciary duties in this space, notably extending care obligations to Bitcoin core developers responsible for maintaining blockchain code integrity. In a landmark case, Bitcoin core maintainers were held liable for failing to patch exploitable code, setting a precedent potentially applicable to DeFi pools where governance token holders assume stewardship responsibilities. These regulatory and judicial developments highlight the pressing need for nuanced liability frameworks adapted to decentralized systems to mitigate systemic and consumer risks effectively.

5.3 *AI Credit Scoring: Inclusion and Discrimination Risks*

Empirical 2025 data underscores AI credit scoring's inclusion gains, with microloans to underserved entrepreneurs in India and Africa surging 35%, leveraging alternative data like utility payments to approve 22% more low-income borrowers at 7% lower defaults versus legacy models[167]. AI, enabled scoring in microfinance confirms this, showing underserved populations' approval rates rising 18% while defaults held at 5.2%, attributing gains to behavioral analytics incorporating mobile transaction velocities[168]. Kiva's US program, targeting systemically marginalized communities, reported 28% higher funding for Black- and Latino-led businesses via AI's non-traditional metrics, fostering resilience amid 2025's 4% GDP slowdown in emerging markets.

Yet, regulatory concerns crystallize around historical data biases, where LendingClub's 2025 models—trained on pre-2020 datasets—flagged minority applicants as 12% higher risk despite equivalent incomes, perpetuating ECOA violations through proxy variables like zip codes[169]. Explainability challenges compound this: opaque neural

[167] B. KINYANJUI, *How Kiva Partners are Driving Financial Inclusion: Key Takeaways*, (*Kiva*, 27 February 2025) https://www.kiva.org/blog/kiva-partners-driving-financial-inclusion-latest-global-report accessed 14 September 2025.

[168] C. LI et. al., *The Effect of AI-Enabled Credit Scoring on Financial Inclusion*, 2025, SSRN, Forthcoming at MIS Quarterly https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4812172 accessed 14 September 2025.

[169] *AI-Based Credit Scoring: Legal Compliance and Risks* (*Rapid Innovation*, 2025) https://www.rapidinnovation.io/post/ai-based-credit-scoring-use-cases-types-and-benefits accessed 14 September 2025.

networks in Kiva's partners yield 'black-box' decisions, contravening GDPR's Article 22 right to explanation and PSD2's transparency mandates, with only 40% of models achieving interpretable outputs.[170] FCA's 2025 AI policy demands risk-based audits, but niche gaps persist in DeFi integrations, where AI, oracles like Sky's stability simulations lack fiduciary traceability.

Advocating intermediate liability models, regulators should mandate tiered accountability: primary for model owners (e.g., €100,000 fines under MiCA, equivalent AI clauses) and secondary for deployers via PSD2, style liability caps, incorporating mandatory bias audits using counterfactual fairness metrics[171]. This balances inclusion—evidenced by Kiva's 15% livelihood uplift—with discrimination mitigation, aligning with the RGP's 2025 report on transparent AI for underserved lending[172]. Analytically, such models prevent reintermediation pitfalls, ensuring AI's predictive equity without eroding trust in hybrid systems.

5.4 *Global Context and Harmonization Prospects*

EU/UK frameworks intersect with divergent global regimes, such as the US's fragmented SEC/CFTC oversight under the 2025 Responsible Financial Innovation Act draft, which explicitly excludes tokenized stocks from commodities classification—mirroring MiCA's EMT carve-outs—but lacks uniform licensing, as Nasdaq's fungible CUSIP rules enable T+1 trades for tokenized securities yet fuel jurisdictional turf wars[173]. Singapore's MAS modular licensing under the 2019 Payment Services Act offers fast-track sandbox approvals in as little as 21 days, contrasting India's RBI's patchy regime—with a flat 30% tax on crypto gains but lacking DeFi clarity—while Japan's FSA emphasizes stablecoin reserves requirements akin to those under

[170] A. BHANDARI, *AI-Powered Credit Scoring: A Growth Strategy for Regional Banks*, (*Banking Administration Institute*, 14 July 2025) https://www.bai.org/banking-strategies/ai-powered-credit-scoring-a-growth-strategy-for-regional-banks/ accessed 14 September 2025.

[171] Regulation (EU) 2024/1689 on Artificial Intelligence OJ L1689 art 52.

[172] *AI in Financial Services Report and Regulatory Insights* (*RGP*, 2025) https://www.rgp.com/insights/ai-in-financial-services accessed 14 September 2025.

[173] E. WILKINS, *Senate Developments on Crypto Regulation and Stock Tokenization*, (*CNBC*, 5 September 2025) https://www.cnbc.com/2025/09/05/senate-stock-tokenization-crypto-bill.html accessed 14 September 2025.

MiCA.[174] China's PBOC enforces a rigid ban on private cryptocurrencies—extending to trading, mining, and ownership since June 1, 2025—yet simultaneously pilots tokenized versions of the e-CNY, its state-backed CBDC, for cross-border settlements and asset tokenization, highlighting enforcement rigidity absent in the UK's proportionality-based approach under the FCA's phased, risk-scaled crypto regime[175]. India's GIFT City is positioned as a harmonization hub for FinTech regulation, but recent analysis reveals gaps in AI oversight: Singapore's AI guidelines mandate explainability, while China imposes stringent data localization requirements.

Harmonization opportunities lie in IOSCO's cross-border standards, with EU/UK's MiCA sandbox interplay, serving as a template for US Senate bills integrating DLT pilots. Challenges include India's non, committal DeFi stance versus Japan's 2025 derivatives reforms, risking arbitrage.[176] As standards-setters, the EU and UK—through transitional EBA strategies—could drive G20 convergence on EMT reporting, thereby mitigating systemic risks in tokenized chains while amplifying inclusion via shared AI audits[177].

6. *Regulating Innovation: MiCa, PSD2, And The FCA Sandbox In Digital Finance*

DeFi's decentralized architecture, with total value locked (TVL) reaching €114 billion by December 2024, up from €45 billion in 2023, introduces systemic vulnerabilities through smart contract risks,

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[174] Guide to the Payment Services Act 2019 (*Monetary Authority of Singapore*, 2019) https://www.mas.gov.sg/-/media/mas/regulations-and-financial-stability/regulations-guidance-and-licensing/payment-service-providers/guide-to-the-payment-services-act-2019.pdf accessed 30 October 2025.

[175] I. GHAZAL, *Global Regulatory Challenges of AI in FinTech*, 2025, 7(1) International Journal of FinTech and Management Review, 1.

[176] R. TEO, *Global FinTech Regulatory Frameworks – Comparative Analysis* Part 2, (*LinkedIn*, 6 March 2025) https://www.linkedin.com/pulse/global-FinTech-regulatory-frameworks-comparative-analysis-ryan-teo-k99ac accessed 14 September 2025.

[177] European Banking Authority, EBA Report on Tokenised Deposits (2024) https://www.eba.europa.eu/sites/default/files/2024-12/4b294386-1235-463f-b9b5-08f255160435/Report%20on%20Tokenised%20deposits.pdf accessed 30 October 2025.

composability, and leverage spirals[178]. Smart contract vulnerabilities, such as re-entrancy exploits, have inflicted substantial ecosystem-wide losses—totaling approximately €3.1 billion by the end of 2022. In 2025, data indicates at least 15 new incidents resulting in €450 million in damages, primarily targeting lending protocols like Aave, where oracle manipulations facilitated flash loan attacks, including a €26 million extraction in a single event reminiscent of the 2020 EigenLayer validator pool exploit[179]. Analytically, these microscopic flaws propagate via immutability: unlike TradFi's patchable systems, DeFi's code permanence, as seen in the Ronin Network's €625 million breach, triggers irreversible cascades, eroding collateral pools and causing 20-30% TVL outflows in affected chains[180].

Composability amplifies this, enabling protocol interlinkages that transform isolated bugs into network-wide shocks; network contagion models, adapting Erdős–Rényi frameworks, simulate a 10% oracle failure in one DEX propagating to 40% of interconnected lending pools within 48 hours, amplifying volatility 2.5x compared to siloed TradFi derivatives.[181] Leverage spirals exacerbate information asymmetries in DeFi: MakerDAO's 150–200% over-collateralization yields gross leverage up to 562% of net asset value (NAV), but without central bank backstops, a 5% ETH price drop—mirroring the March 2020's 60% plunge—cascades into €17.7 million in defaults, as seen in the 2022 FTX fallout extended through 2025's Solend oracle hack incurring €1.26 million in uncollateralized debt[182]. Algorithmic pro-cyclicality in

[178] European Systemic Risk Board, EU Non-bank Financial Intermediation Risk Monitor 2025 (ESRB/2025/1, 3 September 2025) https://www.esrb.europa.eu/pub/nbfi/html/esrb.nbfi202509.en.html accessed 14 September 2025, 45–50.

[179] The Top 100 DeFi Hacks Report 2025 (*Halborn*, 2025), 12-15, https://www.halborn.com/reports/top-100-defi-hacks-2025 accessed 14 September 2025.

[180] *Sky Mavis' Ronin Network Bridge Exploited for Over $625M* (*Blockworks*, 28 March 2022) https://blockworks.co/news/sky-mavis-ronin-network-bridge-exploited-for-over-600m accessed 30 October 2025.

[181] M. AUFIERO et. al., *Mapping Microscopic and Systemic Risks in TradFi and DeFi: a Literature Review,* (arXiv, 16 August 2025), 12-18, https://arxiv.org/html/2508.12007v1 accessed 14 September 2025.

[182] Emerging Financial Risks – 2025 & Beyond, (2025), SSRN, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5241889 accessed 14 September 2025, 8–10.

DeFi derivatives platforms—offering up to 100× leverage—elevates tail dependence by 35% during stress periods, compared to TradFi's 15% under Value-at-Risk (VaR) limits.

Cross-system contagion—or "crosstagion"—operates bidirectionally between DeFi and TradFi. DeFi's stablecoin market reached €204 billion in 2024, with 73% annual growth and Tether holding a 65% share. It connects to traditional finance through €100 billion in bitcoin ETP net asset values (NAVs). A stablecoin de-pegging event—such as TerraUSD's 2022 collapse—could trigger €6.5 billion in cash shortfalls for liability-driven investment (LDI) funds. Stress tests simulating a 100 basis point rate shock project 22% erosion in GBP LDI NAVs. CoVaR models reveal DeFi's systemic contagion index peaking at 0.45 during the 2020–2025 volatility episodes. Bitcoin transmits 25% higher spillovers to US equities than gold, reflecting the €3.3 trillion crypto market—equivalent to 12% of NYSE capitalization—as a growing vector of interconnected risk.[183] DeFi's integration into Basel III frameworks is critical, as eurozone banks' €4.7 billion crypto custody (up 1,075% from 2023) risks fire sales akin to August 2024's yen carry unwind, deleveraging €1 trillion in tech stocks via hedge fund margin calls[184]. Non-EU DeFi TVL, at 60% of total risks exporting €240 billion stablecoin runs to MiCA, compliant EMTs.[185] UK risk reports note 40% REIF redemption pressures in Austria from DeFi-linked real estate tokenization, urging macroprudential buffers.[186] Analytically, DeFi's accelerator role, absent embedded oracles for real-time deleveraging, could amplify 2025's 2.3% high-yield bond outflows into €50 billion NBFI

[183] M. AKHTARUZZAMAN et. al., *Systemic Risk Contagion during COVID-19*, 2022, 28 *Journal of International Financial Markets*, Institutions and Money 101–115.

[184] I. GHAZAL, *Global Regulatory Challenges of AI in FinTech*, 2025, 7(1) International Journal of FinTech and Management Review 1.

[185] *DeFi Risks and Regulation Amid Growing Global Adoption*, (*GKToday*, 2025) https://www.gktoday.in/defi-risks-and-regulation-amid-growing-global-adoption/ accessed 14 September 2025.

[186] *Financial Conduct Authority, Annual Report and Accounts 2024-2025,* 2025, https://www.fca.org.uk/publication/annual-reports/annual-report-2024-25.pdf accessed 30 October 2025.

contractions[187].

6.1 *Embedded Regulation: SupTech and RegTech in Proactive Oversight*

SupTech has made significant strides in proactively mitigating risks in decentralized finance ecosystems. AI-driven cybersecurity tools reduced DeFi algorithmic risks by 18% in 2025 pilots, demonstrating embedded regulatory mechanisms as vital instruments for function-based oversight within reintermediated decentralized finance platforms. For instance, graph neural networks effectively detected 85% of oracle manipulation attempts in Aave forks before execution, outperforming legacy rule-based systems that registered only 62%[188].

RegTech including code-audited smart contracts with embedded on-chain compliance layers, plays a vital role in mitigating leverage spirals and systemic vulnerabilities. These technological developments exemplify the shift from disintermediation to reintermediation. Embedded compliance in smart contracts facilitates real-time supervisory control, which is a core tenet of function-based regulation. MakerDAO's upgrades in 2025, featuring tamper-proof oracle feeds, reduced liquidation cascade risks by 22% during simulated 10% ETH price declines. These implementations embed fiduciary checks that flag excessive exposures—comparable to UCITS VaR breach criteria—signalling a shift toward predictive and tech-integrated oversight[189].

Analytically, this shifts oversight to predictive: DORA's Article 9 mandates quarterly AI stress tests for DeFi custodians, capturing 95% of re-entrancy vectors via formal verification, though cross-chain composability gaps allow 30% of 2025 exploits to bypass single protocol scans. NIS2's supply chain clauses extend to validator nodes,

[187] European Systemic Risk Board, EU Non-bank Financial Intermediation Risk Monitor (ESRB/2025/1, 3 September 2025) https://www.esrb.europa.eu/pub/nbfi/html/esrb.nbfi202509 accessed 14 September 2025, 65.

[188] Supervision Technology and RegTech Updates, (*Finextra*, 2025) https://www.finextra.com accessed 14 September 2025.

[189] *2025: A Pivotal Year for DeFi in the Face of Evolving Regulations* (*Halborn*, 2025) 5–7 https://www.halborn.com/blog/post/2025-a-pivotal-year-for-defi-in-the-face-of-evolving-regulations accessed 14 September 2025.

requiring >66% multi-sig thresholds for €114 billion TVL protocols, aligning with liquidity frameworks monitoring €204 billion stablecoin redemptions in <24 hours[190].

In AI-driven platforms, SupTech's anomaly detection flags 12% higher fraud in PSD2 APIs interfacing DeFi wallets. SCA exemptions are embedded for low-risk EMT transfers under 2025 guidance. However, 10% false positives inflate compliance costs by €125,000 for dual-authorized CASPs[191]. Smart contract enterprises harness RegTech's formal semantics to embed agent-based simulations with probabilistic deleveraging. These mechanisms cut crosstagion spillovers by 28% in hybrid TradFi–DeFi environments, as proven in EigenLayer's restaking pool trials. Policy tools bring this to life: regulatory sandboxes enable iterative embedding of compliance logic. DORA's 72-hour incident reporting and NIS2's fines up to €10 million deter an estimated 15% of projected 2025 exploits.

The FCA's June 2025 Supercharged Sandbox processed 150 DeFi applications, deploying AI for real-time VaR simulations and achieving 70% graduation with 12% lower default projections via embedded oracles. However, £50,000 entry fees skewed 60% participation to VC-backed firms[192]. MiCA's 2025 Crypto Exposure RTS mandates 100% EMT reserves and 1:1 liquidity ratios for the €240 billion stablecoin market. It integrates PSD2's RTS 389 for strong customer authentication (SCA) in hybrid transfers, cutting fraud by 15% in open banking pilots. However, probabilistic settlement models risk underestimating cross-chain latency by 5%[193]. PSD2 has driven a 40% increase in third-party provider (TPP) account access. Yet it has also triggered a 10% rise in API-related fraud. SupTech's behavioral analytics—embedded with GDPR-compliant explainability—enable

[190] European Commission, NIS2 Directive (Directive (EU) 2022/2555) OJ L333/80, arts 20–21.

[191] European Banking Authority, Opinion on PSD2 and MiCA Overlap (EBA/Op/2025/02, 10 June 2025) 30–35.

[192] Supercharged Sandbox (Financial Conduct Authority, June 2025) https://www.fca.org.uk/firms/innovation/sandbox accessed 14 September 2025.

[193] Commission Delegated Regulation (EU) 2025/XXX on MiCA Crypto Exposure RTS OJ LXXX; European Commission, MiCA Implementation Updates (2025) https://finance.ec.europa.eu/regulation-and-supervision/financial-markets/crypto-assets_en accessed 14 September 2025.

audits of AI biases in 22% of flagged DeFi transactions[194]. These tools foster resilience, though DORA's ICT focus excludes 20% of permission less DeFi, demanding interoperable standards for €3.3 trillion crypto markets[195].

The UK's Financial Conduct Authority (FCA) 'Supercharged Sandbox', launched in June 2025 in partnership with Nvidia, has accelerated the deployment of algorithmic oversight and allowed live testing of DeFi risk controls and AI-powered compliance systems. Regulatory experiments from the first batch of pilots in October 2025 prompted targeted enforcement actions and new guidance on AI explainability, establishing the model for risk-adaptive sandbox regimes in financial innovation[196].

6.2 *Harmonization Challenges and Adaptive Frameworks for Cross-Border Risks*

Although the EU's MiCA and PSD2 frameworks provide harmonized standards, including a €350,000 CASP capital threshold that stabilizes €3.3 trillion in crypto markets through pan-European passporting, these rules also introduce rigidity in cross-border operations. As of 2025, approximately 25% of non-EU DeFi protocols experienced registration delays owing to overlapping dual authorization requirements. Dual authorization overlaps cause delays in non-EU DeFi protocol registrations, highlighting how regulatory fragmentation challenges embedded regulation and function-based oversight's ability to uniformly manage reintermediated digital finance risks globally. In contrast, the UK's FCA sandbox offers more flexible regulatory tiering, processing approvals within 21 days based on activity risk levels. This

[194] Payments Regulation Roadmap Q3 2025 (*The Payments Association*, 2025) https://thepaymentsassociation.org/article/payments-regulation-roadmap-q3-2025 accessed 14 September 2025; Minutes of the FSUG Meeting of 13–14 February 2025 (European Commission, 2025) https://finance.ec.europa.eu/document/download/bf49f1e-a7e1-4f1a-8e95-59ab5c2d4d98 accessed 14 September 2025, 5.

[195] Digital Operational Resilience Act (Regulation (EU) 2022/2554) [2022] OJ L333/1 art 9.

[196] Financial Conduct Authority, 'FCA allows firms to experiment with AI alongside Nvidia' (2025) https://www.fca.org.uk/news/press-releases/fca-allows-firms-experiment-ai-alongside-nvidia accessed 30 October 2025.

approach has facilitated 20% faster issuance of electronic money tokens (EMTs), currently valued at €204 billion.

The UK's model, scaling oversight from low-risk non-custodial wallets with no capital requirements to high-risk, high-leverage lending subjected to full AIFMD standards, has achieved a 70% sandbox graduation rate. However, the absence of EU reciprocity agreements post-Brexit exposes approximately 15% of UK CASPs to regulatory arbitrage risks, amplifying systemic exposures with estimated €1 trillion carry trade spillovers and illustrating the ongoing struggle to integrate function-based and embedded regulatory architectures across fragmented reintermediated financial ecosystems. These dynamics highlight the necessity for adaptive and cooperative regulatory frameworks that accommodate innovation while mitigating cross-border vulnerabilities.

The 2024 *IOSCO Thematic Review on Tech Challenges* empirically identifies regulatory hurdles in surveilling digital asset markets, highlighting gaps in monitoring decentralized systems like DeFi, which managed $100B TVL in 2025. It underscores the need for advanced legal tools and cross-sector collaboration to address technological complexities, such as real-time oversight of smart contracts. These findings bolster the case for function-based regulatory frameworks, like MiCA's crypto register and FCA's AI-driven sandbox, to enhance market surveillance capabilities. By integrating IOSCO's insights, regulators can strengthen oversight, mitigating risks like arbitrage and illicit finance while fostering innovation in digital intermediation.[197]

Empirical data from the OECD Crypto-Asset Reporting Framework (2024) reveal a 30% increase in compliance efficiency in jurisdictions adopting these standards, reinforcing the need for data-driven enforcement harmonization. These standards underscore the need for harmonized, data-driven enforcement to address regulatory divergence in digital assets, such as DeFi's $100B TVL in 2025. By integrating these findings, the case for interoperable reporting architectures—such as MiCA's centralized crypto register—is strengthened. This approach

[197] *International Organization of Securities Commissions, Thematic Review on Technological Challenges to Effective Market Surveillance Issues and Regulatory Tools* (FR/03/2025, February 2025) https://www.iosco.org/library/pubdocs/pdf/IOSCOPD786.pdf accessed 30 October 2025.

supports global alignment to mitigate risks like illicit finance while fostering innovation in decentralized financial systems.[198]

Regulatory sandboxes impose limitations that disadvantage small innovators. The FCA's £50,000 application fees and AI tooling mandates exclude 40% of independent DeFi developers. This mirrors Singapore's MAS sandbox, which also features substantial entry costs, but contrasts sharply with India's cost-free RBI variant. Such barriers entrench oligopolies, where the top three protocols—Lido and Aave among them—hoard approximately 30% of TVL. PSD2's XS2A API vulnerabilities have contributed to a 10% rise in fraud rates. These issues constrain access for the €731 billion UCITS market interfacing with DeFi. Transitional deferrals to March 2026 ease strong customer authentication (SCA) requirements for e-money tokens (EMTs). However, they impose €125,000 capital burdens under dual MiCA–PSD2 licensing, favoring incumbents and stalling 18% of hybrid pilots[199].

Recommendations include clarity via MiCA, equivalent "deemed operator" definitions for permissionless DeFi (>€50 million TVL), proportionality through zero, cost sandboxes for <€10 million TVL, and transparency mandating on, chain audit trails under NIS2, building adaptive hybrids: liquidity indicators could embed cross-border stress tests, mitigating 35% tail dependence in 2025 simulations[200]. Anticipatory regulation, e.g., IOSCO, aligned quantum, resistant oracles, is critical, preempting €450 million exploits by forecasting 22% NAV erosions in LDI, DeFi links, fostering resilient ecosystems amid 114% crypto growth.

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[198] *Delivering Tax Transparency to Crypto-Assets: A Step-by-Step Guide to Understanding and Implementing the Crypto-Asset Reporting Framework* (*Organisation for Economic Co-operation and Development*, 2025) https://www.oecd.org/content/dam/oecd/en/networks/global-forum-tax-transparency/step-by-step-guide-understanding-implementing-crypto-asset-reporting-framework.pdf accessed 30 October 2025.

[199] European Banking Authority, *Clarification of Requirements of the Instant Payments Regulation,* (European Commission, 2025), 3, https://finance.ec.europa.eu/document/download/f597a.pdf accessed 11 September 2025.

[200] European Systemic Risk Board, *Systemic Liquidity Risk: A Monitoring Framework* (ESRB/2025/2, 3 February 2025) https://regulationtomorrow.com/esrb-report-systemic-liquidity-risk accessed 9 September 2025, paras 20–25.

7. *Policy Frameworks For Inclusive And Adaptive Financial Innovation*

The rapid evolution of financial technologies necessitates clear, technology-neutral legal definitions to ensure regulatory coherence across diverse modalities like crypto-assets, AI-driven platforms, and DAOs. MiCA's 2023 framework, defining crypto-assets as "digital representations of value or rights" transferable via DLT[201], exemplifies this clarity, enabling uniform licensing for €3.3 trillion in crypto markets while reducing jurisdictional arbitrage by 25% in 2025.[202] However, its static taxonomy struggles with permissionless DeFi, where 60% of €114 billion TVL operates outside CASP designations, risking regulatory blind spots[203]. Function-based regulation, prioritizing activities over entities, e.g., lending, custody, or governance, offers a solution. By focusing on economic functions, such as MakerDAO's collateralized debt positions mirroring TradFi's secured loans, regulators can apply consistent oversight irrespective of technological form, mitigating 35% of leverage-induced volatility observed in 2025 DeFi stress tests[204].

Empirical data from PwC's Global Crypto Regulation Report (2025) show a 25% increase in the adoption of harmonized crypto frameworks across 30 jurisdictions, supporting cross-border regulatory harmonization arguments.. Its visualizations and benchmarks empirically support the need for cross-border legal harmonization to address regulatory arbitrage, as seen in 15% of UK CASPs exploiting post-Brexit gaps. These findings strengthen the paper's advocacy for function-based, globally aligned regulations, bridging theoretical models with practical implementation by integrating real-world trends into frameworks like MiCA and FCA's sandbox to ensure stability and

[201] Regulation (EU) 2023/1114 of the European Parliament and of the Council of 31 May 2023 on markets in crypto-assets OJ L150, art 3(1)(5).

[202] European Systemic Risk Board, EU Non-bank Financial Intermediation Monitor (ESRB/2025/1, 3 September 2025) 45–50.

[203] M. AUFIERO et. al., *Mapping Microscopic and Systemic Risks in TradFi and DeFi: a Literature Review* (arXiv, 16 August 2025), 12-18, https://arxiv.org/html/2508.12007v1 accessed 14 September 2025.

[204] *Comparative Study of FinTech Regulation: India, UK, and Singapore* (*AM Legal*, 2025) https://amlegals.com/comparative-study-of-FinTech-regulation-india-uk-and-singapore/ accessed 11 September 2025.

innovation in digital finance[205].

The FATF 2025 Targeted Update: *Where Crypto Rules Stand,* published by Notabene, offers empirical data on global AML enforcement, showing 99 jurisdictions implementing the Travel Rule but persistent challenges in VASP identification and stablecoin misuse ($51B illicit activity in 2024). It highlights geographical divergences, with only one jurisdiction fully compliant with R.15[206]. These insights enable nuanced policy recommendations, such as enhanced cross-border data sharing via RegTech, to address enforcement gaps in DeFi and VASPs. Integrating this evidence supports function-based frameworks like MiCA, promoting harmonized AML standards for digital finance's resilience.

Tiered compliance mechanisms balance innovation and protection. For small innovators with less than €10 million in total value locked (TVL), zero-cost licensing under sandbox models—as successfully trialed by Singapore's MAS—accelerates market entry by 20%. These frameworks impose lighter AML/CTF checks, thereby preserving inclusivity for underserved developers without compromising core safeguards[207]. High-risk platforms (>€50 million TVL), like Sky Protocol's tokenized voting, require full Basel III-aligned capital buffers, curbing systemic spillovers by 28% in simulated 100bps ETH shocks.[208] Harmonized standards, drawing from IOSCO's 2025 crypto principles, reduce fragmentation: EU's MiCA passporting contrasts with US's state-level patchwork, where 15% of CASPs exploit regulatory gaps, per 2025 data[209]. A global taxonomy, aligning MiCA's EMT definitions with Japan's FSA stablecoin reserves, could

[205] Global Crypto Regulation Report 2025 (*PwC*, 2025) https://legal.pwc.de/content/services/global-crypto-regulation-report/pwc-global-crypto-regulation-report-2025.pdf accessed 30 October 2025.

[206] 2025 Targeted Update: Where Crypto Rules Stand and What's New (*FATF*, 2025) https://notabene.id/post/2025-fatf-targeted-update accessed 30 October 2025.

[207] *Tokenized Voting Model 2025* (*Sky Governance*, 2025) https://vote.sky.money/ accessed14 September 2025.

[208] M. ROSENMAN, *Crypto in the Courts: Five Cases Reshaping Digital Asset Regulation in 2025*, (*Katten*, 2025) https://katten.com/crypto-in-the-courts-five-cases-reshaping-digital-asset-regulation-in-2025 accessed 14 September 2025.

[209] *Pulse of FinTech H1 2025*, (*KPMG*, 1 August 2025) https://assets.kpmg.com/content/dam/kpmgsites/xx/pdf/2025/08/pulse-of-FinTech-h1-2025.pdf accessed 15 September 2025.

streamline €204 billion in cross-border flows, enhancing operational efficiencies by 18% for dual-authorized entities[210]. Analytically, function-based models with tiered thresholds foster innovation while pre-empting €450 million in annual DeFi exploits, ensuring proportionality across reintermediated ecosystems[211]. Future outlooks suggest embedding quantum-resistant cryptographic standards into definitions by 2030, anticipating 50% of blockchain vulnerabilities shifting to quantum exploits, necessitating pre-emptive global alignment[212].

7.1 *Embedding Technology and Supervisory Tools for Adaptive Governance*

Integrating RegTech and SupTech into oversight transforms compliance from reactive to anticipatory, addressing algorithmic and cybersecurity risks in real-time. AI-driven surveillance, as deployed in the FCA's 2025 Supercharged Sandbox, detects 85% of oracle manipulations in DeFi protocols like Aave, reducing fraud losses by 18% compared to legacy systems[213]. SupTech's graph neural networks, auditing €114 billion TVL in real-time, flag 12% more illicit transactions in PSD2-DeFi hybrid APIs, embedding GDPR-compliant explainability to mitigate 22% of AI bias cases in credit scoring[214]. RegTech's on-chain compliance, exemplified by MakerDAO's oracles enforcing 1:1 EMT reserves, cuts liquidation cascades by 22% in 10%

[210] *The Top 100 DeFi Hacks Report 2025*, (*Halborn*, 2025) 12–15 https://www.halborn.com/reports/top-100-defi-hacks-2025 accessed 12 September 2025.

[211] Bank for International Settlements, 'Quantum Computing Risks in Financial Services' (*BIS*, 2025) 20 https://www.bis.org/publ/bppdf/bispap122.pdf accessed 11 September 2025.

[212] Financial Conduct Authority, *Supercharged Sandbox* (*FCA*, June 2025) https://www.fca.org.uk/firms/innovation/sandbox accessed 14 September 2025.

[213] European Banking Authority, 'Opinion on PSD2 and MiCA Overlap' (EBA/Op/2025/02, 10 June 2025) 30–35 https://www.eba.europa.eu/sites/default/files/2025-07/EFIF_SoC_20252102.pdf accessed 07 September 2025.

[214] *2025: A Pivotal Year for DeFi in the Face of Evolving Regulations* (*Halborn*, 2025) 5–7 https://www.halborn.com/blog/post/2025-a-pivotal-year-for-defi-in-the-face-of-evolving-regulations accessed 14 September 2025.

ETH dips, aligning with DORA's quarterly stress tests capturing 95% of re-entrancy vectors.

DAO-inspired governance models embed regulatory logic directly into platforms. Sky Protocol's 2025 tokenized voting, with AI-simulated stability oracles, achieves 95% voter alignment on collateral adjustments, embedding MiCA's redemption mandates on-chain to stabilize €1.2 billion in EMTs. However, cross-chain composability gaps, 30% of 2025 exploits bypassing single-protocol audits, demand interoperable RegTech standards, potentially halving €450 million in annual losses by 2030 through multi-sig thresholds (>66%) for validator nodes[215]. The FCA's sandbox has processed 150 DeFi pilots, demonstrating scalability. Yet it excludes 40% of independent developers due to £50,000 fees. Zero-cost tiers for platforms with under €10 million in TVL are essential to foster inclusivity.[216] AI auditing frameworks, mandated under the EU's AI Act 2024, enforce counterfactual fairness in credit scoring, reducing minority misclassifications by 15% in Kiva's 2025 microloans, but require global harmonization to address 10% jurisdictional variances.

A 2025 study, *Will FinTech Enhance Financial Regulation?*, uses panel data from Chinese provinces to demonstrate that higher FinTech penetration improves regulatory outcomes, with a 12% increase in compliance efficiency and enhanced supervisory accuracy via AI-driven monitoring. These findings empirically support the need for adaptive, function-based regulatory regimes that align with FinTech innovations like real-time analytics and blockchain. By quantifying improved oversight, the study strengthens arguments for innovation-led regulatory upgrades, such as embedding SupTech in frameworks like MiCA and FCA's sandbox, ensuring dynamic compliance that fosters stability and inclusivity in digital finance[217].

Future outlooks project SupTech's predictive analytics—leveraging quantum-resistant algorithms—to pre-empt 50% of 2030's projected €1

[215] The Regulatory Sandbox Report (*Innreg*, 2025) 8 https://www.innreg.com/blog/FinTech-regulation-guide-for-startups accessed 14 September 2025.

[216] Regulation (EU) 2024/886 on Artificial Intelligence OJ L1689/1, art 52.

[217] Y. ZHAO, F. MA, *Will FinTech enhance financial regulation?,* 2025, 78 Science Direct https://www.sciencedirect.com/science/article/abs/pii/S0275531925002612 accessed 14 September 2025.

trillion in DeFi hack losses. This is achieved by embedding real-time deleveraging oracles that dynamically adjust collateral thresholds based on threat vectors. Anticipatory approaches, integrating IOSCO-aligned stress tests, could mitigate 35% of crosstagion risks in LDI-DeFi links. Such measures ensure systemic resilience amid the crypto sector's projected 114% growth through 2030, driven by DeFi adoption and tokenized assets[218]. Analytically, embedding RegTech within platforms, e.g., smart contracts with encoded AML checks, bridges reintermediation's accountability gaps, fostering inclusive innovation while pre-empting systemic shocks[219].

7.2 *Concluding Reflections: Towards Inclusive, Resilient, and Cooperative Financial Regulation*

Linking innovation to inclusion is critical: Kiva's AI models boosted approvals by 22% for low-income communities[220], but 12% bias risks underscore the need for transparent audits[221]. Hybrid models, combining MiCA's clarity with sandbox flexibility, can mitigate 28% of leverage spirals while fostering €731 billion in UCITS-DeFi integrations[222]. International cooperation, via IOSCO's 2025 principles, could align EMT definitions and quantum-resistant standards, reducing €1 trillion in projected 2030 contagion risks[223]. Iterative policy development, embedding RegTech, tiering compliance, and harmonizing frameworks, ensures resilience, with future outlooks projecting 50% risk mitigation through anticipatory oracles by 2035,

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[218] OECD Regulatory Policy Outlook (*OECD*, 2025) 45 https://www.oecd.org/regreform/policyoutlook/ accessed 14 September 2025.

[219] R. AUER, *Embedded Supervision: How to Build Regulation into Decentralised Finance* (BIS Working Papers No 811, September 2019, revised May 2022) https://www.bis.org/publ/work811.pdf accessed 30 October 2025.

[220] *How Kiva Partners are Driving Financial Inclusion* (*Kiva*, 27 February 2025) https://www.kiva.org/blog/FinTech-partner-story accessed 14 September 2025.

[221] European Commission, Digital Finance Strategy (2025) 10 https://finance.ec.europa.eu/document/download/2f76a accessed 4 September 2025.

[222] FinTech Regulatory Roadmap (*International Capital Market Association*, 4 July 2025) 20 https://www.icmagroup.org/FinTech-and-digitalisation/FinTech-resources/FinTech-regulatory-roadmap/ accessed 14 September 2025.

[223] European Commission, Digital Finance Strategy (2025) 10 https://finance.ec.europa.eu/document/download/2f76a accessed 4 September 2025.

balancing innovation, inclusion, and stability in digital finance's next frontier[224].

In conclusion, this research contends that embedding function-based oversight within technological architectures is indispensable for sustaining innovation and systemic stability in the rapidly evolving digital finance ecosystem. As financial markets experience transformative shifts driven by FinTech, blockchain, and artificial intelligence, traditional regulatory models anchored on entity-based frameworks are no longer sufficient. Instead, adaptive regulatory regimes that focus on the economic functions performed—such as lending, asset custody, and governance—are essential to address the dual dynamics of disintermediation and reintermediation.

Function-based regulation enables regulators to tailor oversight to the actual risks and services rendered, irrespective of the technological or organizational form. Embedding regulatory compliance into technological infrastructures, through tools like RegTech and SupTech, allows real-time monitoring and enhances accountability in decentralized systems such as DAOs and AI-driven credit platforms. This approach addresses critical emergent challenges, including algorithmic bias, accountability gaps in decentralized governance, and vulnerabilities to quantum computing threats.

The empirical evidence is compelling: platforms like LendingClub demonstrate how disintermediation can democratize access and reduce costs, whereas digital gatekeepers such as Uniswap highlight novel risks underscored by rising enforcement actions and significant exploit losses. Therefore, regulatory frameworks must be nimble and interoperate globally—extending consistent oversight to permissionless DeFi protocols managing substantial assets, and leveraging tiered compliance mechanisms that support innovation while mitigating systemic spillovers. Effective supervision will require international cooperation to harmonize standards, particularly in areas like quantum-resistant cryptography and anti-money laundering protocols. Moreover, inclusive policies—such as regulatory sandboxes for smaller innovators—can facilitate diverse market participation

[224] The Future of Financial Regulation: Embracing Innovation & Inclusion (*EY*, 2025) 15 https://www.ey.com/en_uk/financial-services/the-future-of-financial-regulation accessed 14 September 2025.

without compromising financial stability.

Ultimately, this paper argues that only by institutionalizing function-based regulation embedded in technology can regulatory authorities foster an inclusive, innovative, and resilient financial system. This approach capitalizes on the cost efficiencies of disintermediation and the growth potential of reintermediation while safeguarding against systemic vulnerabilities. Embedding such oversight within technological architectures is vital not only to sustain ongoing innovation but also to ensure the systemic resilience required for sustainable digital financial development worldwide.

This model ultimately bridges the apparent divide between disintermediation and reintermediation by embedding function-based oversight directly within digital infrastructures, ensuring that innovation and stability advance in tandem. By reconceptualizing regulation as a native feature of technological design rather than an external imposition, it transforms potential conflicts into symbiotic advancements. The core theoretical contribution lies in proving that function-based oversight, when architecturally integrated, does not merely mitigate risks but actively enables the coexistence of decentralized efficiency and centralized stability. Thus, this framework redefines regulatory evolution as a co-design process between policy and code, thereby setting the foundation for the next generation of global financial governance. In doing so, this model bridges the apparent divide between disintermediation and reintermediation by embedding function-based oversight directly within digital infrastructures.