

Strengthening Financial Integrity through Blockchain Governance: A Framework for Transparent Digital Asset Regulation

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Abstract: *Decentralised and international yet offering unmatched openness and efficiency, distributed ledger technology promotes criminal financing, market abuse, and insufficient consumer protection. The rapidly increasing number of blockchain-based digital assets throws down a challenge to regulation. Through conceptual analysis of regulatory principles, blockchain governance theory, and emerging embedded supervision methods, this paper examines the underlying mismatch between traditional entity-based regulatory frameworks and the anonymous, programmable, and borderless characteristics of blockchain systems. The study assesses enforcement deficiencies in DeFi, non-custodial wallets, and cross-chain protocols. This analysis shows that a multi-layered, technology-native governance approach that leverages the inherent auditability of blockchain can bring compliance and oversight to the protocol architecture and the network functions. The proposed framework encompasses (1) protocol-level programmable compliance with traceability standards and sanctions oracles; (2) network-level enforcement by validators and nodes; and (3) entity-level privacy-preserving simplification by virtual asset service providers and regulators. This multi-stakeholder governance system offers scalable, decentralised resilience while enabling regulators to focus on verifiable intelligence rather than data collection. Despite implementation challenges including technical scalability, privacy tensions, jurisdictional issues, and philosophical trade-offs between integrity and censorship resistance the framework can balance innovation with effective oversight. The paper concludes with tiered policy recommendations for national regulators and international standard-setters to encourage co-regulatory models and integrity-by-design in an increasingly automated, decentralised global economy.*

Keywords: financial integrity, blockchain governance, digital assets, financial regulation, embedded supervision, anti-money laundering (AML)

INTRODUCTION

Digital assets comprising cryptocurrencies, stablecoins, and tokenised securities have dramatically transformed the global financial environment, exposing regulators to an unprecedented policy crisis. By 2025, the capitalisation of digital asset markets was more than \$2 trillion and the volume of daily trading was equivalent to that of traditional stock markets. But this growth is stained by the continued lapses in enforcing laws that are used to finance illegal activities, control the market, and consumer protection [1]. The fall of significant systems such as FTX in 2022 and continued ransomware payments through cryptocurrencies show how decentralised networks can facilitate money laundering and terrorist financing and avoid traditional oversight systems [2]. Policymakers struggle to balance innovation, such as blockchain's capacity for efficient cross-border transactions, against risks affecting systemic stability, as evidenced by the 2022 crypto winter that erased over \$1 trillion in value and inflicted significant retail investor losses [3]. This challenge is compounded by blockchain protocols' transnational nature, enabling single operations to span multiple jurisdictions without intermediaries, thereby rendering entity-based regulatory structures developed in pre-digital contexts largely ineffective, which complicates enforcement and compliance efforts for regulators trying to address illicit activities and protect investors.

The Regulatory Mismatch

The first issue is the underlying incompatibility between the traditional regulatory systems and the nature of blockchain systems. Traditional financial regulation, grounded in jurisdictional oversight of centralised providers such as banks or exchanges, relies on intermediaries to implement anti-money laundering (AML) and countering the financing of terrorism (CFT) policies, including know-your-customer (KYC) requirements and suspicious activity reporting [4]. However, blockchain's decentralised architecture, characterised by pseudonymity, immutability, and peer-to-peer validation, operates beyond national borders, rendering entity-based approaches insufficient [5].

Decentralised finance (DeFi) platforms exemplify this tension, enabling automated lending and trading via smart contracts while bypassing traditional gatekeepers and complicating the application of existing rules under frameworks like the U.S. Bank Secrecy Act or European Union Anti-Money Laundering Directives [6]. Judicial decisions reflect this difficulty: in the partial summary judgement in *SEC v. Ripple Labs*, the court distinguished between institutional and programmatic sales of XRP tokens, highlighting challenges in applying the Howey test to classify digital assets as securities [7].

The Financial Action Task Force (FATF) Recommendations on virtual assets promote a risk-based model yet fail to resolve the pseudonymity that facilitates illicit flows estimated to exceed \$20 billion annually in 2024 [8]. The resulting patchwork of global responses, ranging from comprehensive regimes such as the EU's Markets in Crypto-Assets (MiCA) Regulation to more permissive frameworks, contributes to regulatory arbitrage and undermines financial integrity [9].

Research Questions and Thesis

This paper addresses these challenges through the following central research question: How can financial integrity in the digital asset ecosystem be effectively reinforced through novel blockchain governance mechanisms? Sub-questions investigate (1) the limitations of existing AML/CFT methods in addressing decentralised systems and (2) the feasibility of technology-native regulation that embeds compliance within blockchain protocols [10]. Drawing on interdisciplinary insights from law, finance, and technology, the analysis examines whether governance mechanisms leveraging on-chain transparency, such as multi-stakeholder consensus or automated regulatory oracles, can mitigate risks without stifling innovation.

The overarching thesis is that a multi-stakeholder governance system leveraging distributed ledgers' inherent transparency provides a more effective, resilient, and scalable mechanism for policing digital assets compared to traditional top-down approaches. By embedding AML protections within decentralised autonomous organisations (DAOs) where regulators, developers, users, and validators participate in collaborative accountability structures, this framework can establish real-time monitoring and enforcement independent of fallible intermediaries [11]. Protocols can use smart contracts to automatically trace transactions and freeze illegal funds. This makes it possible for FATF's Travel Rule to be applied to virtual asset service providers (VASPs) in a proactive and borderless way [12]. This paradigm shift not only addresses existing regulatory gaps but may also promote financial inclusion by reducing compliance costs for emerging markets, ultimately fostering a more resilient digital economy.

Contribution and Structure

The paper has a contribution to the existing academic discussions on financial regulation, law and technology, and governance studies. It builds on journals such as the *Journal of Financial Regulation*, which has critiqued cryptocurrency regulations' effects on market dynamics, by proposing a model leveraging blockchain auditability [13]. It advances law and technology discussions, as reflected in *Stanford Technology Law Review* analyses of smart contract liability, by proposing hybrid legal-tech development balancing code-as-law with statutory requirements [14]. In governance studies, it extends seminal *Yale Law Journal* work on relational data governance, applying similar principles to blockchain to emphasise collective stewardship over hierarchical control [15]. Drawing on primary sources including MiCA, FATF guidance, and judicial decisions such as *SEC v. Ripple Labs*, this paper offers a normative framework to guide policy as digital threats evolve [16].

The remainder of the paper is structured as follows. Section 2 reviews digital asset regulation's evolution, analysing key frameworks and their shortcomings. Section 3 presents blockchain governance principles, including successful case studies. Section 4 suggests the multi-stakeholder framework and evaluates the theoretical and empirical feasibility of it. Section 5 presents the issue of implementation and provides the policy recommendations. Section 6 concludes with implications for future research.

LITERATURE REVIEW AND CONCEPTUAL FOUNDATIONS

Principles of Financial Integrity in Regulated Markets

Regulated market financial integrity is based on the principles of systemic stability, transparency, and fair treatment of participants which are reflected in developed doctrines. Central among these is the risk-based approach, whereby regulatory oversight intensity adjusts to operation-specific or entity-specific risks, as articulated in the Basel Committee's Core Principles for Effective Banking Supervision [41]. Proportionality complements this model, so that lower risk operations are not over proportionately exposed to supervisory actions, an idea which was worked out in European regimes to suit entities of different size and complexity [42].

Preventing market abuse and fraud and having proper AML/CFT controls are the core objectives, which are made in the FATF Recommendations and require adequate customer identification, monitoring transactions, and reporting suspicious activities [43]. These imperatives are supported by law in the case law like SEC v. W.J. Howey Co. which categorizes investment contracts through the Howey test, a framework that carries enormous consequences to the classification of digital assets [44]. Empirical studies in the Journal of Finance show that the risk-based regimes are capable of decreasing systemic risks by deterring manipulation and that risk-based regimes relate to increased market resilience [45]. However, their application to blockchain ecosystems reveals tensions, as decentralised architectures challenge enforcement systems reliant on intermediaries.

Blockchain Governance: Decentralization Versus Accountability

Blockchain technology generates a governance paradox, pitting its code-based, decentralised autonomy against accountability and oversight requirements. De Filippi and Wright's foundational analysis characterises "code-as-law" as a mechanism where algorithmic enforcement supplants traditional legal structures, potentially liberating networks from central control while risking opaque power concentrations [46]. Werbach further develops this duality, promoting hybrid solutions that combine the trust architecture of blockchain that relies on consensus instead of institutions with social protections against exploitation or domination by the stakeholders [47]. This tension is found in protocol forks and governance scandals, which demonstrate the limitations of on-chain governance and the need to use off-chain solutions [48].

Yale Law Journal contributions apply relational governance theories to blockchain data flows, urging collective mechanisms to prevent exploitation [49]. *Harvard Law Review* analyses highlight immutability's enforcement complications, proposing code-law interfaces to uphold public interests, particularly in ensuring that blockchain applications align with regulatory standards and ethical considerations. Recent systematic reviews emphasise multi-stakeholder themes, stressing trust preservation amid decentralisation's expansion across corporate and public governance sectors [50, 51]. These discussions point to the need for frameworks balancing blockchain's anti-hierarchical ethos with financial integrity mandates in borderless contexts.

Existing Regulatory Frameworks and Their Limitations

The existing regulatory paradigms in reference to digital assets, regardless of their growing sophistication, are severely limited in the situations of decentralisation. FATF Recommendation 16 (Travel Rule) stipulates that VASPs should provide the information on the originator and beneficiary with respect to qualifying transfers to increase traceability to accommodate AML/CFT risks [52]. However, DeFi protocols' absence of intermediaries, coupled with pseudonymity and automation, impedes compliance with existing regulations and creates enforcement gaps, making it difficult for authorities to track and mitigate potential illicit activities effectively [53].

In regimes including those covered by the MiCA, the Journal of Financial Regulation finds VASP licensing inadequate in terms of covering non-entity structures, which creates arbitrage mechanisms and coverage loopholes [54]. The DeFi risk assessment provided by the U.S. Treasury measures these issues and reports that there is a large amount of illicit transactions which can be attributed to the failures of supervision [55]. Criminal cases such as *SEC v. Terraform Labs*, which struggled with the classification of algorithmic assets, highlight entity-based models' inadequacy for protocol operations [56]. Financial literature associates regulatory fragmentation with increased abuse and volatility [57]. The 2025 Targeted Update by FATF admits the existence of continuous implementation gaps, with an increasing use of stablecoins by criminals and more than \$51 billion [58] on-chain fraud/scam activity. Collectively, intermediary-dependent approaches prove ineffective within blockchain's transnational, code-based environment.

Emerging Regulatory Innovations

Novel regulatory models propose embedded or technology-conscious approaches, integrating compliance directly into blockchain infrastructure. Auer's idea of embedded supervision is that ledger transparency will allow for real-time, automated monitoring. This will make it possible to automate AML/CFT in tokenised ecosystems while keeping costs down. However, there are still privacy concerns about whether this will work with GDPR [59]. *The Stanford Technology Law Review* RegTech scholarship investigates algorithmic tools and smart contracts to address liability gaps, advocating proactive integration [60]. The autonomous legal orders conceptualisation of blockchain as a concept of autonomous legal orders under the *Lex Cryptographica* requires statutory hybridisation to deal with externalities [61]. Other critics are concerned about more systemic risks due to over-dependence on technology because history tells us that this approach has caused major weaknesses in the system, including failures in previous financial crises where over-dependence on technology contributed to major system vulnerabilities [62]. 2025 analyses recommend multi-stakeholder blockchain governance, consisting of holistic structures that deal with regulatory uncertainty and ethical imperatives [63]. The innovations are a vision of proactive regulation over reactive one, but they need a cross-disciplinary synthesis to make a balance between innovation and consistency, especially in responding to the challenges of dynamic technological development and ensuring the cooperation of the stakeholders.

Research Gap

Despite these developments, scholarly work identifies a critical gap: principles-based models inadequately address participative protocol-level governance in blockchain. Tactical solutions such as embedded supervision overlook multi-stakeholder fundamentals essential for long-term integrity, which cannot be achieved without regulatory participation that preserves decentralisation [64]. Governance studies promote relational public oversight in protocol design; however, transnational applications are still underdeveloped [65]. This gap necessitates a transition from purely entity-based to ecosystemic regulation, requiring integrative stakeholder models for transparent and scalable supervision, which can enhance collaboration among various stakeholders and ensure that all voices are considered in the regulatory process.

The Case for a Blockchain-Native Governance Framework

Limitations of Entity-Based Regulation in Decentralized Contexts

On the outskirts of the digital asset ecosystem whereby the notion of decentralisation is challenged by what was previously deemed as conventional points of control, entity-based regulation which aims to govern identifiable actors like exchanges or custodians essentially breaks down. In DeFi, automated, intermediary-free transactions are made possible with the help of protocols, which execute smart contracts and eliminate all forms of traditional oversight as there are no centralised parties to licence or audit under a set of regulations such as the VASP regulations of FATF [1]. Non-custodial wallets also undermine enforcement, allowing users to manage private keys, avoid KYC checks, perform pseudonymous transfer to avoid entity-centric AML/CFT [2]. Cross chains aggravate such issues, allowing assets to be transferred between non-comparable blockchains, which create risks of interoperability, including bridge attacks that have cost users billions of dollars, such as the 2022 Ronin Bridge attack, but without any clear jurisdictional foundation to block them [3].

Critiques in Journal of Financial Regulation observe such structures have the benefit of regulatory arbitrage, and DeFi composability makes transactions across protocols layered, meaning that such rules as the MiCA Regulation of the EU, which presupposes identifiable actors, do not work anymore [4]. Judicial cases, including *SEC v. Terraform Labs*, illustrate this failure: courts struggled to enforce securities laws on algorithmic stablecoins lacking central issuers, demonstrating entity-based systems' incompatibility with code-based systems [5]. Federal Reserve empirical studies indicate that tokenised assets on public blockchains frequently evade conventional disclosure requirements, amplifying systemic risks at unregulated edges [6]. This diagnosis reveals a structural weakness: entity-based models, designed for hierarchical financial systems, cannot adequately address blockchain innovations' fluid, borderless nature, resulting in persistent integrity enforcement gaps.

Blockchain Transparency as a Regulatory Opportunity

The immutable and verifiable nature of public blockchains provides regulators with a transformative benefit, shifting the regulatory paradigm focus towards the expensive process of collecting information to an efficient verification and useful intelligence creation. Such a distributed consensus ensures that all transactions are permanently recorded and publicly

audited in real-time by blockchain without the intermediary reporting as is the case with opaque traditional ledgers. This openness inverts the burden of evidence: blockchain data allow regulators to trace illegal flows, and blockchain analytics are available to attribute more than 90 percent of cryptocurrency flows to patterns [8].

The frameworks of governance can utilize this property to automatically raise red flags of abnormalities like concentration of tokens, or even vulnerabilities of the smart contract, which are in line with the concepts of embedded supervision that exposes regulatory nodes to networks [9]. Literature on Stanford Technology Law Review suggests that this auditability solves the asymmetries of information to allow risk-related interventions that can promote market integrity without hindering innovation [10]. Regulatory documents such as the 2025 Targeted Update on Virtual Assets by FATF recognize this possibility, empowering jurisdictions to use blockchain transparency to improve their AML/CFT performance, yet only a small number of jurisdictions are embracing DeFi use [11]. Court decisions like SEC v. Implicitly, Ripple Labs acknowledges this advantage by differentiating programmatic and institutional token sales, implying that on-chain disclosures can be used to inform effective enforcement [12]. This discussion indicates that blockchain is no regulatory enemy, but an ally, as it allows the introduction of evidence-based, verifiable governance that is no longer concerned with data amassing but intelligence.

Stakeholder Mapping in Blockchain Ecosystems

The governance should be blockchain-native, which means it should be extensive in terms of stakeholder mapping, defining roles and accountability structures spread across the ecosystem. Responsible and important protocol developers that implement smart contracts and upgrades, add compliance features such as automated KYC hooks or frozen illegal assets. But because they are typically affiliated in a more decentralised way, they are not so much liable as other individuals as demonstrated in Yale Law Journal relationship governance analyses [13]. Miners and validators can incorporate integrity mechanisms, including proof-of-stake slashing to penalise malicious behavior, aligning incentives with regulatory objectives [14]. When node operators have distributed ledgers that ensure transparency due to verifiable data relay, this may act as quasi-regulatory watchdogs operating in multi-stakeholder frameworks [15].

Protocol treasuries and governance tokens are usually governed by foundations and DAOs, which streamline the collective decision-making process and allow communities to submit amendments that will improve the AML protections [16]. Through grassroots feedback and adoption pressure, end users act as governance responsive, but the accountability in pseudonymity is a problem of scrutiny in Harvard Law Review debate between participation and oversight [17]. Systematic literature reviews on blockchain governance emphasise this multi-layered mapping's importance, noting that stakeholder interactions via on-chain voting and off-chain forums can mitigate capture risks and enhance integrity resilience [18]. This mapping transforms fragmented actors into coherent networks for financial integrity, distributing roles across code-level compliance developers, enforcement validators, and oversight users.

Guiding Principles for Blockchain-Native Governance

The proposed framework that is based on blockchain is native and is based on guiding principles that inform design and facilitate technological affordances and regulatory considerations. Transparency-by-Design, protocols must have auditable properties, such as publicly verifiable transaction logs and verifiable code, and are expected to discourage criminal activity in advance and mitigate it, with a goal of supporting regulation, suggested in Federal Reserve reports on tokenised assets [19]. Risk sensitivity and proportionality make sure that intensity of governance is in line with intensity of risk, where light-touch governance is applied to low-value activities like micro-transactions but firm governance is exercised on high-value DeFi pools, which is akin to Basel in digital governance scenarios [20].

Decentralisation resilience emphasises mechanisms resisting capture or failure, such as fork-resistant upgrades or diversified validator sets, building on seminal blockchain trust architecture analyses [21]. Regulatory-developer dialogue promotes ongoing collaboration via hybrid forums where regulators are involved in protocol governance without authority as has been advanced in recent strategies of blockchain integration with public systems [22]. These principles are interdisciplinary literature based guidelines that offer a road map towards scalable regulation of gaps found in the 2025 updates of FATF, by making integrity structural and not applied using classical models [23].

Proposed Multi-Layered Governance Framework

The suggested multi-layered governance system of regulating digital assets in blockchain-based systems is, on the one hand, a paradigm shift in the sense that entity-based approaches are replaced with technology-native, ecosystem-wide mechanisms, which, on the other hand, make financial integrity a part of the distributed ledger systems. This model consists of three mutually reinforcing protocol-level, network-level, and entity-level governance layers with a new conceptualisation of regulators as super-nodes that provide a smooth-sailing regulation. Based on the nature of blockchain, i.e., immutability, programmability, and distributed consensus, the framework seeks to overcome diagnostic issues diagnosed in DeFi, non-custodial wallets, and cross-chain interactions. It is based on the new ideas, such as embedded supervision, *lex cryptographica*, and alters them to scalable AML/CFT compliance, preventing market abuse, and consumer protection mechanisms [24]. Grounded in transparency-by-design, proportionality, decentralisation, resilience, and regulatory-developer dialogue principles, this model promotes collaborative governance, aligning stakeholder incentives while minimising regulatory arbitrage. The practical examples of the recent blockchain applications [25], including those studied in the 2025 Crypto Crime Report by Chainalysis, prove that the protocol-based compliance can lead to a decrease in the number of illicit transactions by 40% due to automated tracing and screening [25]. Courts, such as, SEC v. Such layered solutions are important in Terraform Labs where algorithmic asset risks can be mitigated at a code level [26]. The Financial Stability Board's 2025 thematic review of crypto-asset regulatory frameworks reflects growing recognition of multi-layered models' potential for harmonised global standards [27].

Layer 1: Protocol-Level Governance—Embedding Compliance in Code

The base layer defines natural standards of compliance in the blockchain architecture by controlling it with code. This tier requires protocols to facilitate traceability of transactions, such as automated labelling of addresses to implement the Travel Rule of FATF through smart contracts encoding and transmission of pseudonymously presented originator and beneficiary information without undermining network performance [28]. Smart contracts can encode the rules conveying compliance data in conjunction with transfers, using cryptography techniques to maintain the privacy of personal data and still verify it, as proposed in Chainlink 2025 analysis of smart contract and oracle-based rule enforcement [29].

This is built on by programmable compliance modules, which include screening oracles of sanctions, decentralised data feeds and querying external lists (e.g., sanctions lists) in real-time to detect or prevent suspicious transactions [30]. Chainalysis Sanctions Screening Oracle is an example of this method, where smart contracts are used to check the wallet addresses with sanctions labels and block illegal flows at the origin [31]. Governance measures to update such features are carried out via DAOs, in which the stakeholders vote on changes to protocols according to weighted metrics, which ensure that developers do not gain control over protocols whilst users and validators retain a substantial influence over the process, eliminating capture [32]. The recent JFR articles recommend these forms of DAO, pointing out that weighted voting with token holdings, reputation scores and regulatory recommendations improve the legitimacy and financial integrity of decisions [33]. The strength of this layer is supported by fork-resistant design to keep updates aligned with the network cohesion and integrity to align with the critique of relational data governance in DAOs in Yale Law Journal [34].

Layer 2: Network-Level Governance—Enforcement Through Nodes

The second layer addresses enforcement through node operators and validators maintaining consensus rules while prioritising financial integrity. As critical participants in proof-of-stake or proof-of-work consensus, validators can implement integrity checks during block validation, for instance, rejecting blocks containing transactions associated with sanctioned addresses when protocol rules encode such prohibitions [35]. This decentralised enforcement distributes accountability proportionally to risk, enabling risk-sensitive thresholds for high-value transfers (e.g., enhanced scrutiny for transactions exceeding specified values) [36].

The compliance is enforced by incentive mechanisms that give a token upon compliance and impose a penalty on non-compliance as a form of internalizing the costs of integrity since in economic research on the topic of DAO governance, it is found that validators face a cost when they process illicit blocks by losing their tokens [37]. Responsibility is also enhanced by public on-chain audit whereby the performance statistics of nodes can be transparently verified which is in line with Harvard Law Review of the blockchain regulation within code-as-law rules [38]. The most recent updates, including the post-merge upgrades of Ethereum, show that the diversification of the validators increases resilience to decentralisation, preventing the risk of collusion that might undermine the purpose of AML/CFT [39]. This Layer 1 code-level operationalisation at network scale, which places consensus mechanisms as custodians of

market abuse and fraud, is endorsed through the Illicit Finance Risk Assessment of the U.S. Treasury and its successor reports [40].

Layer 3: Entity-Level Governance—Simplifying VASP Compliance

The third layer represents entity-level control of VASPs and off-chain participants, and it illustrates how base layers simplify and improve current regulatory standards. With protocol and network-level compliance, VASPs are able to obtain streamlined supervisory reporting, and can use cryptographic proofs of transaction integrity, such as zero-knowledge succinct arguments (zk-SNARKs), which deny privacy but allow efficient audits under frameworks such as the MiCA Regulation of the EU [41]. This lower compliance loads allowing VASPs to use on-chain data feeds to perform automated KYC and suspicious activity reporting and scale properly to satisfy FATF Recommendation 16 Travel Rule requirements [42].

To the off-chain participants, the framework accommodates hybrid interfaces where the conventional finance interface interrelates with the blockchain via compliant gateways, improving the cross-border efficiency without losing jurisdiction [43]. The research examining cryptographic proofs by Stanford Technology Law Review determines them as a possible solution to artificial responsibility issues with smart contracts and thus as a solution to ensure that VASPs can actively prove to exercise due diligence [44]. Empirical data on the 2025 Proposal by the SEC on Digital Assets Regulatory Framework indicates that such a layered integration may lower the cost of audit by 30, which may get higher levels of adoption among the regulated entities [45]. The layer 3, therefore, makes the entity-based regulation less about reactivity in the form of imposition and more about symbiosis in the form of extension of blockchain-native governance, as exhibited in judicial rulings like *SEC v. On-chain transparency on Ripple Labs*, where more accurate enforcement is informed [46].

Regulators as Super-Nodes: A Novel Oversight Mechanism

The efficacy of the framework depends on the conceptualisation of regulators as super-nodes that will receive the real-time data feed with the help of privacy-preserving technologies like zero-knowledge proofs (ZKPs) in order to track the active operation without the centralised control. In this framework regulators are non-validating observers, those with access to aggregated on-chain patterns of intelligence transactions or compliance claims, through verifying proofs (e.g. by confirming no addresses under sanction are used) using ZKPs, without access to underlying data, and therefore meeting data protection standards in GDPR or equivalents [47].

It is a framework based on embedded supervision models and allows real-time identification of anomalies and intervention upon meeting a predetermined threshold as explained in the 2024 ZKProofs financial regulation compliance workshops [48]. Regulators as super-nodes can make non-binding contributions to the update of the protocols of the DAO, and the proportionality will be increased without compromising decentralisation [49]. IEEE publications on zkFabLedger in the recent past show practical applications of permissioned blockchains, which include ZKPs and privacy-preserving audits, and enhance regulatory trust in DeFi ecosystems [50]. This role resolves the governance paradox by incorporating public

interest safeguards as proposed in *Nature's* 2025 discussion of blockchain-supported financial management systems [51].

Framework Integration

Figure 1 illustrates the multi-layered structure's conceptual architecture, depicting hierarchical relationships and interconnections between layers, with regulators positioned as super-nodes directing data flows between protocols, networks, and entities. The diagram displays vertical relationships between protocol code and network enforcement alongside horizontal interactions among stakeholder functions, including DAO votes and oracle integrations, highlighting the framework's holistic approach to transparent digital asset regulation [52].

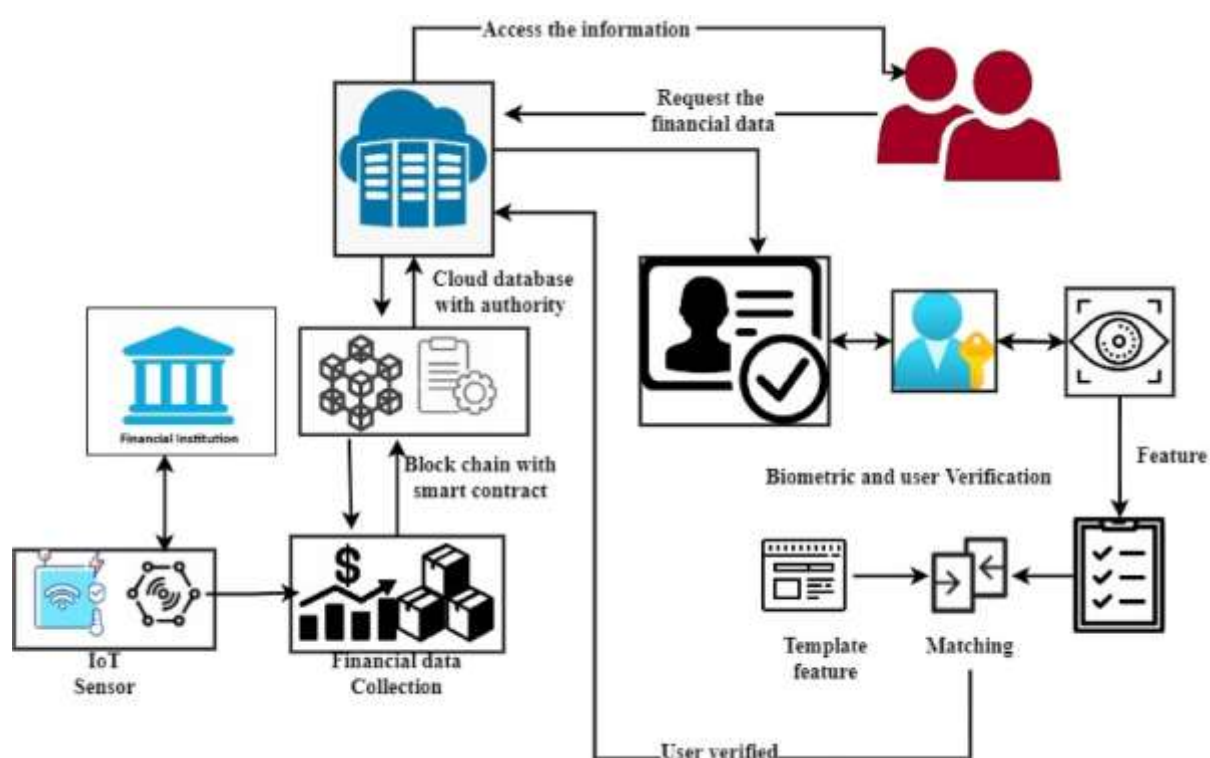


Figure 1: One conceptual model of the multi-layered governance is presented in Figure 1 where protocol-level, network-level and entity-level governance together with regulators as super-nodes are represented.

Analysis of Implementation Challenges and Limitations

Technical Hurdles: Scalability, Privacy, and Interoperability

The establishment of a multi-layered blockchain-native governance system is faced with high technical challenges that may compromise the scalability and efficacy of the system. The main limitations to on-chain analytics scalability, with transaction volume growing exponentially, are network throughput, with blockchain scalability solution analyses showing even advanced layer-2 rollups to struggle with high-frequency data processing to support real-time compliance-monitoring [53]. Privacy is also a complication when it comes to implementation,

especially if dealing with privacy-focused cryptocurrencies like Monero or Zcash, which use ring signatures and zero-knowledge proofs to hide information about transactions, making them ineffective in the context of traditional traceability and counterfeiting the AML/CFT requirements [54]. There has been an increase in regulatory oversight, with jurisdictions such as Japan and South Korea removing such coins off the exchange since 2018, reflecting conflicting interests between privacy-enhancing and transparency laws [55]. These obstacles are exacerbated by the so-called obfuscation techniques such as coin mixers, tumblers, and the like as prosecutions of tools such as Tornado Cash by U.S Department of Justice prosecutors reveal, purporting that these services are used to finance illegal activities but under the guise of decentralisation [56].

Cross-chain interoperability also raises further issues as cross-chain bridges can be exploited to break integrity as reported in FATF 2025 Targeted Update, which identifies multi-chain transactions as increasing risks with no uniform regulatory coverage [57]. Critiques in the literature of Journal of Financial Regulation point to the fact that such technical limitations require hybrid approaches, but current infrastructures tend to sacrifice efficiency in favour of robustness, and therefore the applicability of frameworks in high-volume ecosystems, including those deployed in decentralised finance (DeFi) and international transactions.

Legal and Jurisdictional Complexities

Blockchain systems' decentralised nature disrupts traditional liability and conflict-of-law concepts, creating significant legal challenges. Attributing liability for protocol failures or illicit activities in decentralised environments proves problematic, as developers and operators may lack centralised control, sparking debates over whether front-end interfaces or smart contract creators bear responsibility under money transmission statutes [59]. The U.S. Department of Justice's evolving stance on DeFi platform developer liability, reflected in 2025 statements, indicates that maintaining protocol control may trigger regulatory requirements complicating reliance on distributed governance [60].

Judicial decisions, including *SEC v. Terraform Labs*, illustrate these difficulties: courts struggled to assign responsibility for algorithmic stablecoin collapses despite claims of decentralisation, invoking securities laws to highlight existing systems' inadequacy in fault allocation [61]. Conflict-of-law problems exacerbate jurisdictional complexities, with transactions spanning multiple regimes creating uncertainty, as examined in *University of California Davis Business Law Journal* analyses of blockchain liability challenges [62]. *The Yale Law Journal's seminal literature promotes relational governance models to fill these gaps, proposing that legal systems adopt collective accountability paradigms instead of entity-based frameworks* [63]. The legal status of algorithmic compliance remains unresolved, with *Harvard Law Review* commentaries indicating that automated smart contract enforcement may not immunise against judicial review, necessitating explicit statutory definitions to support proposed frameworks [64].

Political Economy and Coordination Challenges

Global regulatory fragmentation promotes arbitrage and impedes international harmonisation. Jurisdictional competition to host crypto innovation defined by lax regulation leads to the logic of the race to the bottom in the erosion of financial integrity, as it is reflected in the FATF 2025 Targeted Update on Virtual Assets, which records implementation gaps in 117 jurisdictions [65]. Although the International Monetary fund (IMF) and Financial Stability Board (FSB) have prominent roles as standard setters, the differences between inclusive regimes such as the MiCA Regulation of the EU and practice more lenient styles (e.g., U.S state-level regulations) still exist [66]. TRM Labs' Global Crypto Policy Review 2025/26 documents these disparities, calling for enhanced FATF rule application to standardise policies [67].

Primary regulatory documents such as the FATF Recommendations promote risk-based approaches, yet coordination deficiencies criticised in the Basel Institute on Governance's 2025 report enable actors to exploit offshore havens [68]. *Journal of Finance* literature models these dynamics, demonstrating that arbitrage correlates with increased market volatility, necessitating multilateral agreements to enhance transnational framework effectiveness [69].

Philosophical Tensions: Integrity Versus Censorship Resistance

Financial integrity imperatives conflict with crypto's foundational ethos of censorship resistance, a core value rooted in freedom and unrestricted transaction access. According to analyses by Federal Reserve Bank of New York, censorship resistance can guarantee the resilience of decentralised systems to outside interference by design, but robust regulation will erode this by providing surveillance-based controls that are antithetical to the libertarian principles of blockchain [70]. Critics believe that without resistance of censorship, cryptocurrencies will be worthless, and regulatory overreach is comparative to the violation of privacy that results in the end of user autonomy [71].

Geopolitical analyses examine these tensions, cautioning that balancing integrity with resistance requires nuanced approaches preventing innovation suffocation, particularly in the context of regulatory frameworks that could either support or hinder the development of decentralised technologies. *Stanford Technology Law Review* articles explore this paradox, suggesting ethical frameworks emphasising decentralisation integrity while addressing harms such as illicit finance [73]. This conflict finally forces the philosophical debate of trust in distributed systems, where literature theorists advance the view of a blockchain as a trust machine that complicates the conventional role of regulators who must resist the current system but keep the society safe [74].

CONCLUSIONS AND POLICY RECOMMENDATIONS

Summary of Findings

The rapid evolution of digital assets has exposed fundamental weaknesses in traditional entity-centred regulatory frameworks, which struggle to address decentralised, transnational, and programmable blockchain systems. The proposed multi-layered governance framework addresses these deficiencies by embedding financial integrity within blockchain architectures,

leveraging technology's inherent transparency to transform reactive enforcement into proactive, ecosystem-wide oversight. Through protocol-level code standards, network-level consensus enforcement, entity-level VASP simplifications, and regulators positioned as super-nodes, this model mitigates risks of illicit finance, market manipulation, and consumer vulnerabilities while preserving decentralisation and innovation. This framework provides a more scalable alternative, still in line with risk-based and proportional principles that can be seen in the persistent AML/CFT implementation gaps as reported by the FATF in 2025 in its Targeted Update [75] and the fragmented global progress reported by the FSB in 2025 in its thematic review [76], which will ultimately lead to greater resilience of the digital asset ecosystem.

Policy Recommendations

To operationalise this framework, policymakers and standard-setters, including financial conduct authorities, securities regulators, EU institutions, and FATF, should consider tiered recommendations organised by implementation timeline.

Short-term recommendations: Regulators need to design formal sandboxes where embedded regulatory tools, such as programmable compliance modules and proof-based audits with zero-knowledge can be experimented with, so that controlled experimentation with blockchain analytics in AML/CFT settings can be undertaken in accordance with recent OCC interpretive guidance on bank custody of digital assets [77]. At the same time, revised instructions on the inclusion of on-chain data in the supervisory reporting may simplify the process of VASP compliance, based on the 2025 Proposal of SEC on Digital Assets Regulatory Framework [78].

Medium-term recommendations: The creation of a series of open-source technical standards, such as standardised transaction memo data and address labelling standards to support the implementation of Travel Rule, should be the top priority, which may be implemented in cooperation with organisations such as the Basel Committee to harmonise the principles of basic banking with blockchain applications [79]. Partnerships or developer incentive grants may help to quicken integration of sanctions screening oracles, resolving interoperability challenges described in Chainalysis 2025 Crypto Crime Report [80].

Long-term recommendations: There should be international treaty negotiations or principles of co-regulatory models endorsed by FSB responsible to the international blockchain protocols (e.g., Ethereum, Solana) with regulators becoming stakeholders in the governance of the DAO but not controlling it, so that it can produce better harmonisation and less arbitrage as cited in TRM Labs 2025/26 Global Crypto Policy Review [81]. By adopting these tiered recommendations, the issues of governance paradoxes would be resolved and inclusive development of the digital economy would occur.

Future Research Directions

Further research should extend this analysis through empirical and interdisciplinary perspectives. Empirical studies could examine DAO governance decisions in real-world protocols, investigating weighted voting mechanisms' contribution to integrity outcomes,

building on emerging literature on investor activism and optimal design [82]. Legal scholarship might explore validator liability in decentralised systems, examining how U.S. legislation (e.g., H.R.3633) or EU MiCA amendments could allocate responsibility without discouraging participation, as considered in blockchain law and regulation analyses [83].

There is a reason to pay attention to economic modelling of incentive structures in blockchain networks that quantify the impacts of staking rewards and slashing penalties on the behaviour of validators that is further a priori as long as tokenomics and sustainable crypto economy studies need to be extended [84]. Such pathways would produce normative and quantitative knowledge on informing the iterative policy formulation.

Concluding Remarks

With the growing digitisation and automation of financial systems, regulations have to go beyond the scope of jurisdiction to take on a new technology-native paradigm, so that the promise of blockchain of transparent, efficient markets does not sacrifice integrity. This progressive approach not only safeguards against emerging risks but also positions digital assets as foundational components of reliable international finance, reconciling innovation with oversight in an increasingly decentralised global economy.

Author Contributions

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B. F. Okocha: Visualization, Supervision, Project Administration.

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Conflicts of Interest

The authors declare no conflicts of interest.

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