

Civil Law Challenges in Regulating Digital Assets: Redefining Ownership and Liability in Blockchain Transactions

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Abstract

The rapid evolution of blockchain technology has disrupted foundational doctrines of civil law by challenging traditional concepts of ownership, possession, and liability. Digital assets such as cryptocurrencies, non-fungible tokens (NFTs), and tokenised instruments operate within decentralised and autonomous systems that defy conventional legal classifications. This study examines how civil law can adapt to these technological transformations by redefining ownership and liability within blockchain transactions. Employing a mixed-method design, the research integrates comparative doctrinal analysis across continental European and Southeast Asian jurisdictions with semi-structured interviews involving legal practitioners, regulators, and blockchain specialists. The findings reveal that conventional notions of ownership based on physical possession and tangible property are inadequate in the digital context, where cryptographic control and ledger-based provenance serve as functional equivalents of possession and transfer. Similarly, the study identifies a growing “liability gap” in decentralised systems, where fault attribution becomes ambiguous in the absence of a central actor or contractual intent. To address these doctrinal challenges, this paper proposes an integrated analytical model of control–provenance–liability, which reconceptualises ownership as the combination of cryptographic control and verifiable transfer provenance, and defines liability as a distributed construct encompassing smart-contract automation, node responsibility, and network accountability. This model offers a normative and functional framework for harmonising digital-asset governance within civil law systems. By bridging doctrinal theory and empirical evidence, the study contributes a novel perspective to international legal scholarship transforming civil law from a reactive regulator into a proactive enabler of

accountability, innovation, and legal certainty in the era of blockchain-based assets.

keywords: *Blockchain; Civil Law; Digital Assets; Liability; Ownership*

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A. Introduction

In recent years, blockchain technology has evolved beyond its financial origins to become a transformative force reshaping the fundamental architecture of private transactions and asset ownership. The rise of blockchain-based assets, such as cryptocurrencies, non-fungible tokens (NFTs), and tokenised instruments has introduced new categories of value that are decentralised, intangible, and often borderless. These characteristics disrupt the traditional civil law doctrines of property and liability, which historically relied on physical possession, identifiable ownership, and clearly delineated parties. Consequently, civil law systems are now confronted with complex questions: what constitutes an “object of property rights” in the digital realm, how ownership can be legally recognised and transferred through cryptographic control, and how liability is to be allocated when transactions occur without intermediaries or central authorities (Lee 2024; Napieralska & Kępczyński 2024). These challenges necessitate a fundamental reconsideration of how civil law conceptualises ownership and responsibility in a technologically decentralised environment.

Existing scholarship has made significant strides in exploring the legal implications of blockchain-based assets, yet important doctrinal and regulatory gaps persist. For instance, (Lee 2024) analyses the nature of digital assets within the context of global property law and argues that while tokenisation enables new forms of transferable rights, it remains uncertain whether such assets can be assimilated into the traditional taxonomy of civil property. (Pulatov 2024) further examines digital financial assets (DFAs) as objects of civil rights and highlights persistent inconsistencies across jurisdictions in their legal classification, enforceability, and conflict of laws. Similarly, (Liu 2025) observes that smart contracts automated, self-executing agreements on blockchain, complicate classical models of contract and liability because they blur the distinction between intention,

execution, and enforcement. More recent analyses, such as (Martínez Luna et al. 2024), reveal that the evolution from intangible property to crypto assets fundamentally challenges traditional civil law notions of legal personality and ownership attribution, as decentralised control in blockchain systems often diverges from the conventional understanding of possession and ownership recognised by civil law frameworks. Although these studies provide valuable insights, the majority remain confined to single jurisdictions or rely heavily on descriptive doctrinal reasoning, offering limited comparative or empirical understanding of how civil law systems might adapt to the technological realities of blockchain.

The limitations of existing research are threefold. First, most prior works address blockchain regulation from the perspective of public law or financial supervision, rather than private civil obligations. While regulatory discussions abound, fewer studies examine how civil obligations contracts, torts, property rights in a decentralised blockchain environment must be reconceptualised. Second, there is a lack of systematic comparative inquiry across different civil law traditions, particularly between continental European and Asian jurisdictions, that could reveal convergent or divergent patterns in digital asset governance. Third, few studies attempt to develop a conceptual framework that integrates ownership and liability into a coherent model suited to decentralised systems. These research gaps underscore the need for a more holistic analysis that bridges doctrinal theory, comparative law, and empirical practice. As noted in *Private Law Framework for Blockchain* (Kiskis Mindaugas 2024), the evolution of blockchain-based transactions compels civil law systems to reconsider not only *how* ownership is defined but also *why* traditional legal categories persist despite the decentralised and automated nature of digital assets.

Against this background, the present study aims to offer a novel comparative civil law analysis of digital assets by examining how ownership and liability are being redefined in blockchain transactions. Unlike prior descriptive approaches, this research adopts a mixed-method design: (i) a comparative doctrinal analysis of selected civil law jurisdictions specifically those within continental Europe and Southeast Asia to identify how legal systems conceptualise and regulate digital asset ownership; and (ii) a series of semi-structured interviews with legal practitioners, regulators, and blockchain technology specialists to uncover practical implications of liability allocation in decentralised environments.

The novelty of this study lies in proposing an integrated framework of digital asset ownership composed of three core dimensions: control (cryptographic key access), provenance (ledger-based traceability of transfers), and liability allocation (smart contract enforcement mechanisms). This framework will be tested against recent legislative and judicial developments to assess its normative and operational feasibility. Through this approach, the study contributes not merely to theoretical debates but also to the design of actionable legal reforms that reconcile technological innovation with civil law principles of legal certainty, enforceability, and third-party protection.

To guide this inquiry, the article addresses the following primary research question: How should civil law systems redefine ownership and liability in the context of blockchain-based digital assets to ensure legal certainty and innovation-friendly regulation? This overarching question is complemented by three sub-questions: (1) Which elements of traditional civil property and liability law become inadequate in blockchain-based systems? (2) How have different jurisdictions adapted or responded through regulation and jurisprudence? and (3) What model of ownership and liability best aligns with the decentralised architecture of blockchain while preserving the foundational objectives of civil law? By systematically addressing these questions, this research seeks to bridge the doctrinal, comparative, and empirical dimensions of digital asset regulation, thereby enriching both the academic discourse and the practical development of private law in the digital era.

B. Discussion

The emergence of blockchain-based digital assets has brought profound challenges to the structural coherence of civil law, particularly concerning ownership, liability, and jurisdictional harmonisation. Our analysis reveals that the reconceptualisation of ownership in civil law systems requires moving beyond the tangible–intangible dichotomy that traditionally underpinned property doctrine. In civil law, ownership (*dominium*) presupposes exclusive control and the possibility of physical possession; however, blockchain assets exist in a purely digital, non-rivalrous form that can be transferred instantaneously through cryptographic mechanisms. Empirical findings from this study confirm that mere possession of a private key does not suffice as proof of ownership a view echoed by (Lee 2024) and (Pulatov 2024), because technical control may be separated from

legal entitlement or equitable claim. The principle of *transfer of object* (*traditio*) under classical property law becomes destabilised, as transfer in blockchain occurs through ledger modification rather than physical delivery (Cornelius K. 2021). This shift requires recognising blockchain records as functional equivalents of possession, but with additional evidentiary weight attached to provenance the verifiable chain of transfers recorded on the ledger (Alessandro 2023; Lin Zou & Dike Chen 2024). Provenance thus emerges as a new juridical category in defining ownership, reinforcing both traceability and accountability. While previous studies largely stopped at classifying whether digital assets qualify as “property” (Chun Hung 2024; Norouzi 2022), the findings here advance the debate by specifying operational sub-criteria: control through private keys, provenance via ledger traceability, and legal recognition through enforceable rights. This framework reframes ownership not as static possession but as a dynamic relationship between control, traceability, and legitimacy a necessary evolution for civil law systems to remain relevant in decentralised digital markets.

Equally significant is the reconfiguration of liability within blockchain ecosystems. Traditional civil law assumes a determinate actor who bears responsibility for contractual breaches or tortious harm; however, blockchain transactions, executed via smart contracts and distributed nodes, obscure the link between action and accountability (Napieralska & Kępczyński 2024). Our findings illustrate that when autonomous code executes erroneously, practitioners often perceive it as a *control failure* rather than a *liability event*, which conflicts with the civil law requirement of fault attribution or causal nexus (Pulatov, 2024). To bridge this gap, liability must evolve toward an “automated liability” framework, one that recognises accountability embedded in the architecture of smart contracts and network participation.

Comparative evidence demonstrates that jurisdictions adopting functional definitions of property and liability those combining control, transferability, and traceability tend to achieve greater legal certainty (Keijser Thomas 2025; Lehmann 2021). For instance, Indonesia has begun recognising digital assets as movable intangible property usable as collateral (Darmawan Kevin et.al. 2025), while Japan remains restrictive under its Civil Code. The variation underscores the urgency for harmonised doctrines that accommodate both technological autonomy and legal

responsibility. The integrated model proposed in this study comprising control, provenance, and liability addresses these doctrinal gaps by linking ownership evidence to liability attribution. By embedding provenance as proof and codifying “node liability” and “smart-contract default” as new categories of civil obligation, the framework provides a coherent response to the decentralisation paradox. It positions civil law as an adaptive, rather than reactive, system one capable of safeguarding private rights while fostering innovation within the digital asset economy.

Reconceptualising Ownership in Civil Law

Our results show that conventional civil law categories struggle to accommodate digital assets because the characteristic features of blockchain-based assets deviate from key property law assumptions. For example, many interlocutors emphasised that mere cryptographic control (possession of a private key) does not always translate into legal ownership as recognised in civil law jurisdictions, echoing the argument that technical possession is not conclusive evidence of ownership (Lee 2024; Pulatov 2024). Unlike classical movable or immovable property, digital assets exist in blockchains, are non-rivalrous in some respects, and can be transferred without physical delivery, which destabilises the traditional requirement of ‘transfer of the object’ under civil law (Cornelius K. 2021). Prior studies, such as the Chinese-comparative analysis, found that civil law jurisdictions tend to deny property status to crypto assets because they do not satisfy tangibility or classical exclusivity criteria (Chun Hung 2024; Pulatov 2024), but our empirical findings suggest that even where recognition exists, practical enforcement and third-party protection remain severely uneven.

What is new in our analysis is the “provenance” component: we found that interviewees and legal practitioners place increasing importance on the blockchain ledger as evidence of history of transfers (provenance) in ownership claims. This aspect has been under-emphasised in earlier doctrinal literature, which focused more on control or possession (Alessandro 2023). By emphasising provenance, we extend the model of ownership beyond mere control to include a traceable transfer-history criterion. This deeper specification of ownership is a novelty compared to earlier descriptive works, which largely stopped at the question “Is it property?” without developing practical sub-criteria (Norouzi 2022; Lin Zou & Dike Chen 2024).

Liability Allocation in Decentralised Transactions

Second, our research reveals that liability remains an under-addressed but critical challenge in civil-law regulation of digital assets. The interviews show that many civil law systems assume a clear responsible party for breach of rights or losses, but in blockchain transactions the identity of the liable party may be obfuscated by decentralised architecture, smart contracts and anonymous nodes. Literature on decentralised autonomous organisations (DAOs) emphasises this gap: liability boundaries blur, and classical legal personhood or contract default frameworks become ineffective (Napieralska & Kępczyński 2024). In contrast to older studies that explored liability in smart contracts in general (Norouzi 2022), our results highlight that civil liability regimes need to integrate “automated liability” (smart-contract enforcement) and “node liability” (participants in blockchain networks) as part of the legal model.

A key difference from previous research is that we observed malfunctioning smart-contract mechanisms are often interpreted by practitioners as “control failures” rather than “liability failures”, yet civil law requires attribution of fault or causation. This empirical observation diverges from many normative works, which assumed that smart-contract execution is automatic and faultless (Pulatov 2024). The implication is that civil law systems must adapt by recognising liability even when autonomous code executes, for example through reversible default rules or statutory presumptions of liability when fault cannot easily be located.

Comparative Jurisdictional Insights

Third, our comparative doctrinal review shows considerable variation across civil law jurisdictions in how digital assets are treated. Some jurisdictions, such as Indonesia have begun to recognise digital assets as movable intangible property that may serve as collateral. However, regulatory implementation remains fragmented and enforcement mechanisms are weak. As discussed by (Darmawan Kevin et.al. 2025) in “*Regulatory Optimization of Bitcoin as Collateral: Property Classification and Secured Lending Framework in Indonesia*”, Bitcoin fulfils the legal criteria of an intangible object and, in theory, can be used as an object of fiduciary security; nevertheless, the authors highlight that explicit regulation and a comprehensive collateral registration system for digital assets are still lacking.

Other jurisdictions, such as Japan, adopt a more restrictive stance by applying traditional property law definitions to exclude cryptocurrencies from ownership rights. In a landmark decision, the Tokyo District Court (2015) held that Bitcoin could not be classified as a “thing” under Article 85 of the Japanese Civil Code, as it constitutes an intangible asset (United Nations Commission 2023). The study by (Cornelius K. 2021) also shows that U.S.-derived systems treat crypto as property more readily offering greater third-party protection, but civil law jurisdictions lag. Our findings confirm these differences but go further by mapping how certain jurisdictions are actively reforming, whereas others rely on analogical reasoning, leading to legal uncertainty and fragmentation.

Importantly, we found that jurisdictions which adopt a more functional approach (recognising control + transferability + traceability) deliver greater legal certainty and enforcement reliability. This supports the argument in (Keijser Thomas 2025) that international harmonisation efforts should accept blockchain ledger entries as *prima facie* evidence of ownership (Lehmann 2021). Thus, the proposed framework aligns with the emerging trend but operationalises it within civil law logic.

Integrated Framework: Control-Provenance-Liability

The proposed integrated framework of *control–provenance–liability* provides a doctrinal and functional synthesis for civil law adaptation to blockchain-based digital assets. Control, in this model, represents the factual and technical ability to access or transfer a digital asset via a private key, paralleling but not equating to traditional possession. Provenance introduces a novel evidentiary function that extends beyond the mere assertion of control it encapsulates the ledger-based traceability that authenticates transactional legitimacy and ownership continuity. Liability, the third pillar, reflects the redistribution of accountability across code, nodes, and network participants. This triadic model responds to the limitations of fragmented reforms that treat property and liability as isolated domains, instead proposing a unified analytical framework for both legal theory and practical governance.

Recent legal analyses (Keijser Thomas 2025; Kiskis Mindaugas 2024) affirm that this integrated perspective enhances both legal certainty and interoperability across jurisdictions by recognising blockchain records as *prima facie* evidence of ownership and identifying smart-contract

malfunctions as legal, not merely technical, breaches. In effect, the model provides a legal grammar for decentralised systems one that maps control to possession, provenance to title, and liability to enforceability, offering civil law jurisdictions a structured methodology to reconcile innovation with predictability.

The framework's novelty lies in transforming civil law's reactive posture toward technology into a proactive jurisprudential structure capable of guiding statutory reform. Rather than redefining ownership or liability in isolation, it conceptualises digital-asset transactions as a continuous legal process, where control initiates possession, provenance validates succession, and liability ensures restitution. By embedding these principles, civil law systems can operationalise accountability within automated environments without dismantling doctrinal coherence. This approach aligns with contemporary scholarship that calls for *functional equivalence* between traditional and digital property rights (Liu 2025), ensuring that blockchain innovations remain anchored to the fundamental objectives of private law: protection of legitimate expectations, transparency of transactions, and predictability of outcomes. Furthermore, it bridges normative and empirical domains by allowing legislators to draft provisions that accommodate decentralised enforcement mechanisms while preserving fault-based liability standards. Hence, the *control–provenance–liability* model does not merely reinterpret ownership and liability it re-engineers their structural relationship to reflect the decentralised, autonomous, and global nature of blockchain technology.

Comparative Advantages over Previous Research

This research contributes a significant advancement to existing scholarship by transforming the discourse on digital asset regulation from descriptive mapping to normative innovation. Unlike earlier studies that merely diagnosed legal uncertainty surrounding blockchain and property law (Norouzi 2022; Pulatov 2024), this article develops an integrated civil-law framework that merges empirical findings with doctrinal reform. The inclusion of practitioner perspectives through semi-structured interviews enriches the theoretical landscape by grounding legal propositions in the realities of technological implementation and market practice. Prior analyses, such as (Lee 2024) and (Martínez Luna et al. 2024), primarily addressed classification and recognition issues, whereas this research incorporates the evidentiary dimension of provenance and the liability

dynamics arising from smart contracts. Moreover, the comparative scope covering both European and Southeast Asian jurisdictions, extends beyond the territorial limitation of most prior works, providing a cross-systemic understanding of how legal pluralism influences blockchain governance. These innovations collectively elevate the study from theoretical abstraction to practical applicability, offering a cohesive framework that guides legislators, courts, and policymakers in harmonising digital-asset regulation under civil law systems.

Beyond comparative extension, the methodological synthesis of doctrinal analysis and empirical inquiry marks a paradigm shift in blockchain law scholarship. Earlier doctrinal approaches tended to isolate property from liability or relied heavily on hypothetical reasoning detached from operational realities (Lehmann 2021; Keijser Thomas 2025). In contrast, the present study bridges conceptual and practical dimensions by specifying the interdependent functions of control, provenance, and liability within decentralised transactions. This multidimensional perspective enables civil law to address issues of enforceability, third-party protection, and technological reliability in a single analytical framework. Furthermore, it advances the international conversation on harmonisation by demonstrating that civil law need not reject technological autonomy but can reinterpret it through normative coherence and evidentiary adaptation (Kiskis Mindaugas 2024; Liu 2025). The resulting framework not only provides a doctrinal blueprint for future legislation but also establishes an epistemic foundation for integrating blockchain governance within transnational civil law traditions. Hence, the research's comparative advantage lies in its capacity to combine empirical insight, theoretical rigour, and normative innovation into a single coherent model, thereby setting a new benchmark for studies on digital assets and private law adaptation.

Implications for Civil Law Reform and Policymaking

The contemporary evolution of blockchain-based assets necessitates a paradigmatic shift in civil law policymaking, demanding not only incremental regulation but structural transformation of core property doctrines. Legislators must explicitly recognise digital assets as legitimate objects of property rights when criteria of control, transferability, and traceability are satisfied, aligning with the broader movement toward functional equivalence between tangible and intangible property. As blockchain ledgers provide immutable transaction records, civil law

frameworks should incorporate such provenance as prima facie evidence of ownership, thus ensuring legal certainty in decentralized systems. This transition entails amending civil codes to accommodate the evidentiary function of distributed ledgers and to extend the notion of possession to include cryptographic control. The integration of these principles strengthens the enforceability of digital transactions and protects third parties who engage with tokenised or cryptographically secured assets (Kiskis Mindaugas 2024). Empirical findings across jurisdictions demonstrate that countries embracing functional reform, such as Indonesia's recognition of Bitcoin as an intangible movable property (Darmawan Kevin et.al. 2025), achieve higher legal predictability and cross-border interoperability compared to those adhering rigidly to traditional tangibility doctrines. Hence, a harmonised approach grounded in control, provenance, and liability principles offers an operational pathway toward modernising civil law systems in line with blockchain innovation.

Furthermore, civil law reform must address the liability vacuum inherent in decentralized and automated environments by embedding “smart-contract liability” and “node accountability” provisions within private law. This approach would ensure that damages arising from malfunctioning code or distributed consensus errors can be traced to a legally recognisable source of responsibility, thereby upholding fault-based principles within an autonomous framework (Napieralska & Kępczyński 2024). Policymakers should develop statutory presumptions for automated liability when human fault cannot be attributed, enabling fair compensation without stifling technological advancement. Additionally, transnational coordination through UNCITRAL or the Hague Conference should be pursued to align national laws governing digital assets and prevent jurisdictional fragmentation (United Nations Commission 2023). The implementation of these reforms will not only reduce litigation uncertainty but also reinforce market confidence in blockchain-based transactions. By integrating technological functionality with doctrinal precision, civil law can evolve from reactive adaptation to proactive governance, ensuring that innovation and accountability coexist within a coherent legal order (Keijser Thomas 2025).

Limitations and Future Research

Although this study integrates doctrinal and empirical insights across diverse civil law jurisdictions, certain limitations remain inherent to its design. The semi-structured interviews, while enriching the analysis with practitioner-based perspectives, are limited to selected continental European and Southeast Asian jurisdictions. Consequently, they may not fully capture variations in interpretative doctrines, enforcement practices, or systemic path dependencies across broader global civil law systems. Moreover, the rapid technological evolution of blockchain and smart-contract mechanisms may render some identified legal and operational risks transient, outpacing the ability of formal legal reforms to adapt. This temporal gap between technological change and normative adaptation constitutes an enduring methodological challenge for research in digital asset law.

Future research should expand the comparative horizon through longitudinal and multi-jurisdictional case studies on blockchain-related disputes and digital-asset enforcement outcomes. Cross-sectoral investigations particularly in Decentralised Finance (DeFi), tokenised real-world assets, and decentralised identity frameworks could refine the proposed control–provenance–liability model and test its practical interoperability. Additionally, empirical collaboration between legal scholars and technologists would allow for simulation-based testing of smart-contract failures and their legal consequences, providing an evidence-based foundation for liability calibration. Such interdisciplinary and longitudinal research is vital to developing harmonised doctrines of ownership and liability that remain responsive to technological transformation yet anchored in the principles of civil law coherence and legal certainty.

C. Conclusion

This research demonstrates that the emergence of blockchain-based digital assets demands a fundamental reconfiguration of civil law doctrines concerning ownership and liability. The proposed control–provenance–liability framework provides a novel juridical model that integrates cryptographic control, ledger-based provenance, and decentralised liability attribution into a coherent analytical structure. This framework not only bridges the conceptual divide between tangible and digital property but also

establishes a doctrinal foundation for harmonising legal certainty with technological autonomy. By combining comparative civil law analysis with empirical insights from practitioners, the study introduces a functional method for recognising ownership and allocating liability in decentralised environments, thereby transforming civil law's reactive stance into a proactive governance paradigm capable of adapting to blockchain's decentralised architecture.

The principal contribution of this research lies in its ability to move beyond descriptive classification of digital assets toward normative innovation in private law theory and practice. Unlike prior studies limited to jurisdictional mapping or regulatory description, this study offers a transnational and interdisciplinary synthesis that embeds accountability, traceability, and control within a unified legal structure. The findings underscore that civil law can evolve without sacrificing doctrinal coherence, aligning technological evolution with traditional objectives of fairness, predictability, and protection of legitimate expectations. Ultimately, the integrated framework proposed herein provides a sustainable pathway for reforming civil law systems worldwide, reinforcing their capacity to uphold justice and reliability in an increasingly autonomous and digitised global economy

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