COMPARATIVE LAW REVIEW

Comparative Law Review

VOL. 17 · N. 1 · 2026

SPECIAL ISSUE

European Law and Digital Technologies

ISSN
2038 – 8993

OPEN ACCESS JOURNAL

COMPARATIVE LAW REVIEW
The Comparative Law Review is a biannual journal published by the
I. A. C. L. under the auspices and the hosting of the University of Perugia Department of Law.

Office address and contact details:
Email: complawreview@gmail.com

Comparative Law Review is registered at the Courthouse of Monza (Italy) - Nr. 1988 - May, 10th 2010.

COMPARATIVE
LAW
REVIEW
VOL. 17/1 – 2026

SPECIAL ISSUE

European Law and Digital Technologies

Edited by Federica Giovanella

TOKENISING PROPERTY

*Edoardo D. Martino – Veronica Zerba**

TABLE OF CONTENTS

*This article examines how the blockchain technology reshapes the traditional contract-property divide in private law, leveraging on the peculiar features of non-fungible tokens (NFTs) and real-world asset (RWA) tokenisation. Building on foundational doctrines—*in rem *rights, the* numerus clausus *principle, and third-party notice—we show that blockchain enables the creation of* de facto *property entitlements, including exclusivity and enforceability against subsequent transferees, without State involvement or adherence to traditional publicity requirements. We label this phenomenon "tokenising property." Through illustrative examples, such as NFT royalties, we show how on-chain entitlements may override or bypass the allocation of rights under existing property regimes, raising coordination and enforcement challenges. Using a transaction cost framework, we assess the conditions under which tokenizing property can deliver efficiency gains and when it generates new frictions.*

Finally, we argue that blockchain regulation rather than private law reforms can reassert control over this new form of property by intervening directly in the technical layer of blockchain systems. This may help in ensuring consistency between tokenised entitlements and the broader legal order, as illustrated by the EU Data Act and the Liechtenstein Blockchain Act.

Keywords: property rights; incompatible contracts; tokenization; NFT

I. INTRODUCTION

In the past years, blockchain applications experienced an extraordinary development. Indeed, the operations that can be run on blockchain are not anymore limited to the issuance and exchange of virtual currencies. There is a whole new set of heterogeneous activities running on chain which were hardly imaginable when the Bitcoin white paper

* Edoardo D. Martino is Associate Professor of Law at the University of Amsterdam (UvA). Veronica Zerba is PhD Candidate at the University of Trento. This article is the product of shared reflections and thought between the authors. However, for the relevant institutional purposes, paragraphs 1, 2 and 3 can be attributed to Edoardo D. Martino; paragraphs 4, 5, 6 can be attributed to Veronica Zerba.

The authors would like to thank Ugo Malvagna, Filippo Sartori and Massimiliano Vatiero, Maddalena Rabitti. A previous version was presented at the 19th Italian Law & Economics Conference in Brescia, the comments of participants are gratefully acknowledged. All remaining errors are our own.

was first published,[1] such as smart contracts and decentralised autonomous organizations.[2] All these new applications came with the second generation of DLTs, starting with the Ethereum blockchain.[3] The key innovation of these new ledgers was to enable users to build their 'layer two' applications on the naked blockchain.[4]

This article specifically focuses on one of these innovations: non-fungible tokens (NFT). The key technological innovation enabling NFT is the possibility to encode tokens holding unique characteristics leveraging on different blockchain standards.[5] Traditional cryptocurrencies are fully fungible and, accordingly, each unit of Bitcoin or Ether is identical and replaceable with another unit of the same cryptocurrency. In contrast, NFTs are, as the name itself suggests, non-fungible so that each token is unique and distinct from all others.[6] Crucially, these tokens can uniquely represent either a digital asset, such as digital art, or a real-world asset (RWA), such as a piece of real estate or a commodity. The combination of NFTs and RWAs tokenization is still in its technological and business infancy but it holds an immense potential to reshape many industry segments and to challenge traditional institutions–chiefly, the institution of property.

In such landscape, we want to understand what criteria should drive a regulatory intervention on this technological innovation.

To do so, we show that the ability to encode non-fungible assets into tokens and to transfer these via smart contracts change the conditions in which the traditional contract-property divide operates–one of the basic tenets of private law. In fact, parties can privately design and encode rights into tokens and, thanks to the characteristics of the blockchain, these rights are automatically enforced upon the transfer of the token or other pre-specified contingencies. The strength of the automatic enforcement of encoded promises led many crypto enthusiasts equals code to law, following the famous *motto* 'the code is law' proposed by Lessing.[7] While we do not ascribe to such a draconian view, we want to investigate the intricate relationships between code and law.

Specifically, the phenomenon we are describing allows private parties to create new *de facto* property rights. We label this as 'tokenising property'. To steer clear of misunderstandings, this article does not aim to answer the question of whether and to what extent crypto assets can be object of property and the necessary legal amendments to embed crypto assets into the legal system.[8] Rather, we investigate the more structural impact of the,

[1] S. Nakamoto, *Bitcoin: A peer-to-peer electronic cash system*, available at <https://bitcoin.org/en/bitcoin-paper> (2008), last visited 24 July 2025.

[2] See, respectively, M. Vatiero, *Smart contracts vs incomplete contracts: A transaction cost economics viewpoint*, Computer Law & Security Review 1 (2022) and O. Borgogno, E. D. Martino. *Decentralised autonomous organisations: targeting the potential beyond the hype*, Law, Innovation and Technology, 19, (II, 2024), 392.

[3] V. Buterin, *Ethereum Whitepaper. Ethereum Whitepaper A Next-Generation Smart Contract and Decentralized Application Platform*, available at https://ethereum.org/en/whitepaper/ (last visited 24 July 2025).

[4] *Ibid*, 34.

[5] M. Kumar, B. Mondal, *Secure Non-fungible Token Marketplaces Using ERC-721*, In *International Conference on Computational Intelligence in Communications and Business Analytics*, Cham: Springer Nature Switzerland, 189 (2024).

[6] J. Fairfield, *Tokenized: The law of non-fungible tokens and unique digital property,* Indiana Law Journal, 97 (2022), 1261

[7] L. Lessig, *Code Is Law. On Liberty in Cyberspace*, Harvard Magazine, 1 (2000).

[8] See, for instance, UK Law Commission, *Digital Assets: Final Report*, available at https://lawcom.gov.uk/project/digital-assets/ (last visited 24 July 2025). For an academic perspective, see R. Sarel, *Property rights in cryptocurrencies: a law and economics perspective*, in North Carolina Journal of Law & Tech., 22 (2021), 389.

currently, most far reaching application of the blockchain technology on the institution of property.[9]

The article demonstrates the disruptive potential of 'tokenising property' and assesses its impact both on the legal system and on societal welfare. In so doing, we build on foundational function frameworks for the analysis of property rights, grounding the economic rationale for the contract property divide.[10]

Relevantly, similar issues arouse from the implementation of Digital Rights Management technology, which was used to protect the right holders in copyright law. DRM prevented the malevolent user to access protected content, allowing only the licensee. However, at the end it had the effect to widen the protection of the right holders beyond the scope of copyright law, as limited by general clauses such as fairness.

In this context the consistency between the digital and legal layer was often difficultly and insufficiently granted. This depended firstly on the lack of a clear-cut distinction between contract and property rights in the field, which often prevented an *ex ante* regulation of the technological layer. Secondly, the legislator was often unable to provide legal and factual access to the beneficiaries of the copyright exception[11].

The peculiarities of blockchain show the importance of our study. From the one hand, the *de facto* effects of tokenizing property potentially involve all rights traded on chain. Tokenising property may, in some instances, bring about efficiency gains, especially in downscaling transaction costs. However, the lost coercive power of the State in the creation and enforcement of property rights may allow for systematic externalization of costs and losses, decreasing the overall welfare and atomizing property entitlements[12]. From the other hand, the blockchain allows to simplify the problem in two respects. Firstly, as all rights traded are involved, it allows to consider situations where the limitations to the property rights are clearly set. Secondly, the DLT is highly programmable, immutable and traceable; this fosters a regulatory response that could help to reconcile the gap between digital and legal layer.

This exercise provides a strong analytical framework to assess the impact of property tokenisation especially on one key dimension–the extent to which the law can still shape property (i.e., '*erga omnes*') entitlements. We show that regulatory provisions on blockchain and smart contracts are the simpler way for the State to still exert control over property creation. In contrast, traditional property law will likely lose its grip given the limited scope of ex-post judicial enforcement, especially when it comes to the breadth of available remedies. The findings of this article are necessarily non-conclusive, given the partly anecdotal nature of the analysis and the impossibility of foresee the evolution of the technology in the future. Nevertheless, we provide a rigorous analytical framework to analyse the impact of tokenising property on traditional legal systems. This can be applied, *mutatis mutandis*, to new applications and upgraded technologies.

The rest of the article unfolds as follows. Section 2 sets the framework, discussing the traditional contract-property divide and mapping the economic justifications of the *numerus clausus* principle. Section 3 provides a brief explanation of the key technological

[9] D. North, *Institutions, institutional change and economic performance,* Cambridge University Press, Cambridge, 1990.

[10] H. Hansmann, R. Kraakman, *Property, contract, and verification: The numerus clausus problem and the divisibility of rights*, The Journal of Legal Studie, 2002, 31, S373 and T. Merrill, H. Smith, *Optimal Standardization in the Law of Property: The Numerus Clausus Principle*, Yale Law Journal, 2000, 110(1), 1.

[11] S. Bechtold, Digital rights managements in the United States and in Europe, American Journal of comparative law, vol. 52, 2004, 323 ff.

[12] M. Heller, *The tragedy of the anticommons: property in the transition from Marx to markets,* Harvard Law Review, 11, 621 (1998). See also F. Parisi, *Entropy in property*, American Journal of Comparative Law, 50, 595 (2002).

components for tokenising property, focusing on the automatic execution to the terms that define the relationship between the parties. Section 4 specifically explains the mechanisms for tokenising property, providing anecdotal examples of its growing importance in market practices. Section 5 analyses the remaining public grip in controlling the creation of property entitlements, focusing on how regulatory law has the potential to shape this new form of *de facto* property.

II. THE CONTRACT-PROPERTY DIVIDE

Modern Western legal traditions, with different paths and nuances, are rooted in Roman Law at least with regards to private law institutions. Therefore, to investigate the impact of technological disruptions on the institution of property, it is pivotal to introduce an analytical framework that captures the key design features shaping such an institution. In so doing, this section discusses the key 'design features' of property rights as opposed to contractual rights. This allows to appreciate how impactful tokenising property can be, vis-à-vis an institutional equilibrium built in centuries of business experiences. Notably, the contract-property divide is crucial in both civil and common law traditions, despite diverging details linked to the different ways in which these legal systems developed.[13] This latter remark makes the disruptions brought by tokenising property even more momentous.

We focus on three key design features: first, the *in rem* nature of property rights as opposed to the *in personam* nature of contractual ones (Section II.1); second, the *numerus clausus* system of property rights and the control of the State therein (Section II.2); third, the importance of notice towards third parties (Section II.3). Eventually, we discuss the economic justifications for the contract-property divide so to better position the analysis of the impact brought by tokenising property (Section II.4).

II.1 *In personam & in rem*

The key question for private law institutions tradition is the ways in which individuals exerts control on resources and the extent to which such control is limited. From this standpoint, the contractual or proprietary nature of individual rights over assets shapers the ways in which control can be exerted.

Property rights represent the strongest form of control over assets, ensuring that the owner can benefit from the asset as desired and excluding others from doing the same; in this case, the right insists on the asset itself–the right is *in rem*.[14] This results in the overlap between the thing object of the right and the right itself. This relational view links the right of the owner with a corresponding duty that compels an undetermined number of people–to the limit, the whole society members–not to interfere with the use of the good–the right is *erga omnes*.[15] Such a broad control over the asset is dense of further legal consequences. Chiefly, with regards to the remedies deviced by the State for protecting the property entitlement against breachers, they focus on injunctions and specific performance–

[13] H. Hansmann, R. Kraakman, cit., S402. For an introduction to the role of legal culture in comparative regulatory analysis, see E. D. Martino et al, *An analytical framework*, A. M. Pacces, E.D. Martino, H, Nabilou (eds.) *Comparative Financial Regulation*, Edward Elgar Publishing, Cheltenham, 8. (2025)

[14] R. Epstein, *Takings : Private Property and the Power of Eminent Domain*, Harvard University Press, Harward, 1985, 57 and ff.

[15] W. N. Hohfeld, *Fundamental legal conceptions as applied in judicial reasoning.* The Yale Law Journal, 26, (VIII, 1917)

proprietary remedies–and reflects the prevailing position recognized to the owner.[16] In contrast, contractual rights reflect a legally relevant relationship with a specified person or group of people that are bound by a specific agreement. Such a relationship usually materializes in an obligation that the grantor is required to discharge and that can be enforced against him in case of default. Accordingly, contracts usually bear no third-party effects, i.e., no other member of society is bound by the agreement between the private parties–the right is *in personam*. In this case, the remedies protecting the entitlement of the contractual parties are, by and large, based on the compensation of the damages caused by the default; injunctions and specific performance have a much more limited scope.[17]

Things become more entangled when adding two more variables: the possibility of devising partial rights on assets and the possibility to transfer such asset to a third party. Here the distinction between proprietary and contractual rights becomes extremely consequential. On the one hand, property rights have long been described through the metaphor of the 'bundle of sticks', whereby the full property of an assets can be divided into several specific rights, all supported by the *in rem* nature of property rights–such as the right to use; to manage; to exclude, to possess, to pass, and so forth.[18] Accordingly, the owner can dispose of its right as a whole or partially, by transferring one of the 'sticks' to someone else, with each stick maintaining the proprietary features of the right, including the possibility to enforce such (partial) rights against the whole world.[19] In contrast, if an asset burdened by a contractual right is transferred to a third party, that is transferred free of any burden.[20]

A simple example clarifies this point. *Adam* owns a piece of land that is adjacent to that of *Bernie*. He only needs to access his land during summer months, as it is where *Bernie* spends holiday. To satisfy Bernie's need, the parties can either establish a (property) right of easement, allowing *Bernie* to pass through *Adam*'s land. Alternatively, they can enter into a more complex agreement establishing when and under which conditions *Bernie* can pass through *Adam*'s land. Both structures fully satisfy both *Adam* and *Bernie*'s needs and are considered as equivalent by the parties. However, a few years later, *Adam* transfers the land to *Chloe*. After the transfer, does *Bernie* still have the right to pass to *Chloe*'s land? As most of legal questions, especially when fictional, the answer is 'it depends'. Crucially, it depends on the nature of *Bernie*'s right of passage. In most jurisdictions, an easement is considered a property right: the right of passage for specific days or periods of the year are considered contractual rights. Therefore, upon the transfer, *Chloe* is burdened by the property rights attached to the land, not by the contractual relationship between the previous owner and a third party. The reason why some rights have a proprietary nature and other not is further discussed later on. At this point, it is important to underline that an extremely consequential implication of the *in rem* nature of property rights is that these run with the asset, which means that they "survive unaltered through all kinds of transactions and transformations dealing with other rights" on the same asset.[21] In contrast, contractual rights only bind contractual parties and not subsequent transferees.

[16] G. Calabresi, D. Melamed, *Property Rules, Liability Rules, and Inalienability: One View of the Cathedral*, Harvard Law Review, 85(6), 1089, 1092 (VI,1972).
[17] H. Hansmann, R. Kraakman, cit., S413.
[18] H. Demsetz, K. Lehn, *The structure of corporate ownership: Causes and consequences*, Journal of Political Economy, 93, 1155, (VI, 1985); see also A. Dorfman*, Property and collective undertaking: the principle of "numerus clausus*, The University of Toronto Law Journal, 61, 467 (III, 2011).
[19] R. Epstein, cit., 57 and ff.
[20] B. Arruñada, *Property Enforcement as Organized Consent*, Journal of Law, Economics, & Organization 19, 401, 408. (II, 2003)
[21] Ibid, 404.

As we shall see later in this article, tokenising property relaxes this constraint, posing a first significant challenge to the traditional institution of property. To understand why this is so relevant, we need to go back to the earlier unanswered question: why only some rights can be '*in rem*'?

II.2 *The 'numerus clausus' principles*

Why is a general easement of passage on land considered a property rights while a more specific contract allowing a party to pass through a piece of land on specified days or period of the year is commonly considered a contractual right? The answer to this question, however unsatisfactory this may appear, is tautological: because only the specific rights recognized by the legal system as property rights are *in rem* and *erga omnes*. This is known as the *numerus clausus* principle. In all modern jurisditions, including common law ones, "property rights are limited in number (…) and in content" so that "private parties must choose from a predefined set of property rights of which the content is already pre-established, to a considerable degree".[22] In contrast, parties enjoy wide freedom in the design of contractual obligations, with the external limits of not infringing recognized property rights and–especially in the past decades–complying with regulatory provisions.
In modern western legal systems, the *numerus clausus* principle emerges as a push back to the feudal system which was based on the power of the lord to allocate specific powers to specific people, realizing an excessive parcelization on the control of resources. This development is connected to the raise of the middle class of merchants and entrepreneurs in ladder.[23] Therefore, it can be considered one of the basic tenets of modern societies. In this context, the possibility to establish partial property rights was limited as it imposes long-lasting burden on assets[24]. Accordingly, partial property rights were always associated with some central power, granted to the executive or the judicial branch, to unify property rights ex post: think for instance of eminent domain or the judicial dissolution of co-ownership[25].
The *numerus clausus* principle marks the control of the State over the creation of property rights – i.e., of rights that can be coercively enforced against all members of the society. This is consistent with the premises of the Westphalian State as well as with the constitutional approach to private property in the post WWII constitutional democracies. Unsurprisingly, tokenising property holds challenges for the public control over the creation of property-like entitlements, therefore challenging the *numerus clausus* principle. Section 2.4 discusses the economic rationale for the current contract-property divide and further details the dense implications of the existence of the *numerus clausus* principle. Before doing so, it is necessary to look at the information dynamics linked to the contract-property divide and, specifically, to the dissemination of information required to rightfully establish property rights on an asset.

[22] B. Akkermans, The Numerus Clausus of Property Rights, M. Graziadei, L. Smith (eds.), *Comparative Property Law: Global Perspectives*, Edward Elgar Publishing, Cheltenham, 100 (2017). For common law specifications, see H. Hansmann, R. Kraakman, cit., S404.
[23] S. van Erp, Sjef, *Contract and property law: distinct but not separate*, European Property Law Journal, 2, 240 (III, 2013).
[24] H. Hansmann, R. Kraakman, cit., S375.
[25] *Ibid*, S418.

II.3 *Third-party notice*

If a right is enforceable *erga omnes* and runs with the asset in case of subsequent transfer, then all members of society must be put in the condition of knowing who holds property entitlements over such asset. This is the necessary condition for rights to bind third party.[26] Therefore, each property right recognised by the State as such is accompanied by a specific notice mechanism. In contrast, the privity of contract justifies simpler and less formal ways to keep track of parties' reciprocal rights and obligations.[27]
Crucially, parties do not have the freedom to choose the notice system they deem fit, but to validly establish property rights they need to abide by the specific notice mechanisms elected by the political power. The *in rem* nature of the rights directly derives from the observation of the formalities required by the legal system in disseminating the information about the establishment of the right itself.[28] This introduces a ritual element in the establishment of property entitlements in a way that is not dissimilar from ancient Roman forms to transfer property, such as the *mancipatio*.[29]
Therefore, the *numerus clausus* system of property rights goes hand in hand with codified formalities to disseminate information about the establishment of property entitlements. The examples are countless: for the property on movables, good faith possession is usually considered a sufficient notice to third parties, for real estate property the rightful transcription in public registries of the deed of transfer is constitutive of the right to property. In a similar vein, the contract establishing a business organization is granted proprietary features, such as limited liability, only if correctly listed in the business register according to the procedure prescribed by the legal system.[30] The constitutive nature of these formalities allows to govern potentially incompatible contracts granting, for instance, the same property entitlements to different individuals. Only the right established following the prescribed formalities is protected *erga omnes*, including those who acquired the right without following such formalities.[31] Therefore, the *numerus clausus* principle and the notice requirements can be understood as a way to govern incompatible contracts.[32]

II.4 *The contract-property divide: economic justifications*

We have sketched the defining features of the contract-property divide, highlighting how it is the result of centuries of legal evolution. Assessing the economic rationale of this equilibrium is crucial to, eventually, analyse the impact of tokenising property on welfare. A complete analysis of all welfare implications of the property system is clearly out of the scope of this contribution. However, the key elements at play can be easily derived from the seminal and Nobel Prize winning contribution by Ronald Coase. In his work, Coase demonstrates that transacting property rights over assets leads not only to mutually beneficial outcomes for the transacting parties, but also to social welfare maximisation,

[26] C. Rose, *What government can do for property (and vice versa)*, N. Mercuro, W. Samuels (eds), *The fundamental interrelationship between government and property*, Routledge, London, 213 (1999).
[27] H. Hansmann, R. Kraakman, cit., S383.
[28] B. Arruñada, *Property Enforcement,* cit., 411.
[29] B. Arruñada, *The Institutions of Roman Markets*, G. Dari-Mattiacci, D. Kehoe (eds.), *Roman Law and Economics*, Oxford University Press, Oxford, 247, 255.
[30] J. Armour, John, M. J. Whincop, *The proprietary foundations of corporate law*, Oxford Journal of Legal Studies, 27, 429, 450 (III, 2007).
[31] B. Arruñada, *Property Titling and Conveyancing*, K. Ayotte, H. Smith (eds.), *Research Handbook on the Economics of Property Law*, Edward Elgar Publishing, Cheltenham, 237 (2011)
[32] G. Dari-Mattiacci, *The theory of business organizations*, A. Badawi (ed.), *Encyclopedia of Law & Economics*, Edward Elgar Publishing, Cheltenham, 8, 14 (2023).

handling the 'problem of social cost'–i.e., externalities.[33] This is in line with the new institutional economic analysis that approaching institutions – such as property – as a set of formal or informal rules that giving structure economic cooperations in modern societies.[34]

Transacting around property rights can maximise social welfare only under two specific assumptions: first, the costs of transacting must be negligible; second, the allocation of property entitlements before the transaction takes place must be clear.[35] The extent to which these two assumptions are satisfied defines the social efficiency of private bargaining.

Looking at the contract-property divide and the *numerus clausus* principle, the literature has proposed two main interpretations. On the one hand, a closed system of property, centred around the *numerus clausus* principle, generates a remarkable level of standardization that, in turn, reduces transaction costs. Standardized property rights limit the additional information that third parties would need to acquire to ascertain the nature and the value of the asset and, consequently to transact on the asset and allocate it to whom valuer it the most.[36] In this perspective, the State must trade off the benefit of standardization with the costs of the inflexibility of the *numerus clausus* system, adapting the menu of rights with *in rem* effects accordingly.

On the other hand, many see that the standardization of rights and entitlements is more a myth than a reality and, in any case, not the decisive variable to justify a closed system of property rights.[37] In contrast, the *numerus clausus* principle as complemented by third-party notice mechanisms allows all members of society potentially interested in transaction on the assets to clearly ascertain the allocation of property rights over such asset.[38] Such mechanisms work as rules that parties and courts can use to solve both the problems of coordination and enforcement. The first refers to the correct understanding of the allocation of rights on an asset, the second refers to the enforcement of the right against opportunistic behaviour. This literature has identified relevant trade-offs between the third-party notice mechanism (and the information they are able to convey) and the costs connected with their establishment and use[39]. In this perspective, the *numerus clausus* principle is crucial to ensure that property rights are clearly defined *ex ante* and enforceable *ex post*, and, thence, negotiable. Against this background, we analyse the impact of tokenising property and the challenges it brings to the traditional system of property described in this section. Before moving to this analysis, Section 3 introduces in a brief and functional manner the key technological features surrounding tokenising property.

[33] R. H. Coase, *The Problem of Social Cost*, in The Journal of Law & Economics, 3, 1 (1960).
[34] D. North, cit., 61 and ff.
[35] F. Parisi, *Coase Theorem*, in *New Palgrave Dictionary of Economics*, S. N. Durlauf, L. E. Blume (eds), Palgrave Macmillan, London, 859, 863 (2008).
[36] T. Merrill, H. Smith, cit., 24.
[37] H. Hansmann, R. Kraakman, cit., S401.
[38] *Ibid*, cit., S382.
[39] *Ibid*, cit., S382

III: THE BLOCKCHAIN TECHNOLOGY AND THE INSTITUTION OF PROPERTY

III.1 *The technological building blocks*

Tokenising property, i.e., the technical possibility for private individuals to design and customise *de facto* property rights over (digital) assets, requires a wealth of technological capability. This section briefly introduces the building blocks necessary to this end.
First, blockchain technology is a necessary pre-requisite for tokenising property. To appreciate the importance of this technological advancement, it suffices to recall that the idea of 'smart property' is not completely new but was already theorized at the end of the 90s as the possibility of controlling real world resources through a protocol.[40] However, doing so would require technological capabilities unknown at the time. Specifically, the blockchain technology features two key characteristics that facilitates tokenising property. First, the distributed ledger, where data representing digital assets is recorded and stored. Second, the consensus protocol that allows the nodes of the network to amend the ledger, adding new blocks which are, in turn, stored and timestamped. The consensus protocol requires the node of the blockchain to invest resources, either computational or financial, to validate the transaction, making sure that the transaction is uniquely carried out, solving the 'double spending' problem.[41] In the context of the contract-property divide, the consensus mechanism can be understood as a device to govern incompatible transactions: only the transaction validated through the mechanism is valid and implemented on the ledger.[42] Therefore, the blockchain is an inherently transactional technology, perfectly fit to allocate rights over (digital) assets and determining who has control over them.[43]
The initial blockchain, the Bitcoin one, only allows for transacting its native token–the Bitcoin. However, this would not be enough for tokenising property as it does not allow for the customization of rights and for the transfer of assets other than the native token. Therefore, smart contracts are the second necessary building block for tokenising property. Unsurprisingly, the theorisation of smart contract dates back to the pre-blockchain era and were first defined "a set of promises, specified in digital forms, including protocols within which the parties perform on these promises".[44] In other terms, smart contracts can be understood as promises encoded in machine readable scripts and formulated in 'if *X* then *Y*" form. These were first embedded in the Ethereum blockchain which allowed to set the terms for the computational execution of a relationship between two or more users through complex operations, and is deployed and executed as an on-chain transaction.[45] Once again, to steer clear of misunderstanding, the discussion about the legal classification of smart contracts is not within our scope.[46] What is relevant for tokenising property is the technical possibility for parties to devise promises that are self-enforceable on-chain when the encoded condition materialize and when the resulting amendment of the ledger is validated through the consensus protocol.

---

[40] N. Szabo, *Formalizing and securing relationships on public networks*, First Monday, 2 (IX, 1997).
[41] M. Xie et al., *A survey on blockchain consensus mechanism: research overview, current advances and future directions*, in International Journal of Intelligent Computing and Cybernetics, 16, 314 (II, 2023).
[42] A. Wright, P. De Filippi, *Decentralized Blockchain Technology and the Rise of Lex Cryptographai,* 7, (2015) available at https://ssrn.com/abstract=2580664 (last visited 24 July 2025).
[43] E. D. Martino, W. G Ringe, *The Social Cost of Blockchain: Externalities, Allocation of Property Rights, and the Role of the Law*, in European Journal of Risk Regulation, 1, 7 (2025).
[44] N. Szabo, cit.
[45] V. Buterin, cit., 11.
[46] For that see, among other, R. De Caria, *The Legal Meaning of Smart Contracts*, European Review of Private Law, 2019, 26 (6), 731.

One additional building block for tokenising property is the ability to transfer the control over assets. Leveraging only on the blockchain and smart contracts parties would be able to transact only on cryptocurrencies and utility tokens. While this is already noteworthy, it lacks the breadth and depth to challenge the institution of property itself. Therefore, the possibility for tokens to uniquely represent either digital or real assets is crucial. This is why the advent of non-fungible tokens (NFTs) holds more disruptive potential than one would think only looking at the rise and fall of the art NFT industry between 2021 and 2023.[47] The possibility of transacting over tokenised non-fungible goods is a fully technical problem that has, indeed, been solved technically through the development of new blockchain protocols, specifically the ERC-721 protocol. The use of this protocol allows for attaching a unique identifier to each token.[48] This technical functionality makes NFTs suitable for encoding singular entitlements and mimicking the exclusivity of traditional proprietary rights and, consequently, opening the door to tokenising property.
Finally, one last necessary building block is the possibility to transact a wide variety of assets on chain, including real world assets. The development of real-world asset (RWA) tokenisation is the most ambitious and the most early-stage element of the construction we are analysing.[49] RWA tokenization requires to represent off-chain assets—ranging from commodities or securities to real estate—through on-chain tokens. Both fungible and non-fungible digital tokens can be used for this purpose, depending on whether the underlying asset is homogeneous or uniquely identifiable. The development of RWA tokenisation has both a technical and legal component. On the technical side, of course, it requires reliable mechanisms for linking the digital token to its off-chain counterpart, ensuring that the token exactly identifies the specific asset it represents. On the legal side, the link between the token and the specific asset must be valid, guaranteeing that on-chain transfers correspond to changes in ownership off-chain.

III.2 *Freedom of code, automatic enforcement & de facto property*

How can the technological building blocks for tokenising property allows to reproduce on-chain the key features traditionally associated with property rights thereby enabling the creation of *de facto in rem* entitlements? This section tries to connect all the elements introduced so far and, in so doing, offering a grounded analytical bedrock for the proceeding of the article.
Programmable smart contracts allow parties to encode their promises through "if *X* then *Y*" statements. This allows to an extremely high level of sophistication and customizability of these promises keeping transaction costs fairly low. The automatic enforcement guaranteed by the consensus mechanism is the key game changer, eliminating the need for an external coercive apparatus at the point of performance.[50] In fact, standard contractual obligations are guaranteed by *ex post* enforcement through courts; encoded promises are self-executing: the obligation is automatically performed when the encoded conditions are met. This is possible thanks to the consensus mechanisms of the blockchain: once a transaction is validated and recorded on the distributed ledger, it becomes effectively

[47] J. Fairfield, cit., 1268.
[48] X. Tan et al., *Bubble or not: an analysis of ethereum erc721 and erc1155 non-fungible token ecosystem*, International Symposium on Circuits and Systems (ISCAS), IEEE, 2024, 1.
[49] H. S. Shin, *Tokenisation for the real world*, OCC Symposium on the "Tokenization of Real-World Assets and Liabilities", Washington DC, 2024, available at https://www.bis.org/speeches/sp240209.htm (last visited 24 July 2025).
[50] M. Vatiero, cit., 3.

immutable and enforceable within the network.[51] Notably, the ability to hard-code (partial) entitlements within the asset itself effectively mimic the "bundle of sticks" in a digital token. In this setting, the rights and duties encoded in the token runs with it and are enforced at any subsequent transfer.

Compared to the off-chain system, the power of the State in enforcing property rights is by and large substituted by cryptographic and computational consensus. The blockchain can provide a degree of reliability in executing entitlements that rivals, and in time may even surpass, traditional property enforcement. Finally, on-chain transactions are recorded, immutably, on the ledger effectively providing notice of the transfer of (partial) ownership over an asset. The information is technically accessible to all network participants, reducing the risk of hidden encumbrances and strengthening the expectation that entitlements are respected, as long as the blockchain is permissionless.

To appreciate the remarkable paradigm shift of tokenising property, it is useful to reframe the example of Section 2.1. In a (not so) dystopian future, *Adam* has tokenised his piece of land. *Adam* and *Bernie* encode in a smart contract *Bernie*'s right to pass through the land during summer months and attaches this promise to a "tokenised land" asset. When *Adam* transfers the tokenised land to *Chloe*, the token is burdened by the partial encoded right of *Bernie*; hence, it automatically binds *Chloe*. In this example, the right of Bernie to pass through a specific piece of land only during summer months runs with the tokenised asset and is, thereby, enforced *erga omnes*, a result that is not possible under the traditional contract-property divide, unless the *Bernie*'s right is part of the limited menu of rights to which the State assigns proprietary nature Nonetheless, challenges remain. Tokenisation cannot, by itself, prevent the coexistence of conflicting on-chain and off-chain rights. While code can govern entitlements within the network, it cannot unilaterally resolve conflicts with rights recognised–or created–outside it. These frictions underscore the hybrid nature of tokenised property: it emulates the core attributes of *in rem* rights yet lacks the full coherence and integrative power of State-sanctioned property law, at least under the current legal systems.[52]

IV: A NEW CONTRACTUAL ENVIRONMENT

IV.1 *Contractual rights running with the asset*

The blockchain environment applied to contracts yields a whole new landscape for the generation and transmission of rights through (smart) contracts.[53] The key features of this environment are transparency, immutability and – most importantly for this contribution – automatic enforcement of the encoded promises.

For a more concrete understanding of such a disruptive contractual environment, a real-life example of tokenising property helps. Consider the case of the art market, both the off-chain version through traditional sales of pieces of arts, and the on-chain one through the sales of NFTs representing pieces of digital art. In the US the monetary rights (i.e.: royalties) of the artist on its art are contractual.[54] This means that artists are weakly protected upon resales, as they have no recourse against the second buyer and can only

[51] A. Wright, P. De Filippi, cit., 11.

[52] S Bechtold et al., *Property Without Law. Personalized Property Rights Through Smart Contracts on the Blockchain*, Yale Journal on Regulation (forthcoming).

[53] E.D. Martino, W.G. Ringe, *cit.,* 13. See also S. Davidson, P. De Filippi, J. Potts, *Blockchains and the economic institutions of capitalism*, Journal of Institutional Economics, 14, 655 (2018).

[54] H. Hansmann & M. Santilli, *Royalties for Artists versus Royalties for Authors and Composers*, in Journal of Cultural Economics, 25 (2001), 261.

sue the original buyer for damages. In contrast, in the EU, royalties are recognized as property right according to the Resale Rights Directive.[55]

In the on-chain market for art, the NFT exchanges for digital art attempted to solve this problem, tokenising the entitlement to receiving royalties upon resale and making it a *de facto* property right. These exchanges were first established in dedicated marketplaces, such as Opensea and Rarible, where artists could opt for a fee, determined as percentage of the price, in the piece of digital art and bind the subsequent purchaser[56]. This option allowed to tokenise the (property) right to royalties but was fairly easy to arbitrage, as the NFT could be wrapped in another token without the royalty option, or moved to a competitor that did not enforce royalties. Therefore, the marketplaces decided not to implement this option anymore. In response to this, the blockchain community created a specific standard for art tokens, the ERC721C – where C stands for Creator – designed to encode the royalties immediately in the smart contract regulating the NFT transactions. These functions close the arbitrage opportunity and allow the original creator to receive a percentage of the sale prize whenever the NFT is transferred, as the fee provision in the smart contract regulates the relationship with subsequent transferees and gives automated enforcement to the creator's claim, making the tokenization of the right to receive royalties upon resale effective.[57] In fact, the effects of the transfer of an NFT are comparable with *in rem* entitlement and this derives directly from the NFT's technical features.

Comparing the outcome of the on-chain tokenization of the right to royalties US law, the disruptive potential of tokenizing property becomes clear: even in the absence of legally sanctioned property rights, artists can have *de facto* property protection. It is important to notice that the royalties embedded in the smart contract is only the last attempt to reach the same result. In the 1970s, the «Projansky contract»[58] (also known as the «Artist's contract»)[59] was conceived for the same purpose[60]. It provided a template contract where a clause provides that in case of resale of the work of art, the original buyer is bound not only to pay to the artist a royalty of a certain amount, but also to use the same contract form in any future sale, so that the subsequent buyer will be bound to the same terms (royalties included).

Looking at the differences between off-chain and on-chain contractual solution helps to further highlight the disruptive potential of tokenizing property. Firstly, while the Artist's contract was seldomly used, this function is widespread in the community. Secondly, the Artist's contract was difficult to enforce in courts, because the courts themselves were suspicious of such a stretch of typical contractual rights effects[61]. In contrast, in the blockchain the automatic execution provided by the code prevents the breach of the provision and ensures the protection of the artist. Given the characteristics of the DLT, an opposite transaction would be required to grant an absolute control to the subsequent

[55] See Art. 1(1) of the EU Resale Rights Directive (Directive 2001/84/EC of the European Parliament and of the Council of 27 September 2001 on the Resale Right for the Benefit of the Author of an Original Work of Art, 2001 OJ (L 272) 32.

[56] Opensea, For developers, Setting fees on secondary sale, https://docs.opensea.io/docs/10-setting-fees-on-secondary-sales updated 03/2023.

[57] A. Kutsenko, *ERC721C, a new approach to royalty payments*, at https://metalamp.io/magazine/article/erc721c-a-new-approach-to-royalty-payments-2, 3.06.2025, last visited 21.07.2025

[58] E. Harris, *Mint, sell, repeat: Non-fungible tokens and resale oyalties for Indigenous artists*, in Alternative Law Journal, 48, 11 ff. (I, 203); L. Van Haaften-Schick, A. Whitaker, *From the Artist's Contract to the blockchain ledger: new forms of artists' funding using equity and resale royalties*, in Journal of Cultural Economics, 46, 287. (II, 2022).

[59] The contract can be found at https://primaryinformation.org/product/siegelaub-the-artists-reserved-rights-transfer-and-sale-agreement/.

[60] B.L Frye, *Equitable Resale Royalties* in Journal of Intellectual Property Law, 24 237 ff. (II, 2017).

[61] B.L Frye, *Equitable Resale Royalties,* 246 ff.

transferee, as such requiring the consent of the beneficiary. In this scenario, contractually created rights effectively run with the asset, a characteristic that only state sanctioned property rights can have off chain.

The on-chain tokenization of property rights may collide with off chain legal property. We can think at least of two examples. First, the content of the on-chain claim may not be compatible with a property right as established by law off chain; second, the legal publicity requirements to create property rights off chain are not satisfied. In this latter case, a transfer on chain alone could not immediately confer a legal property to the recipient but require the fulfilment of the applicable publicity rule and, when necessary, the collection of the consent of every property right owner.[62] In the former case, the tokenisation of real-world asset further complicate the matter: off-chain transactions are not constrained by the consensus mechanism so that it is in principle possible that incompatible rights are granted on chain and off chain. Due to the control exerted on the asset through DLT technology, the smart contract will always grant a substantial advantage, regardless of the classification of the claim as a property or contractual right. In this context, DLT technical features will hinder the enforcement of legal provision, even after judicial proceedings, leaving only damages remedies and making injunctions unavailable.[63] Blockchain offers a powerful tool to grant to others a substantial control on (tokenized) physical and digital resources, publicly recorded on a DLT ledger and automatically executed, altering the traditional economic justification of the *numerus clausus* principle: namely, the necessity to give a solution to the coordination and enforcement problem, and the deriving transaction costs.

IV.2 *A transaction cost analysis*

Transaction costs are determined by the interaction of legal and informal constraint and how contracts are enforced[64]. Relevantly, they can derive from discrepancies between the technology functioning and legal rules. When DLT is concerned this is recurrent, due to the difficulty (or impossibility) to effectively replicate legal rules (national-bound) through technical layers (internet based)[65].

When the technology clashes with legal institutions and hinder their functioning, it can also alter the equilibrium of the market for the allocation of entitlements, resulting in deadweight losses and inefficient allocation as a direct consequence of the automatic enforcement guaranteed by smart contracts.[66]. On the other hand, smart contracts can also provide a solution to the coordination and enforcement problems, going beyond the *numerus clausus* principle. In fact, smart contracts also provide publicity, automatic

[62] B. Arruñada, *Blockchain's Struggle to Deliver Impersonal Exchange* in Minnesota Journal of law, Science and Technology 19, 55 ff. (I, 2018); R.M. Garcia-Teruel, H. Simón-Moreno, *The digital tokenization of property rights. A comparative perspective* in Computer Law & Security Review, 41 (2021); O. Borgogno, E. D. Martino, *cit.*

[63] This rewrites some of the most foundational analysis about property and liability rules. See G. Calabresi, D. Melamed, *Property Rules, Liability Rules and Inalienability: One View of the Cathedral*, Harvard Law Review, 85 (1972).

[64] D.C. North*, cit.*

[65] E. Tjong Tjin Tai, *Smart Contracts As Execution Instead of Expression* J.G. Allen & P. Hunn (eds.), Smart Legal Contracts, Oxford University Press, Oxford 2022, 222. The author actually suggests that is sterile to even attempt such an operation, given the advantages brought by smart contracts of "simply attaching factual consequences to the fulfilment of certain conditions".

[66] H. Eenmaaa-Dimitrieva, M.J. Schmidt-Kessen, *Creating Markets in No-Trust Environments: The Law and Economics of Smart Contracts*, Computer Law & Security Review: The International Journal of Technology Law and Practice, vol 35, 2019, 69-88. The author brings many examples – one for all, the impossibility to verify whether the consent of one of the parties is defective.

execution and are characterized by a necessary internal consistency. Therefore, understanding the net impact of DLT contracting on transaction costs is not straightforward,

On the one hand, the DLT technology provides an easy access to reliable information concerning the features of the token and its previous transactions on chain. The availability of browsers that search public ledgers levels the playing field between users and non-users. This substantially reduces search costs, minimizing adverse selection or the possibility to transact on assets burdened by competing claims, as long as they are recorded and traded on chain. In this instance, the blockchain reduces the need to build reputational capital and to rely on traditional intermediaries[67]. In the enforcement phase, the automatic execution relieves parties from the cost of monitoring the counterparties to detect defaults.[68]

On the other hand, the DLT technology can also increase transaction costs. Firstly, its immutability and automatic execution result in lack of flexibility. It must be noted that, while parties can take into account a great variety of contingencies, there will be always limitation determined by human failure. In other terms, smart contracts cannot be perfectly contingent: contracts remain incomplete and, unlike the off-chain environment, do not provide flexibility for adaptation.[69] Moreover, any efficient breach would be automatically prevented.[70] Finally, the phrasing of the smart contract as a code will also deprive the parties from the shades of the legal language, providing only for on/off solutions[71].

In addition to the transaction costs borne by the contracting parties, there can be significant externalities. The use of consensus mechanism leads to environmental concern, due do its consumption of energy and water[72]. Moreover, the necessity to check for tokenisation by non-users raise questions on digital literacy: as the population is averagely becoming older and older, it is impossible to imagine that the blockchain will be so widespread (and elder-friendly) that everybody could access easily such new technologies, at least at the moment.

From the existence of not negligible transaction costs that arise from tokenizing property, we can infer that the *numerus clausus* principle may still be economically justified. However,

---

[67] C. Catalini, J.S. Gans, *Some simple economics of the blockchain* in NBER Working Paper Series, Cambridge, (2016 revised 2019), available at http://www.nber.org/papers/w22952; J. McMurren, A. Young, S. Verhulst, *Addressing Transaction Costs Through Blockchain and Identity in Swedish Land Transfers* (2018) available at https://blockchan.ge/blockchange-land-registry.pdf (last visit: 1st February 2026).

[68] D. Tapscott, A. Tapscott, *How blockchain will change organizations* in MIT Sloan Management Review, 58 (II, 2017) available at https://sloanreview.mit.edu/article/how-blockchain-will-change-organizations/; S. Davidson, P. de Filippi, Primavera, J. Potts *Economics of Blockchain* in Public Choice Conference, May 2016, Fort Lauderdale, United States; C.G. Schmidt, S.M. Wagner, *Blockchain and supply chain relations: A transaction cost theory perspective,* in Journal of Purchasing and Supply Management, 25 (IV, 2019).

[69] M. Vatiero, *Smart contracts and transaction costs*, Discussion Papers del Dipartimento di Economia e Management – Università di Pisa, n. 238, 2018 http://www.ec.unipi.it/ricerca/discussionpapers.html; M. Vatiero, *Smart contracts vs incomplete contracts: A transaction cost economics viewpoint*, in Computer Law & Security Review, 46 (September, 2022) 1 ff.; J.M. Sklaroff, *Smart Contracts and the Cost of Inflexibility,* University of Pennsylvania Student Papers, Prize Winning Papers n. 9, 2018, https://scholarship.law.upenn.edu/prize_papers/9.

[70] E. Mik, *Smart Contracts: Terminology, Technical Limitations and Real World Complexity*, 12 (2017), Available at SSRN: https://ssrn.com/abstract=3038406; H. Eenmaaa-Dimitrieva, M.J. Schmidt-Kessen, *cit.,* 40 ff.

[71] M. Vatiero, *Smart contracts and transaction costs*, cit.,11; J.M. Sklaroff, *cit.*, 282 ff.

[72] D. Ramirez-Escudero, *Bitcoin's water consumption is an environmental threat?,* https://cointelegraph.com/news/bitcoin-water-consumption-environment-adoption, last visited 28/07/2025.

finding the right balance between on chain property tokenization and off chain property guided by the *numerus clausus* principle is, again, a complex exercise.[73]
The potential differences between the legally provided allocation of rights and the technological allocation of resources are clearly a new source of transaction costs that should become part of any cost-benefit analysis when considering the desirability of State intervention. In fact, in case of competing on-chain and off-chain claims on the same asset the impossibility to edit the chain, would require the parties either to enter into an equal and opposite on chain transaction or to grant the owner the control of the blockchain account ex ante.[74] As a consequence, the absence of a *numerus clausus* on-chain leads to an extraordinary increase in the number of transactions and entropy in property, with the creation of too many tokenized rights enjoying property-like status.[75]

Furthermore, the enforcement of legal rights can become increasingly problematic. Since on chain promises are self-executing, courts may be extremely restrained in the type of remedies they can adjudicate outside of what has been encoded: all mandatory rules would be set by the parties and not by the law. It is technically possible to provide for some flexibility in the code, allowing judges to intervene, but this depends entirely on the parties' willingness.[76] Thereofre, the power of the judge would arise *if and only if* the parties agree to it ex ante, and *if and only if* they *allow* judicial authorities to take control of the tools. This looks much more like an arbitration clause that the standard powers of the judiciary.

IV.3 *Possible private law solutions*

The use DLTs and smart contracts to allocate tokenised entitlements that enjoy property-like protection alter the dynamics between contract parties and affect transaction costs. This questions the *numerus clausus* principle, both when understood as a standardization tool and as a way to solve issues arising from incompatible contracting.

When facing this challenge, legal systems have two options to try and achieve optimal legal solutions through private law, so to ensure that entitlements are allocated to parties that value them the most. The first approach can be labelled as "do nothing approach", where a jurisdiction accepts this change while not addressing it directly. This first approach can be found in several legal systems. For instance, the UK Jurisdictional Task Force has adopted a Legal Statement in 2019 for transactions of native digital assets, recognizing that crypto-assets can be the object of property but, at the same time, considering DLT records as merely presumptive and unable to "be treated as a definitive record of legal rights".[77] Finally, a bill has been passed that introduces a third object of property beyond the traditional categories of things in action and things in possession in order to accomodate digital assets as the object of property.[78] Such principle is already judicially sanctioned[79] and the bill would simply provide it with statutory recognition without altering the essence

[73] E.D. Martino, W.G. Ringe, *cit.*
[74] J. Woxholth, D.A. Zetzsche, R.P. Buckley, D.W. Arner, *Competing Claims to Cryptoassets*, University of Hong Kong Faculty of Law Research Paper No. 2023/27, Available at SSRN: https://ssrn.com/abstract=4394952 or http://dx.doi.org/10.2139/ssrn.4394952.
[75] F. Parisi, *Entropy in Property*, American Journal of Comparative Law, 50 (2002).
[76] O. Meyer, *Stopping the Unstoppable - Termination and Unwinding of Smart Contracts, in* Journal of European Consumer and Market Law, 9, 17 ff. (2020).
[77] UKJT, *Legal statement on cryptoassets and smart contracts,* pt. 132 ff, 30. M. Lehmann, *National blockchain laws as a threat to market integration*, in Uniform Law Review, 26, 157, (2021).
[78] Property (digital asset) Act 2025, approved on 2nd December 2025; See: L. Palmieri, D. Pyper, Property (digital assets etc) Bill [HL], https://commonslibrary.parliament.uk/research-briefings/cbp-10305/
[79] AA v Person Unknow, [2019] EWHC 3556 at [55]; D'Aloia v Person Unknown [2024] EWHC 2342 (Ch)

of existing property laws, as its applicability depends ultimately from the traditional indicia[80].

This approach has the advantage that it does not preemptively bend the existing legal categories. However, it may result in increased inefficiencies when a) the entitlements transacted on chain and off chain are likely to be incompatible; *or* b) the content of the entitlement transferred on chain is compatible with an off-chain entitlement but the transfer on chain does not fulfil the publicity requirements; *and* c) the benefits from using the blockchain are sizeable, so that parties mainly use on chain transactions An alternative, second approach could be to statutorily alter the divide between property and contractual right, for instance recognizing the control exerted through smart contract as a mechanism to establish (existing) property rights. In a more daring version, this could mean to expand the number and features of existing property rights. An early example of this approach can be found in in the Italian legal system, in the case of trading of security-token. Under Italian law, the circulation of securities requires an annotation on the registries as a form of third-party notice. In contrast, with a legislative reform introduced by the Law 52/2023 (artt. 3 and 5), security-tokens can be issued and traded simply through the DLT platform, which also means that issuing and trading generates and transfer property rights also off-chain.[81]

The Unidroit Principles on Digital Assets represents another example of this sort.[82] The principles are applicable to the governance of property on digital assets by choice of the parties who encode them in the digital assets or in its recording system, or by reference of the State Law (pr. 5, par 1). The Unidroit Principles define "control" as an exclusive but shareable *de facto* relation with a digital asset, conferred by the asset itself, the system or the protocol, pertaining the possibility of exploiting the asset, excluding the others from doing so and transferring such powers. These conditions are satisfied in DLT technology whenever a private key controls a digital asset (comm. 2.24, 6.5). Despite its *de facto* nature, transferring control on a digital asset allow the creation of a security right effective against third parties, additionally to the methods provided by State law (pr. 15). With this principle, blockchain can effectively be used to create a property right on a digital asset, transferring it on chain, and with priority against the creditors who claim a security right on the same asset but created and made effective against third parties with other methods (pr. 16).

Both the 'do nothing approach' and the partial shift in the contractual and property divide can work as a tool to address the shift in transaction costs in the digital environment. The best solution obviously depends on the particular features of the market sector considered. Both of them foster a reflection on the current allocation of property rights, as a private law solution that leaves unaffected the traditional market mechanisms. Nonetheless, they cannot ultimately solve the enforcement issues and the creation of potential externalities. To the contrary, externalities may even increase. Therefore, in some legal systems additional regulatory provisions were implemented in order to close the gap between the digital and legal layer. In the next section, we investigate the regulatory potential to govern tokenising property.

[80] UK Law Commission, Digital assets as personal property: Supplemental report and draft Bill, 2024, many times in the report, eg. 49.

[81] S.M. Scalera, *Tokenizzazione di partecipazioni di società di capitali*, phd thesis dissertation (2024) available at https://ulb-dok.uibk.ac.at/ulbtirolhs/content/titleinfo/9627035 (last visit 2 february 2026)

[82] UNIDROIT, *Principles on Digital Assets and Private Law* adopted on 10-12 May 2023, and published on 4 October 2023 at https://www.unidroit.org/work-in-progress/digital-assets-and-private-law/#1488897069871-af7a84cf-bd9a.

V: REGULATING THE TECHNICAL LAYER

In recent year, several experimental solutions have been advanced to address the legal challenges of the blockchain technologies. Some of these also impact the allocation of entitlements complementing the application and enforcement of traditional legal categories. We can consider these as solution enabling to close the gap between the digital or real-world layer, ensuring consistency. Through these lenses, we briefly analyse the relevant provisions of the EU Data Act and the Lichtenstein "Blockchain Act".

V.1 *EU Data Act*

The Act provides a legal framework for non-personal data produced by the "Internet of Things" and aims at a wider access to data, opposing the tendency of data manufacturers to lock in data through a technical layer not accessible for the users (Recital 20). Accordingly, the Act allocates specific rights to users such as a right to access, share with third parties, and switch provider. The access and use of data, when non statutorily mandated, are contractually regulated between the user and the data holder (art. 4 par. 13 and par. 14). Data must be shared between the data holder and the data recipient upon request of the user (art. 8). While strengthening the position of the user in exploiting data, the Act does not generally recognize new property rights,[83] nor does it establish protection for the data holders, allowing to ask for compensation to data recipient.[84]

What is interesting for our purpose, is that the Data Act envisions the use of smart contract to reduce transaction costs connected to data sharing (Recital 47)[85] as well as to prevent unauthorised access to data (art 11 par. 1). Within this framework, smart contracts are defined in art. 2, par. 1, n. 39 as "*a computer program used for automated execution using a sequence of electronic data records and ensuring their integrity and the accuracy of their chronological order*". This definition, though conceived in a technologically – neutral fashion (Recital 104), clearly includes the DLT smart contracts.

The Data Act establishes specific requirements for the use of these smart contracts, in the attempt to incentivize their use while curbing the risks arising from interoperability. Specifically, the vendor or the deployer of the smart contract shall include in the smart contract a mechanism for its "*safe termination and interruption, to ensure that a mechanism exists to terminate the continued execution of transactions and that the smart contract includes internal functions which can reset or instruct the contract to stop or interrupt the operation, in particular to avoid future accidental executions*". The provision aims to ensure the respect of the "mutual consent among parties" (Recital 106) and halts accidental executions. From the formulation, it remains doubtful who will push the button.

Given the spirit of the Act, it is maybe not too forward to interpret the provision in the sense that it prevents a *de facto* control, in favour of the data holders or of the data recipient, to grant the smooth circulation of data. This regulatory provision supports an on-chain transactional environment for data, clarifying the initial allocation of property rights and providing remedies against unwanted self-executions.

---

[83] H. Graux, *What is data ownership and does it still matter under Eu Data law?, https:*//data.europa.eu/.

[84] M. Eckardt, W. Kerber, *Designing the Bundle of Rights on IoT Data: The EU Data Act*, The Data Act: First Assessments, A. Sattler, H. Zech, (eds) Trier.3-22, Available at SSRN: https://ssrn.com/abstract=4879176 or http://dx.doi.org/10.2139/ssrn.4879176.

[85] F. Casolari, M. Taddeo, A. Turillazzi, L. Floridi, *How to Improve Smart Contracts in the European Union Data Act,* Digital Society, 2023, vol. 9, 8 ff.

V.2 *The "Blockchain Act" in Liechtenstein*

A second example of rules 'enabling' the efficient allocation of entitlements through tokenising property can be found in the "Blockchain Act" adopted in Liechtenstein in 2019.[86] The Act applies to "trustworthy technology", including (but not limited to) the blockchain and showcase innovative solutions in regulating the civil law effects of the token economy. The Act defines the token as a "container"[87] that can represent every right, property included. Consequently, there are two relevant features to considered: the digital assets, and the claim embedded in the token.

As for the digital asset itself, Liechtenstein civil law does not allow to establish ownership on immaterial objects. The Blockchain Act does not modify that but defines the legal entitlement towards the token as a "right of disposal", with features comparable to a property right[88]. Its acquisition is conditioned not only to the DLT transfer of the token but also to the agreement between parties and the legal entitlement of the transferor (art 4): the provision replicates the duality of title and *modus* for the transfer of property typical of German Law countries.[89] When these conditions are met, the disposal of the token determines also a legally valid transfer of the embedded right (art 7, par. 1)[90]. The disposal through DLT can be opposed against both the transferor and third parties in case of enforcement proceedings against the transferor (art 7 par 3). However, in case of further mandatory publicity requirements provided by law, these cannot be overlooked so that the mere transfer of the token does not effectively transfer property but only implies the legal obligation to do so (art 7 par 2 lett. a).[91]

The Liechtenstein Blockchain Act expands traditional property law. First, it creates a new legal object of rights that is functionally equivalent to a property right. Second, it tokenizes contractual claims, and opposes their transfer through DLT against third parties. However, for the valid transfer of property rights, existing legal requirements must be upheld: the handover of the possess of the asset, in case of movables; the registration, in case of immovables.

When it comes to incompatible contracts, Liechtenstein is conscious of the possibility of competing claims on the same asset and, accordingly, the Blockchain Act established various procedural safeguards. First, when the transferor has correctly disposed the token on the DLT but has still not fulfilled all the other necessary requirements for the transfer of property, he must make sure that no competing claims are established on the subject (art 7 par. 2).

---

[86] Also known as Token and Trusted Technology Service Provider Act (TVTG), entered into force on 1st January 2020.

[87] *Unofficial Translation of the Report and Application of the Government to the Parliament of the Principality of Liechtenstein concerning the Creation of a law on Tokens and TT Service Providers (Tokens and TT Service Provider Act; TVTG) (Blockchain Act),* n. 54/2019, 54 available at https://impuls-liechtenstein.li/wp-content/uploads/2021/02/Report-and-Application-TVTG-extract.pdf.

[88] A. Ferreira, P. Sandner, T. Dünser, *Cryptocurrencies, DLT and crypto assets – the road to regulatory recognition in Europe,* Handbook on Blockchain, M. Thai, D. A. Tran, B. Krishnamachari (eds), Springer 661 ff (2022).

[89] S. van Erp, *Land registration and "disruptive" (or "trustworthy"?) technologies: Tokenisation of immovable property*, in IMOLA II Project. The European Land Register Document (ELRD): A common Semantic Model for Land Registers Interconnection, A. Fraga, E. Ioriatti S. van Erp (eds.), 13, (2019) Available at SSRN: https://ssrn.com/abstract=3441938; M. Lehmann, *cit.,* 159.

[90] *Unofficial Translation of the Report and Application of the Government to the Parliament of the Principality of Liechtenstein concerning the Creation of a law on Tokens and TT Service Providers (Tokens and TT Service Provider Act; TVTG) (Blockchain Act),* cit. 57; literature: A. Ferreira, P. Sandner, T. Dünser, *Cryptocurrencies, DLT and crypto assets – the road to regulatory recognition in Europe*, cit.

[91] S. van Erp*, Land registration and "disruptive" (or "trustworthy"?) technologies: Tokenisation of immovable property,* cit., 14.

Further obligations rests with professional service providers, in particular, the tokenisation service provider and the physical validator. The first "*puts Tokens into circulation for clients and ensures the legal and technical requirements vis-à-vis third parties for effective representation and transfer of rights via Tokens*" (art 2 lett. m). She is required to ensure that the technical and legal features give consistency to the disposal of the token and the disposal of the embedded right against third parties. In particular, she must ensure the correct representation of the right, that its disposal is the immediate consequence of the disposal of the token, and that competing rights on the embedded right are technically and legally excluded (art 17 lett. b) [92]. When rights to physical assets are involved, a physical validator plays a complementary role in working off chain and in ensuring "*the enforcement of rights in accordance with the agreement, in terms of property law, represented in Tokens on TT systems*" (art 2 lett. p; art 17 lett e.). Practically, this involves also to ascertain the existence of the asset, the identification of parties, and that no incompatible claims are granted [93]. Both the tokenisation service provider and the physical validator are liable if they cause damages as a result of a breach of their obligations (art. 9a) and must award compensation.
Both the tokenization service provider and the physical validator are supervised entities: they must be registered and are under the supervision of the Financial Market Authority, which can cancel their registration if they systematically fail to abide to its legal obligations. The main purpose of these intermediaries is to ensure the consistency between the legal, factual and technological landscape. Operating in the tokenisation phase, the tokenisation service provider is able to provide consistency in an environment where smart contracts are able to shape property right in an asset. From the one hand he ensures the correct representation of the right; from the other, he grant the opposability of the transfer of a token against third parties. At the same time, the risk of incompatible contracts in token representing physical assets is minimized thanks to physical validators. In this perspective, the two professional figures support the legal allocation of entitlements. imposing constraint to limit the freedom of parties on chain.

V.3 *Regulatory provision shaping the transaction environment*

These two examples highlight the possibility to use the regulation of the technical layer to support the allocation of entitlements in the digital environment, ensuring the coordination with the legal system. It is still too early to say whether this will become a general trend.
In particular, in the case of the EU Data Act, the decision not to allocate a property right on data leaves with the need to ensure that the use of smart contract does not *de facto* nullify this provision. Consequently, the lawmaker intervenes directly on the technical layer, providing a mechanism to halt the smart contract.
In the case of Lichtenstein, a similar role is played by the intermediaries introduced by the policymaker and supervised by the administrative authority. The tokenisation of contractual claims has an effect similar to securitisation, with the consequence that its transfer is opposable to third parties, and consequently, that the debtor can discharge her obligation by paying directly to the holder. In this context, the Blockchain Act mandates the tokenisation service provider to ensure that the token has the digital and legal

[92] *Unofficial Translation of the Report and Application of the Government to the Parliament of the Principality of Liechtenstein concerning the Creation of a law on Tokens and TT Service Providers (Tokens and TT Service Provider Act; TVTG) (Blockchain Act),* cit. 60. while the text refers to the token generator, after the modification of art 17 of the Blockchain Act in 2024, some functions, previously exerted by the token generator, were conferred to the tokenisation service provider.
[93] *Unofficial Translation* … cit., 68.

characteristics to grant consistency with the legal system. As far as property claims on physical assets are concerned, the physical validator, who takes care that the assets exist, is owned by the transferor, and that no incompatible contracts are concluded.
The regulation of the technical layer is promising; however, key challenges still persist. One can for instance thinks of the high quantity of transactions on chain, the anonimity and the number of players constantly updating the chain.[94] The choice to impose the relevant requirements on the vendor and deployer on chain (EU Data Act) or on supervised intermediaries (Lichtenstein Blockchain Law) appears appropriate.

VI. Concluding Remarks

This article analyses how blockchain technology and smart contract, particularly NFTs and real-world asset tokenisation, disrupts the traditional contract-property divide. By revisiting foundational private law doctrines—in rem rights, the *numerus clausus* principle, and third-party notice—we show that blockchain allows private parties to replicate many of the core features of property rights without State involvement. Through smart contracts, entitlements can be embedded directly into tokens, enforced automatically through consensus mechanisms, and made publicly visible on a distributed ledger. This combination effectively creates de facto property entitlements, allowing rights to "run with" tokenised assets and bind subsequent holders, even in the absence of formal recognition by the legal system.
This phenomenon challenges the institutional balance carefully built into private law. By bypassing the *numerus clausus* and publicity requirements, tokenising property risks proliferating uncoordinated, privately designed entitlements, potentially increasing transaction costs and generating negative externalities. At the same time, it can offer efficiency gains by lowering enforcement and information costs, expanding access to sophisticated transactional mechanisms, and enabling novel forms of asset management and monetisation.
Our analysis suggests that the State's traditional control over the creation and enforcement of property rights cannot simply be transposed into decentralised digital environments. Reforming private law may be feasible only for subset of tokenised assets, like securities. In contrast, public law should intervene at the technical layer to ensure alignment between tokenised entitlements and the broader legal order. Instruments such as the EU Data Act and Liechtenstein Blockchain Act illustrate how regulatory provisions—through interoperability requirements, supervisory oversight, and technical safeguards—can restore coherence to an otherwise fragmented property landscape.
Tokenising property ultimately forces legal systems to face a pivotal question: should the creation of property-like entitlements be left to code? The answer will shape not only the future of property law but also the institutional role of the State in digital markets.

[94] V. Lehdonvirta, R. Ali, *Governance and regulation,* UK Government Chief Scientific Adviser (ed.), Distributed Ledger Technology: Beyond Blockchain.