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The Blockchain Paradox

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I. Introduction

'Bitcoin anarchy is a feature, not a bug. Sometimes it's good to have no human governance' read the headline of a recent and interesting article in Bloomberg.[1] The *leitmotiv* of the entire debate has been synthesized as follows: 'In blockchains, anarchy is the worst form of governance.'

However, this was not the first time that the now-famous cryptocurrency and the technology upon which its functioning is based, the blockchain, has been coupled with terminology taken from political philosophy, specifically that of 'anarchy'. In a public discussion that took place in February 2018, Thiel, while comparing the blockchain to another now-famous technological innovation, artificial intelligence ('AI'), declared: 'crypto is libertarian, AI is communist'.[2] In spite of their differences, 'libertarianism' and 'anarchy' agree on two points: (i) the full affirmation of individual freedom as a political end; and (ii) the elimination or reduction of the public authorities from the individual's autonomy.

The same values, come to think of it, were even invoked prior to Bitcoin's popularity. Back in 1996, Barlow warned that 'cyberspace does not lie within your borders. Do not think that you can build it, as though it were a public construction project. You cannot. It is an act of nature and it grows through our collective actions.'[3] Whilst the difficulty of regulating cyberspace (i.e. its 'unregulability') by public authorities has been debunked in the literature for some time,[4] the contemporaneous development of distributed ledger technologies has reinvigorated this declaration and caused it to assume renewed substance.

This chapter is organized as follows. Section II introduces Lessig's four modalities of regulation. Section III applies Lessig's framework to distributed ledger technologies in order to illustrate the complexity of the regulatory dynamics involved in the already complex blockchain code. Finally, in section IV, the results of the analysis are applied to a particularly topical problem in this area: the so-called single-ledger dependency due to the absence of interoperability between blockchain systems.

II. Lessig's Four Modalities of Regulation

The relationship between technology and regulation has been the object of study by jurists, science and technology studies, and sociology scholars for many years. No formula has

[1] Elaine Ou, 'Bitcoin's Anarchy Is a Feature, Not a Bug' (*Bloomberg*, 14 March 2018) https://www.bloomberg.com/view/articles/2018-03-14/bitcoin-blockchain-demonstrates-the-value-of-anarchy.

[2] Peter Thiel and Reid Hoffman, 'Technology and Politics' (January 2018) Conference speech, Stanford.

[3] John Perry Barlow, 'A Declaration of the Independence of Cyberspace' (Davos, 8 February 1996).

[4] See, Julie Cohen, 'Cyberspace as/and Space' (2007) 107 *Columbia Law Review*, 210; Mireille Hildebrandt, 'Extraterritorial Jurisdiction to Enforce in Cyberspace? Bodin, Schmidt, Grotius in Cyberspace' (2013) 63(2), *The University of Toronto Law Journal*, 196, 203. Goldsmith and Wu summarize the dreams of cyber-utopianism as those of self-governing cyber-communities that would escape geography forever. However, in their history of the (partial) territorialization of cyberspace, they argue that, even if geography no longer rules, national states still manage to pull the strings—or, rather, the wires. Jack Goldsmith and Tim Wu, *Who Controls the Internet? Illusions of a Borderless World* (Oxford University Press 2008).

caused as much stir among jurists as Lawrence Lessig's famous assertion that 'Code is Law',[5] according to which the technology architecture constitutes a 'form of regulation', together with state legislation, market forces, and social norms.

Indeed, the concept of technology capable of regulating is not novel. The example proposed by Winner, according to which the overpasses of the Long Island roadway system were planned by architect Robert Moses with a maximum height that prevented the transit of buses and coaches, known to be used by people of the lower classes, to Manhattan, is emblematic in this regard.[6] Thus, an engineering technology lent itself to the realization of a policy of social exclusion. In the same way, Bruno Latour affirmed the technological artefacts in some examples: speed bumps, or cars which do not start unless the seat belts are buckled, have prescriptive capacities, operating like silent traffic cops.[7] Therefore, whether technology is a complex information technology architecture or a simple functionality, it is capable of modifying and re-orienting the scope of permitted actions and, in so doing, contributes to the regulation of an individual's behaviour.[8]

However, Lessig's contribution does not end here. Rather, the biggest part of the novelty is the observation that the different modes of regulation do not operate in isolation. The interaction between architecture, law, market forces, and social norms is a property of regulation in the physical world just as it is in cyberspace. Each modality, in fact, causes two distinct effects—one direct, the other indirect. 'One is the effect of each modality on the individual being regulated i.e. how does law, for example, directly constrain an individual? How does architecture directly constrain an individual? The other is the effect of a given modality of regulation upon a second modality of regulation, an effect that, in turn, changes the effect of the second modality of individuals.'[9] A regulator acts directly when it uses just one modality; it acts indirectly when it avails itself of a second modality to pursue its own purposes.

Finally, two other points of Lessig's analysis are particularly important for our study. First, the interaction between law and architecture can be adversarial: when architecture promotes a value which conflicts with those espoused by the law, the latter may accept or reject it. Second, the greater the decentralization of the architecture, the less effective the government's power to regulate: regulating open-source software is far more difficult than regulating proprietary software.[10] Thus, the granting of property rights is fundamental to the control of behaviour, particularly in cyberspace.

III. Blockchain Regulation and Its Multiple Facets

The framework offered by Lessig is of the utmost importance in providing a comprehensive framework for distributed ledger technologies.[11] The initial studies on this subject have mainly focused on the effects that the blockchain code has introduced in the law (of contracts) and on models of governance.[12] However, these studies have ignored the action of the

[5] Lawrence Lessig, *Code and Other Laws of Cyberspace* (Basic Books 1990), 5.

[6] Langdon Winner, 'Do Artifacts Have Politics?' (1980), *Daedalus*, 121, 124.

[7] Bruno Latour, 'On Technical Mediation—Philosophy, Sociology, Genealogy' (1994) 3(3) *Common Knowledge*, https://philpapers.org/rec/LATOTM.

[8] Julia Black defines regulation as 'intentional attempts to manage risk or alter behavior in order to achieve some pre-specified goal': Julia Black, 'Learning from Regulatory Disasters' (2014) 24 LSE Law, Society and Economy Working Papers, http://eprints.lse.ac.uk/60569/1/WPS2014-24_Black.pdf. See also, Julia Black, 'Critical Reflections on Regulation' (2002) 27 *Australian Journal of Legal Philosophy*, 1–35.

[9] Lawrence Lessig, 'The Law of the Horse: What Cyberlaw Might Teach' (1999) 113 *Harvard Law Review*, 511.

[10] ibid., 534.

[11] Chief Scientific Adviser, 'Distributed Ledger Technology: Beyond Block Chain Report' (Crown 2016) UK Government Report, 17: 'Distributed ledgers are a type of database that is spread across multiple sites, countries or institutions, and is typically public. Records are stored one after the other in a continuous ledger, rather than sorted into blocks, but they can only be added when the participants reach a quorum.'

[12] Primavera De Filippi and Aaron Wright, *Blockchain and the Law* (Harvard University Press 2018).

other modalities, in particular those of market and social forces and their interaction with the code.

This approach result from a failure to correctly frame the nature of blockchain, to adequately account for weaknesses in the law in regulating this sector, and to guide public authorities in their regulatory actions. Blockchain code, like the law, not only modifies individual behaviour directly, but it also does so indirectly; it conditions other modalities, which, in turn, condition it. It is essential to understand the dynamics of above-mentioned interactions in order to be able to soundly regulate blockchain. In the following sections, we will isolate the reciprocal effects of the following modalities: blockchain code and the law; blockchain code and the market; and blockchain code and social norms.

A. Blockchain code and the law

Initially introduced as a technology to support the functioning of a decentralized payments system outside the brokering circuit of central banks, distributed-ledger technologies have evolved from both a quantitative and a qualitative perspective. In addition to the Bitcoin network, many other distinct blockchain systems have been developed and have gone beyond the simple transferring of funds to implementing different and/or supplementary functions.[13] Despite the passage of time, the philosophy upon which the operation of blockchain is based has remained substantially unchanged. It is a distributed database based on two core cryptography technologies seeking to ensure the validity and authenticity of transactions: (i) the public–private key cryptography for storing and spending money; and (ii) the cryptographic validation of transactions.[14] The data of past transactions is ordered in a series of 'blocks', such as in a public register, and cannot be altered except through the consensus of, at least, 50% of the blockchain nodes.[15] Cryptographic technologies can create a 'trustless' infrastructure to enable transactions:[16] the trust is directly guaranteed by the blockchain system.

The application potential of blockchain has increased with the development of modern blockchain codes. The result of the 'datafication'[17] of society is that more and more information has become available in digital format. Consequently, it has become clear that the blockchain code could be used for multiple other applications beyond money circulation.

Modern blockchain technologies make it possible to incorporate instructions into the code, thereby permitting any person to enter into contractual relations with other persons or machines. The contractual agreements are validated in a decentralized manner by the various nodes of the blockchain and are immediately and automatically executed. In practice, these agreements have been labelled 'smart contracts',[18] they simplify the organization and execution of the contract to a mere blockchain transaction. The intricacy of smart contracts can

[13] For a complete blockchain taxonomy, see Paolo Tasca and Claudio Tessone, '"Taxonomy of Blockchain Technologies", Principles of Identification and Classification' (31 March 2018) https://ssrn.com/abstract=2977811.

[14] Rainer Böhme, Nicolas Christin, Benjamin Edelman, and Tyler Moore, 'Bitcoin Economics, Technology, and Governance' (2015) 29(2) *Journal of Economics Perspectives*, 213.

[15] Similar characteristics apply to blockless blockchains (e.g. DAG- dependent blockchains). See Tasca and Tessone (n 13).

[16] De Filippi underlines the paradox of a 'trustless' technology, only relying on maths and cryptography, which is precisely what is needed in order to build a new form of distributed trust. Primavera De Filippi and Benjamin Loveluck, 'The Invisible Politics of Bitcoin: Governance Crisis of a Decentralised Infrastructure' (2016) 5(3) *Internet Policy Review*, 5.

[17] Sue Newell and Marco Marabelli, 'Strategic Opportunities (and Challenges) of Algorithmic Decision-Making: A Call for Action on the Long-Term Societal Effects of "Datification"' (2015) 24 *Journal of Strategic Information Systems*, 3.

[18] According to Nick Szabo, smart contracts are 'programs whose correct execution is automatically enforced without relying on a trusted authority': Nick Szabo, 'Formalizing and Securing Relationships on Public Networks' (1997) 2(9) *First Monday*, https://journals.uic.edu/ojs/index.php/fm/article/view/548/469; Melanie Swan, *Blockchain: Blueprint for a New Economy* (O'Reilly Media 2015), 16.

vary depending on the number of parties seeking to interact in complex organizations, as demonstrated by the so-called decentralized autonomous organizations ('DAO').[19]

Nowadays, the broad trend is to incorporate contractual agreements and clauses into the code. This leads to recognition in the blockchain of an authentic 'regulatory technology',[20] in the sense that it orients and modifies the behaviour of the individuals who use it in their personal capacity and in their relations with others.

The majority of legal studies have focused on the effects that blockchain technology entails for contract law.[21] In particular, the literature has noted how, unlike other technological innovations (such as digital rights management systems ('DRMs'), which impact upon legal enforcement by rendering the relevant rule self-executing),[22] the blockchain also effects the creation of the law that stems from the contract. In this respect, a new process according to which 'law is progressively turning into code' has been observed.[23] This process conditions both the modalities of negotiation and stipulation of the contract and the whole system of guarantees prescribed by the (national or international) contract law system. One may think of principles, such as *bona fide*, or institutions, such as force majeure and the hardship clause, or of vitiating factors. However, in smart contracts, because the effects of the contract are indelibly written in the relevant code the parties can easily bypass these traditionally necessary contractual safeguards.

Conversely, the law has yet to regulate the blockchain system. For example, although in the literature questions have been raised regarding the possibility of equating smart contracts with traditional contracts,[24] there have been only a few legislative interventions concerning either their qualification or the penetrating effects of this architecture on contract law. The only legislative interventions to date, with blockchains as their object, have been in relation to some categories of subjects (e.g. the promoters of an Initial Coin Offering) and assets (e.g. token) and their qualification.[25] This raises questions as to whether the law is

[19] A decentralized autonomous organization ('DAO') is a computer program, running on a peer-to-peer network, which incorporates governance and decision-making rules programmed to operate autonomously.

[20] The literature has extensively investigated the so-called regulatory technologies. See Jonathan Wiener, 'The Regulation of Technology and the Technology of Regulation' (2004) 26 *Technology in Society*, 483, 500; Karen Yeung, 'Towards an Understanding of Regulation by Design' in *Regulating Technologies*, edited by Roger Brownsword and Karen Yeung (Hart 2008).

[21] De Filippi and Hassan focus on smart contracts by pointing out their rate, efficiency, clarity, and ability to cut trading, monitoring, and execution contractual costs, turning traditional legal obligations into self-executive transactions. Primavera De Filippi and Samer Hassan, 'Blockchain Technology as a Regulatory Technology: From Code is Law to Law is Code' (2016) 21(12) *First Monday*, 5, http://firstmonday.org/ojs/index.php/fm/article/view/7113/5657#author.

[22] Dan L. Burk, 'Legal and Technical Standards in Digital Rights Management' (2005) 74(2) *Fordham Law Review*, 53. Graber states the difference between code and law: in the real space, law is a means of communication resulting from a political process and enacted by a constitutionally competent legislative body. The laws regulating the architecture of technology (of code) are imposed by a private actor, which leads to serious concerns from a constitutional perspective. Furthermore, code is different from law since it is self-executing. Law, instead, needs to be enforced by the state and accepted by its addressers. Christoph B. Graber, 'Internet Creativity, Communicative Freedom and a Constitutional Rights Theory Response to "Code is Law"' in *Transactional Culture in the Internet Age*, edited by Sean A. Pager and Adam Candeub (Edward Elgar 2012), 137.

[23] De Filippi and Hassan (n 21).

[24] Reggie O'Schields, 'Smart Contracts: Legal Agreements for the Blockchain' (2017) 21 *North Carolina Banking Institute*, 177.

[25] The Swiss Federal Supervisory Authority for Financial Markets ('FINMA') published a practical guide explaining how it intends to handle requests to access *initial coin offerings* in accordance with current financial market law. FINMA identifies the minimum information required to process these requests and the applicable principles, thereby rendering the process transparent to the market operators involved: https://www.finma.ch/it/news/2018/02/20180216-mm-ico-wegleitung/. Furthermore, virtual currencies are defined by European Banking Authority ('EBA') as a 'digital representation of value that is neither issued by a central bank or public authority nor necessarily attached to a fiat currency ("FC") but is used by natural or legal persons as a means of exchange and can be transferred, stored or traded electronically'. European Banking Authority, *EBA Opinion on 'virtual currencies'* (EBA/Op/2014/08), 11; Sarah Jane Hughes and Stephen T. Middlebrook, 'Advancing a Framework for Regulating Cryptocurrency Payments Intermediaries' (2015) 32 *Yale Journal*, 495.

capable of reaffirming its primacy over the blockchain system and the values it promotes, or whether it is the particular configuration of the blockchain system that exercises a certain restraint. It is useful to recall Lessig's lesson that as decentralization increases, the possibility of control decreases.

The availability of open-source blockchain software, together with the extreme fragmentation of the single nodes of the network, which is not controlled by a single well-defined entity when it comes to public blockchain, renders it difficult for public authorities to directly regulate the architecture. Even if, hypothetically speaking, public authorities decided to deprive a smart contract of legal validity, thereby removing the guarantee of its enforcement before a court of law, this would not discourage the use of the technology by the individual users. Rather, the enforcement of the contract would be ensured by the very same code by which it was enacted. Once signed, a smart contract seeks to fulfil the terms and conditions it contains because the parties, in their contractual autonomy, have previously decided to forfeit the guarantees supplied by the legal order. In this case, public authorities could seek to impose behavioural obligations on the physical persons behind the terminals but given the obvious enforcement difficulties (e.g. the controlling and sanctioning of a node failure, which could be located anywhere in the world) the blockchain system could decide to refuse them *en bloc*.

Thus, we have reached an important conclusion regarding the relationship between blockchain code and the law. In the blockchain ecosystem, the code makes changes to the law but the reverse process of the law changing the properties of the blockchain code is much more difficult to occur.

B. Blockchain code and market forces

Blockchain constitutes an ecosystem in which one may find different markets. One of the primary markets is that of 'mining' (or better that of transactions' validation): it sustains the entire blockchain code and it can only exist within completely decentralized public blockchain systems.[26] The services offered by miners consist in the resolution of complex mathematical problems required for the creation of a new, valid, and encrypted block. In return for payment, the miners offer a system-verification service.

With the increase in the popularity of Bitcoin and the development of other blockchains, new ancillary markets have subsequently emerged downstream of the mining market.[27] One of these is the market for currency exchanges. It operates like a trading platform for cryptocurrencies.

Other examples include markets for digital wallet services and those for mixing. With the development of smart contracts, yet another new market has opened up: that of decentralized applications, namely software applications that run on a peer-to-peer network of computers.[28] These are distinguished from both centralized systems, which follow a centralized server-client model, and from distributed systems, which are based on a network made up of autonomous computers connected by a middleware of distribution. The potential link to the development of blockchain applications and the opening of these new markets has brought about the emergence of the term 'blockchain as a service' to indicate the possibility

[26] On the distinction between public and private blockchain, see further on in this section.

[27] For a market report see, e.g., Paolo Tasca, 'Digital Currencies: Principles, Trends, Opportunities, and Risks' (7 September 2015) https://ssrn.com/abstract=2657598.

[28] Among these, Cunningham mentions Airlock, a 'next generation keyless access protocol for smart property', and Boardroom, a 'blockchain governance suite' that, among its proposed uses, includes arbitration and equity allocation to board members: Alan Cunningham, 'Decentralisation, Distrust and Fear of the Body—The Worrying Rise of Crypto-Law' (2016) 13(3) *SCRIPTed*, 235.

of making a series of applications necessary for the provision of various services, aimed at satisfying the needs of individuals, available to the public.

Even in the great diversity of the ecosystem, it is worth highlighting one distinction: on one side, there is the market, which is instrumental to the operation of the blockchain code; on the other side, there are downstream markets based on the original market. This distinction recalls two other prevalent distinctions found on the internet: (i) the distinction between the physical infrastructure to access audio-visual content and the market for audio-visual content; and (ii) the distinction between the intermediaries involved in content accessibility and the market of downstream applications. The blockchain code suffers from the same problem as that of the physical infrastructure required for access and that of the intermediaries, namely that of the non-interoperability by design. We will discuss this issue in more detail below.

Let us now consider the complex effects between the code and the market. Using Lessig's words, it can be said that the market regulates behaviour in cyberspace and it does so, for example, through prices.[29] The same occurs in blockchain: the price of mining is affected by the price of energy and it affects in turn the behaviour of the blockchain nodes; the transaction fees determine the behaviour of the network members; the elevated costs of verification of a transaction through the proof-of-work mechanism bring the miners together in mining pools; the long validation times, which are indirect costs, cause developers and users to migrate to alternative models of blockchain. In all of these cases, the market regulates the behaviour of individuals. However, Lessig has further stated that the market is only able to modify individuals' behaviour where there exists a framework of social and legal norms and that this framework is capable of influencing individuals' behaviours: reference is made to property and contract law.[30] Similar rules also exist in the blockchain ecosystem, but here they are often informed by the logic underlying the architecture of the code. The infrastructure, which supports the network within completely public blockchain systems, does not belong to anyone: given the free nature of the code, there are no inherent property rights in it. Furthermore, the asset software is freely available online and the contract is written in the language of the code, with all the limits that derive from it. The assets, cryptocurrencies, and tokens, which are stored in the system, are the network members' property but they only have value insofar as the network is capable of connecting these assets to a unique member's ID code. Finally, the contracts for transferring such assets are written in the language of the code, with all the consequences that derive from it. These circumstances have an effect on the configuration of the markets upstream and/or downstream of the ledger. For example, the mining market presents atypical rules, which differentiate it from any other type of market. The system's demand for the service does not affect prices directly; rather, it is the blockchain system that determines the miners' (future) level of retribution as the number of transactions increases. The architecture of the blockchain (i.e. the blockchain code) thus moulds the market, according to the consensus mechanisms embedded in the system. A further example is the block size limit,[31] which is inserted into the blockchain system. It limits the number of transactions that the circuit of a blockchain system can process per second; in other words, it limits the speed at which transactions can be verified and added to the chain. The size of the blocks generated large-scale debate immediately, dividing proponents and opponents on the issue of enlargement of the block size.[32] Proponents of enlargement hold that the limited capacity of the system reduces the scalability and mass adoption of the technology: Bitcoin miners would, thus, have to add additional capacity to the system, instead

[29] Lessig, 'The Law of the Horse' (n 9), 507. [30] ibid.

[31] The Bitcoin max block size limits the rate at which information is etched into the blockchain. Essentially, it acts to throttle the entire system. Jordan Clifford, 'Understanding the Block Size Debate, The Crux of the Issue' (*Medium*, 27 September 2017) https://medium.com/@jcliff/understanding-the-block-size-debate-351bdbaaa38.

[32] De Filippi and Loveluck (n 16), 7.

of being bound to a certain production quota. Conversely, opponents to enlargement argue that this would cause decentralization which, in turn, would raise the miners' costs of participation in the market, and thereby erect a barrier to entry.

Also, a particular rule of the system which opposes the miners' contractual freedom to offer more efficient services would impact upon markets downstream of the ledger, which are structurally dependent upon the operation of the upstream system. Thus, the code influences individuals' behaviour and the markets' functioning; it redefines proprietary and contractual concepts. However, it is not possible to find any direct effect of the market on the code. The market limits itself to regulating individual behaviour: any change in the code underlying a particular market is mediated through the intervention of social forces external to the code.

C. Blockchain code and social forces

The qualification of blockchain as a complex ecosystem also accounts for the fundamental role played by the social forces involved into the promotion of a project (founders, developers, and users), which eventually decide the internal operational and organizational rules. From the very beginning, these social forces have accompanied, and continue to accompany the development of any single blockchain system.

Generally, each project begins with the study and presentation of a White Paper by their promoters.[33] The White Paper commonly results from a process of creative debate within a community or group of diverse people in a forum or in another circle or physical place. It illustrates the founders' vision regarding the function of the new blockchain and how this specific blockchain could contribute to a particular social purpose. The White Paper also contains technical information regarding the specific protocol, the internal rules that the software follows, specific security measures, its scope, scalability, roadmaps, and other information. In some cases, the White Paper may contain rules concerning community involvement and/or rules concerning the system's internal governance;[34] in other cases, the rules may not be expressly written down but are premised upon informal mechanisms.

However, in each case, it is the overall community that defines the rules of the system by embedding them into the code.

However, what is peculiar is that within each individual blockchain system there exists not one but two types of rules: those that inform the operation of the system (i.e. the rules which structure the consensus network topology, the transaction capabilities, the security and privacy, etc.) and those that define how the first type of rules can be changed. This is reminiscent of the distinction developed by Hart to describe the essence of the law on the distinction between primary and secondary rules.[35]

The identification of these two types of rules helps to understand the reciprocal interactions between the code and social forces. Take as an example of the first kind of rule the principles embedded in the consensus mechanism. These principles shape the operation of the blockchain system: in fact, blockchain verification is managed on the basis of consent between multiple nodes. These rules are entered into the code and impose a certain structure on a specific system. From this structure derives a (actually, more than one) certain obligation upon all the members of the community: for example, this obligation could be to keep copies of the previous transaction blocks in one's own terminal and to permit the verification to only happen in the case where 50% or more of the nodes have consented

[33] The most famous is certainly Satoshi Nakamoto, 'Bitcoin: A Peer-to-Peer Electronic Cash System' White Paper.

[34] The concept of corporate governance is defined within the Cadbury Report as 'the system by which companies are directed and controlled'. Committee on the Financial Aspects of Corporate Governance, 'Report of the Committee on the Financial Aspects of Corporate Governance' (1992).

[35] Herbert L. A. Hart, *The Concept of Law* (first published 1961; Oxford University Press, 2002), 87.

to it. In any case, it is the matter of an obligation entered in the code by a programmer or by a company in response to one political end or another: for example, to decentralize or centralize the control. Thus, in relation to the chosen architecture of the distributed consensus mechanism, three different categories of blockchain systems can be distinguished: public (i.e. permission-less), private (i.e. permissioned), and consortium. The public category allows all nodes to participate in the consensus mechanism. Conversely, in the consortium category, access and participation in the consensus mechanism is granted exclusively to specific pre-chosen nodes (partially decentralized structure). In the middle of these two categories lies the private category in which access and participation in the consensus mechanism is only granted to certain nodes from specific organizations that control the network (centralized structure). Acceptance of the obligations by an individual occurs at the moment in which he adheres to the system and its rules and becomes a part of the community.

Upon becoming a member of the community each node is not necessarily confined to a system whose rules were set by others; rather, in certain cases it may contribute to their modification. This governance possibility derives from the existence of a second nucleus of (possibly informal) rules that are either based on consensus or have been written into the code. These so-called governance rules can establish, for example, the process to implement the protocol, the process to upgrade the system, or the process to change the internal coordination of the nodes. In turn, these rules directly affect the interaction dynamics between participants in the network; indirectly, they affect the content of the system's operating rules. Governance models which are more participative will tend to shape operating rules in a way that responds to the interests of a larger range of members.

In general, two alternative models of governance can be contrasted here.[36] On the one hand, there are the so-called informal models of governance (e.g. Bitcoin, Ethereum). On the other hand, more complex systems of governance have emerged, the so-called 'on-chain' models (e.g. EOS, NEO). The first model[37] provides for the participation of a nucleus of developers who formulate the proposals for protocol amendments and to whom the duty of obtaining the stakeholders' consensus (that of the miners, those very same developers and the relevant users) is assigned. Once established, this mechanism effectively acts as a self-reinforcing cycle that concentrates power in the hands of a small group of people, often to the detriment of others, who are sometimes forced to get out of the system by breaking the main blockchain: this is the so-called 'hard fork'. The second governance model differs from the first for two reasons. First, its voting procedures are open to all coin holders thereby rendering the system more democratic. Second, the result of the vote is directly incorporated into and implemented by the system. The system is able to automatically execute the decision made by the majority of votes cast. Without entering into a detailed analysis of the various models, it is necessary to emphasize the following point in relation to the architecture of the blockchain system. On the one side, the architecture of the blockchain system is the result of the interaction of social forces and markets external to the system, both of which serve to shape the operating rules and rules of governance. On the other side, the architecture of the blockchain system affects upstream social forces: the more the code provides models of participative and open governance, the less it is likely that a hard fork will result, even in the case of a disagreement within the network.[38]

[36] Vitalik Buterin, 'Notes on Blockchain Governance' (*Vitalik Buterin's website*, 17 December 2017), https://vitalik.ca/general/2017/12/17/voting.html.

[37] O' Neil referred to Bitcoin governance as a form of domination based on charismatic authority: Mathieu O'Neil, 'Hacking Weber: Legitimacy, Critique, and Trust in Peer Production' (2014) 17(7) *Information, Communication and Society*, 872.

[38] Odysseas Sclavounis, 'Understanding Public Blockchain Governance' (*Oxford Internet Institute*, 17 November 2017) https://www.oii.ox.ac.uk/blog/understanding-public-blockchain-governance/.

D. Law, market, and social forces

To sum up this discussion, the blockchain code, as opposed to any other type of code, demonstrates a far more powerful regulatory capacity and capability to resist the influence of other modalities. The blockchain code regulates the behaviour of individuals directly—substituting itself for the law—but, at the same time, it has relevant effects on the other modalities. Not only does the code influence the modalities of interaction between the participants to the network (i.e. social forces or norms), but it also influences the market dynamics that inform the functioning of the system (i.e. market forces). At the same time, the decentralized nature of the architecture makes the blockchain code particularly impervious to the direct effects of the law. The only social forces capable of impacting upon its way of being stem from within: they highlight new internal mechanisms capable of limiting the 'power' of the code.

The above necessitates a reflection on the role of the law and of the public authorities. The code does not only pose a problem for the public authorities insofar as it cancels that entire system of guarantees provided by the law of contracts; it also structures the dynamics of multiple markets upstream and/or downstream of the ledger.

Hence, possible distortive effects on the market, due to the architecture, could become a public policy problem, which could call the regulator into question. It is in this case that the particular decentralized and closed-off 'organization' of the system weakens the impact of public action. In particular, the difficulty for the public authorities lies in the fact that the technological architecture appears to be conceptually inseparable at the functional level from the network of individuals who organize it and who, at the same time, contribute to its modification.[39] Therefore, if it is true that the public authorities can indirectly regulate the architecture in any case by exploiting the market, it is also true that each modification to the same architecture must be approved by the community. This happens through those mechanisms of governance, whether informal or formalized in the code, which regulate their co-existence. In other words, the community becomes the filter for any changes to the code.

IV. Interoperability and Distributed Ledger Technologies

A. Interoperability at a glance

We have observed the complex blockchain ecosystem in light of the framework offered by Lawrence Lessig so far. At this point the framework shall be analysed in order to consider a further concept into which research literature has not yet delved but which is essential for the future and full development of the ecosystem: interoperability among distributed-ledger technologies. Understood as a technical and economic concept, 'interoperability' can be defined as the capacity of a system, product, or service to communicate and function together (that is, to be compatible) with other systems, products, or services which are technically different.[40] This interoperability is the result of a series of choices that depend on the type of good or service and on the underlying market dynamics. In fact, there are existing goods and/or services that have no value if consumed individually but do, and only, generate value if and when they are combined with other products or services. For example, consider telecommunication or social media services. For them, the market is characterized by positive network externalities, i.e. the utility that a consumer gets from the relevant certain good or service is proportional to the number of other consumers benefitting from the

[39] ibid.

[40] Wolfgang Kerber and Heike Schweitzer, 'Interoperability in the Digital Economy' (2012), Marburg Centre for Institutional Economics Paper 2/2017, 3, https://www.uni-marburg.de/fb02/makro/forschung/magkspapers/paper_2017/12-2017_kerber.pdf.

same good or service. Katz and Shapiro distinguish two types of network externalities: direct and indirect. The former depends on the number of consumers who benefit from the same product or service; the latter depends on the increase in goods and services which are complementary to the first, thereby increasing its value.[41] The nature of interoperability or non-interoperability of a good or service is the result of a strategic choice by a company in the market. Companies with larger networks tend to offer goods or services that are incompatible (i.e. non-interoperable) with the goods and services of competing undertakings. These companies do this to maintain their dominant position and to exploit direct network externalities. Conversely, companies with smaller networks seek to produce technologies that are highly compatible with other products or services (i.e. interoperable) in order to exploit the possible indirect network externalities.

B. Blockchain non-interoperability

The current blockchain architecture is not interoperable. Each blockchain system is closed off to its surrounding environment and does not communicate with other systems. This condition restricts the potential of the blockchain so that it operates only within the one relevant blockchain system: any member's transactions of a specific blockchain system, for example Bitcoin, are only recognized by other members of the same system. For members of any other system, for example Ethereum, there is no trace on the Ethereum blockchain of that specific transaction on the Bitcoin blockchain system; it is as if the transaction had never occurred and, thus, it has no binding force within its own (i.e. within the Ethereum) system.

There are multiple reasons for the lack of interoperability. Although a blockchain system is hard to compare to a company, due to the absence of unified management and coordination, all of the subjects which form a part of it are motivated by individual reasons and so conduct themselves opportunistically. Developers and miners of a certain blockchain system seek to maximize (market) profits.

Each individual's behaviour is guided by the expectation that enlarging the network will cause a correlated increase in both its value and in the monetary assets (i.e. tokens) held in the system. At the same time, the user's choice to enter into one blockchain system over another often significantly depends upon the relevant user's expectations regarding the future breadth of the network. Project developers and promoters are then motivated by the desire to maintain or increase their own political power within the system. They organize the system's architecture in pursuance of a specific aim, they work hard to promote the project and, as holders of top-level positions in the internal governance, they will adopt any measure to keep such. All of these factors make it disadvantageous for members of a specific blockchain to make their ledgers interoperable with other ledgers.

Apart from the absence of economic incentives, there is another rationale which discourages the adoption of the same protocol by two separate blockchain systems: the lack of trust among network members of different infrastructures. As we have seen, each blockchain system is made up of an infrastructure of nodes, which corresponds to a network of persons. Given that transactions are verified through the interaction of nodes, the network performs an essential function for the operation of the infrastructure: it is solely reliant on itself and the nodes comprising it. In this sense, interoperability would contradict the system's operating rules. The above discussion leads to the following conclusion: the interoperability of the ledger, beyond being a technical impossibility, results from a series of intentional choices to defend a given blockchain system and from its operating dynamics. Thus, the ledger is non-interoperable.

[41] Michael L. Katz and Carl Shapiro, 'Network Externalities, Competition and Compatibility' (1985) 75(3), *American Economic Review*, 424.

With the non-interoperability of the blockchain framed as a social problem, which finds its emergence point in the code, we must now concentrate on the effects that this limitation in the blockchain architecture has on the law and the market.

In relation to the effects of the non-interoperability on the law, the following examples should be considered. David may want to enter into a service agreement with Alice by which he pays to Alice a monthly fee (in ETH on Ethereum network) in exchange for having access to some data stored in the Bitcoin network by Alice. Or, for example, Charlie may want to lend money (in ETH) to Bob under the condition that Bob will pledge as collateral an asset registered in the Bitcoin network. Or simply, Alice, Bob, David, and Charlie may want to exchange private information recorded on different blockchains.

For various reasons, 'any information, goods and value [for] which (unencrypted, encrypted or hashed) data is tracked and stored in a blockchain system could become of interest to other people (or applications) outside that system'. And for various reasons, an individual could be interested that such information is recognized and validated by the system of which it forms a part. For instance, a protocol could be the only one to have implemented a certain feature or, for security and trust reasons, a party could be uninterested in entering the blockchain system of its contractual counterparty. However, in the absence of interoperability between protocols, these rules of interest cannot be achieved. In this sense, the non-interoperability of the protocols neither responds to the needs of international commerce nor does it bolster the principle of contractual autonomy. In fact, individuals can only subscribe to the contractual models permitted by the applications developed for, and on the basis of, a specific ledger. Only those typical agreements defined in the ledger protocol, by its developers, have citizenship in the relevant environment.

In relation to the impact upon the market, non-interoperability could strengthen technological lock-ins and could block the competitive and prosperous development of a market for the downstream applications of the ledger. The problem is similar to the one tackled by the supporters of net-neutrality,[42] who have fought against differential internet speed over the past several years. In that case, the subject of debate was the discriminatory behaviour of the internet service providers ('ISPs') in relation to the content services of the downstream market of the physical accessibility infrastructure. Through complex traffic management practices, ISPs tended to block or slow down competing services as opposed to the traditional communications services offered by their own business divisions. This behaviour was justified by the need to guarantee the content quality given the infrastructure's limited capacity. However, it caused harm to new market entrants who were not willing to pay for traffic prioritization. Once legislators recognized the principle of net neutrality and intervened,[43] the debate shifted to the discriminatory practices of the over-the-top media services that adopted non-interoperable standards with the potential to damage competition on the market.[44] Similarly, the non-interoperability among ledgers, in the case where this results in

[42] According to Tim Wu: 'Network neutrality is best defined as a design principle. The idea is that a maximally useful public information network aspires to treat all content, sites, and platforms equally': Tim Wu, 'Network Neutrality: Broadband Discrimination' (2003) 2 *Journal of Telecommunications and High Technology Law*, 141; According to Suzanne Crawford, "*A neutral Internet must forward packets on a first-come, first served basis, without regard for QoS considerations*": Suzanne P. Crawford, 'Transporting Communications' (2009) 89 *Boston University Law Review*, 871.

[43] Regulation (EU) 2015/2120 of the European Parliament and of the Council of 25 November 2015 laying down measures concerning open internet access and amending Directive 2002/22/EC on universal service and users' rights relating to electronic communications networks and services and Regulation (EU) No. 531/2012 on roaming on public mobile communications networks within the Union.

[44] José Marino García, Aurelia Valiño Castro, and Antonio Jesús Sánchez Fuentes, 'Price Discrimination of OTT Providers under Duopolistic Competition and Multi-Dimensional Product Differentiation in Retail Broadband Access' (2017) Public Economics, Governance and Decentralization Paper 1607, Universidade de Vigo, Governance and Economics Research Network ('GERN') https://econpapers.repec.org/paper/govwpaper/1607.htm.

the emergence of a dominant system capable of raising the standards would prejudice the natural development of the market of underlying applications, thereby damaging innovation.

C. Technical and business solutions hold complex social, economic, and legal implications

Since the outset, the problem of non-interoperability in blockchain has divided developers and influential individuals of the industry. Three alternative solutions have been advanced. Some base their force on the power of a particular community or market operator, others on the development of the code.

The first approach is proposed by the likes of Ethereum Enterprise Alliance[45] and Hyperledger Fabric,[46] which advocate that a dominant blockchain will take over the others and that different networks will be run on top of this blockchain. These enterprises aim to offer blockchain-as-a-service ('BaaS') applications for the industry and, although differing in their business approaches, promote a specific protocol.

The second method offers a network approach to link any two different blockchains via new, 'intermediate' blockchains that—thanks to special nodes and adapters—create a bridge between them at the 'transaction level'. Wanchain, Cosmos, Polkadot,[47] and AION are examples of this model. With respect to the first model, this second model favours the creation of a new technological architecture in third position, supported by its own community and by a new market: that of intermediary blockchain systems for inter-ledger communications.

A third alternative method is based on a layer approach. It connects different blockchains at the application level, instead of the transaction level, by decoupling the business logic from the underlying ledger. In this case, there is no need to route the information across ledgers, since all the ledgers are directly connected in the application layer. The information is retrieved from different ledgers, standardized and grouped in a 'message layer', then ordered in a 'filtering and ordering layer'. A blockchain program interface defines the rules, set by blockchain *B* user, for blockchain *A* user to follow in order to read and/or write messages in/from blockchain *B* without the need of intermediate blockchains. Overledger[48] by Quant Network is an example of this type of blockchain operating system. Unlike the first and second models, this approach did not come about in order to promote or create a specific blockchain infrastructure, but to offer particular types of software applications which make interoperability possible downstream of the ledger.

All these solutions present issues of an economic, legal, and/or social nature.

(The first solution to the issue of non-interoperability is unconvincing for two reasons. First, it is doubtful that a single blockchain can gain significant enough levels of traction with firms so to impose itself above all other competitors. In fact, as far as the network effects of a given blockchain system are concerned, the infrastructure upon which they rely is not only comprised of telephone wires and trellises, as in the case of telecommunications, but of natural persons who could, for opportunistic reasons, decide to exit the network and develop their own blockchain systems. This is possible due to low costs concerning the reproduction of the code and the code's high level of malleability and adaptability. For example, if half the Ethereum nodes decided to substitute the Ethereum protocol with another protocol in a

[45] Ethereum Enterprise Alliance, 'Introduction and Overview' (*Ethereum Enterprise Alliance* February 2017) https://entethalliance.org/wp content/themes/ethereum/img/intro-eea.pdf.

[46] Hyperledger Architecture, Volume II, (*Hyperledger*) https://www.hyperledger.org/.

[47] Polkadot Whitepaper (*Polkadot*) https://github.com/w3f/polkadot-white-paper.

[48] Gilbert Verdian, Paolo Tasca, Colin Paterson and Gaetano Mondelli, 'Quant Overledger ®' (*Quant*, 18 January 2018) https://objects-us-west-1.dream.io/files.quant.network/Quant_Overledger_Whitepaper_v0.1.pdf.

very short time period, the Ethereum chain would break in the same way as it did when the hard fork emerged from the Ethereum Classic. The possibility of this happening is inversely proportional to the degree to which internal governance is centralized but, in any case, revolutions can happen. For this reason, it is difficult for one particular protocol to impose itself as the de facto standard.

The second reason is that, even in the case where a specific system manages to autonomously gain a prevalent ledger position, the competition of the downstream market could be jeopardized. As set forth in section IV.B ('Blockchain non-interoperability'), the internal governance of a given system could decide to favour certain applications over others, to the latter's disadvantage. This is a real problem when one considers that both the Ethereum Enterprise Alliance and the Linux Foundation are legal entities with their own governing bodies, within which there are large stakeholders operating in various sectors. Given the network's limited capacity, due to the long-standing problem of scalability, it is not so unrealistic to imagine that some applications would end up being treated differently by the system. Consequently, that specific dominant infrastructure could risk assuming a gatekeeper's position for access to the market underlying the applications. In any case, whether a given system can become dominant and whether this hypothetical imposition can cause prejudices in the downstream markets will depend, for the most part, on the internal governance rules adopted.

The second solution provided is equally unconvincing. There are essentially two reasons for this. First, the same problems that plague the first solution would also arise here: given the lack of entry barriers, many blockchain systems could emerge, causing the fragmentation of the market; even where, for example, Polkadot imposed itself above the others, this situation would foster abuse in the downstream markets and—unlike the first solution—also in the upstream markets. In addition to discrimination in the application layer, for instance, Polkadot could decide to communicate with Ethereum and not do so with NEO, which has always been considered to be a similar blockchain system in terms of the application potential that allows the implementation, and this would unjustifiably damage the latter system to the former system's advantage. Second, this would raise the issue of how to build people's trust in the system. The problem of trust is extremely topical in markets characterized by imbalances of information and, for this reason, it arises also in the area of contractual interactions between parties belonging to different blockchain systems. This is because a member of a given blockchain code tends to know and trust only his own system: another system could, in fact, reveal security leaks or bugs in the code and, therefore, fail to guarantee a positive outcome in the transaction. This lack of trust would then be exacerbated by the existence of specific, and often complex, rules of governance of the intermediary system, which may or may not be shared by the member in another system. Polkadot uses a governance system based on the stakeholders' vote and on the principle of majority decision-making. Decision-making powers are granted to a specific body, the 'Board', an on-chain entity whose members are elected through an approval procedure and which shall propose referendums capable of affecting the system and thus, also single transactions.

The third solution provides an interesting compromise between the need to make persons, machines, or goods with citizenship in two different systems interact and the need to avoid that this must necessarily occur through the use of a particular blockchain infrastructure. To use an analogy, the Overledger software offered by Quant Network seeks to replicate for blockchain systems that have been done by Java Virtual Machine ('JVM') for software. Just as JVM operates as an interpreter for Java applications and allows their programmers to disregard the underlying operating system, Overledger aims to make the specificities of a given blockchain system neutral for all applications offering interledger services. This approach has the advantage of freeing up the entire potential of the blockchain to the application layer without requiring members to adhere to the operating and governance rules of a specific dominant, or intermediary, blockchain system. In other words, the user chooses the blockchain ecosystem in which it wishes to live and Overledger acts as a bridge between the two or more relevant ecosystems. Given the absolute neutrality of the software with respect to the overlying layer and the important linking function between networks, this solution limits the network effects of a system and possible situations of technological lock-in whilst favouring innovation and downstream market competition. For these reasons, it is believed that it can be favourably considered in blockchain systems, above all of those that are less popular and cannot boast an extensive network. In any case, as the debate on network neutrality has shown, market limitations can also happen through traditional over-the-top media services, acting as gatekeepers. This is certainly possible if an innovative technology develops to become the standard that is protected by intellectual property rights. Consequently, public authorities should keep a cautious eye on this solution.

V. Conclusion: The Paradox of Interoperability

The issue of interoperability cannot be construed as a simple technical and economic problem. It constitutes the point where tension between three distinct ways of being for the blockchain, which is intended as a regulatory technology, economic infrastructure, and model of social organization, emerges. These three concepts give rise to a fusion in the code that, just like a relentless dog with three heads, ends up structuring not only the technical operating rules of the system, but also the possibilities of interaction between members of the system, the logic of the underlying markets, and the social norms which guide the functioning of the community.

In Greek mythology, Cerberus monitored the underworld to stop the living from entering and the dead from leaving. Similarly, the blockchain code not only demarcates the impassable frontier between cyberspace and the real world but also that between the different blockchain systems. Hence, the idea of interoperability between ledgers gives rise to a paradox: that of trying to make two or more socio-technical-economic constructs communicate with each other, despite the fact that they were built by different communities to function as independent systems that do not communicate with each other. It would be wrong to reduce the interoperability between blockchain systems to a mere problem of standards. It is preferable to consider it a problem of reciprocal recognition between sovereign powers in their own space. Unlike the internet, where interconnection has always been a need of the entire cyberspace population, while it was the market that gave rise to monopolies, in blockchain the social forces exercise power in the opposite way, towards the closure and independence of their own system. This is reflected in initiatives that have thus far emerged to circumvent the problem of non-interoperability: they range from the emergence of a single prevalent system, to the affirmation of intermediary blockchain systems, to the adoption of a middleware software able to serve as an intermediary vessel for communication. All three models present solutions in line with the structural closure of the systems. To make an analogy with well-known concepts of international law: the first approach recalls the idea of a military conquest of one order over another; the second resembles the institution of a third-party organization which allows dialogue among equals; and the third is based on a principle similar to that of mutual recognition of the rules of different entities. The analogy is not so absurd, particularly in the case where one considers the internal limiting mechanisms present in one single system and the legal impacts of the non-interoperability among different networks. The game has already begun and it is still too early to say which of the three approaches will prevail. Public authorities will assist in the comparison from the side lines and sharpen the weapons for what promises to be not just a corrective action of the market but a true and actual fight between sovereign powers.

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