

Blockchain, bitcoin and stigmergy: an explanation and a new perspective for regulation

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BLOCKCHAIN, BITCOIN AND STIGMERGY: AN EXPLANATION AND A NEW PERSPECTIVE FOR REGULATION

ABSTRACT: The need for a legal framework that explains a decentralized system is compulsory to understand whether regulation could be useful and effective. Previous academic frameworks did not manage to explain the intimate development and success of a decentralized cryptocurrency system interpreting the difficult relationship among the various layers and activities. This essay tries to create a model based on swarm intelligence and stigmergy explaining the “organization without organizer”. This innovative model can be useful to obtain a new framework that accounts for the different dynamics of cryptocurrencies and how regulation could affect different classes of actors. The distinction in Essential, Native and Metamorphic actors together with the concept of the “organization without organizer” could explain some dynamics and possibility of intervention.

KEYWORDS: Blockchain; bitcoin; Distributed Ledger Technology; algorithm; virtual pheromone

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1. Introduction

The explosion of expectations about the *blockchain* requires a semantic reflection: is this technology clearly defined to have a common base to start a discussion?

There are really too many definitions and interpretations that led to an ambiguity that does not allow any serious analysis.

The semantics become central: what is a blockchain and how is it possible to decentralize a system? It becomes compulsory to start from some basic notions; Distributed Register Technology or Distributed Ledger Technology (DLT) consists in a system of recording and storing data through multiple data files (*ledger*), in which each "point" contains the same data: these data are collectively maintained and controlled by a network of distributed computers, called nodes¹. The *ledger* contains the chronology of the transactions.

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¹H. NATARAJAN, S. KRAUSE, H. GRADSTEIN, *Distributed Ledger Technology (DLT) and blockchain*, 2017, FinTech note, no. 1. Washington, DC, <http://documents.worldbank.org/curated/en/177911513714062215/pdf/122140-WP->

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There are various schemes used to update and maintain the database, and the system based on the chain of transaction blocks linked one to one another on an append-only philosophy is called *Incremental Block DLT*. In this system, the chronology of the transactions takes place through the connection of blocks with mathematical functions aimed at creating an “unalterable” chain².

The computer network can be “without authorization” (*Permissionless DLT or PDLT*), in which each participant can become a node without the need of permission from any authority, just with the use of a *software* connected to the network. In this way everyone can take part in the network, keeping a complete copy of the ledger, participating in *the consensus mechanism*, or leaving without any consequence for the system.

The network, on the other hand, may be subject to “permission” (*Permissioned DLT or Authorized DLT or ADLT*), where some preselected nodes/users could perform some functions and/or activities and, therefore, only certain ones can participate in the network. These networks can be private, hence accessible only to some users, which can coincide with the nodes or with other authorized users, or public, accessible and viewable by anyone.

Authorized DLT may have transactions originating from any user or only by some authorized users but, in any case, modifications in the registry are carried out by the pre-selected nodes.

The DLT has value if the participants reach a consensus on (i) rules, (ii) history and (iii) the fact that the *cryptoassets* has a value.

While understanding central/private/permissioned DLT is quite simple given the existence of a conceptual framework, the creation and existence *ex nihilo* of a decentralized system is very difficult indeed.

The distinction does not regard the storage of data, because a database could have data stored on multiple computers or nodes (distributed database), but on the management of the system. Usually, an entity or a control group may manage the network in various ways: from directly controlling the algorithm to authorizing nodes to perform certain activities.

In decentralized systems (i.e. *Bitcoin*) there is no central entity, and the network relies upon an open source algorithm.

[PUBLIC-Distributed-Ledger-Technology-and-Blockchain-Fintech-Notes.pdf](#) (last visit on 29.05.2020); The COMMITTEE ON PAYMENTS AND MARKET INFRASTRUCTURES, *Digital currencies*, November 2015, <https://www.bis.org/cpmi/publ/d137.pdf> (last visit on 29.05.2020); R. HOUBEN, A. SNYERS, *Cryptocurrencies and blockchain Legal context and implications for financial crime, money laundering and tax evasion*, Policy Department for Economic, Scientific and Quality of Life Policies, Directorate-General for Internal Policies, PE 619.024, July 2018, <https://bit.ly/2B2bn6A> (last visit on 29.05.2020).

² L. LAMPORT., R. SHOSTAK, R. PEASE, *The Byzantine Generals Problem*, ACM Transactions on Programming Languages and Systems, 1982 4 (3): 387–389, M. CASTRO, B. LISKOV, *Practical byzantine fault tolerance and proactive recovery*, ACM Trans. Comput. Syst. 20,4, 2002, 398-461, S. HABER, W.S. STORNETTA, *How to time-stamp a digital document*, Journal of Cryptology, 3,2 1991, 99- 111, D. BAYER, S. HABER, W.S. STORNETTA, *Improving the efficiency and reliability of digital timestamping*, in R. CAPOCELLI, A. DE SANTIS, U. VACCARO (eds) Sequences II, New York, NY 1992.





2. An organization without organizer.

In a decentralized system operations are guaranteed despite the absence of a coordinator, but through self-organization.

The organizational element consists of an instruction, a *script*, an element that allows the participating individuals to generate the organized system, similarly to *swarm* intelligence and stigmergy³.

The organization is, therefore, neither spontaneous nor self-organized, but generated by that aggregating element of the individual's behaviour, becoming an organization without an organizer.

The script contains the architectural project, the DNA of the system, and even contains a pheromone, portmanteau of the Greek terms *Phero* (bring) and *Orme* (excitement), biochemical/semiochemical substances emitted by living organisms that generate behavioural reactions to the contact of organisms of the same species.

It could be useful to analyse the studies and theories of the swarm behaviour and the organizational system that arises from the interactions of individuals in these cases.

2.1. Swarm Intelligence

The study on the swarm intelligence generated a heterogeneous doctrine, aimed at explaining the behaviour of animals and humans, without reaching shared theories and definitions.

The concept of pheromone is the basic point of this unconscious behaviour, a concept that relies upon four main features⁴:

1. A pheromone corresponds to one (or a few simple) chemical compounds (*simplicity*);
2. The functional response to contact is specific to each species (*specificity*);
3. The response, endocrine or behavioural, is well defined (*predictability*);
4. The answer does not depend on the level of learning (*automatism*).

The pheromones, then, are generally divided into four classes depending on the effect they cause on the recipient:

1. *Tracing pheromones*; if released by an individual they are followed as a trace by the other individuals;
2. *Alarm pheromones*; emitted in dangerous situations induce a greater state of vigilance in the individuals who pick them up;
3. *Priming or triggering pheromones*: induce long-term behavioural and/or physiological changes in the recipient;
4. *Free pheromones or signalling*: trigger aggression or mating behaviour in the individual who captures them.

³ G. BENI, J. WANG, *Swarm Intelligence in Cellular Robotic Systems*. Proceed. NATO Advanced Workshop on Robots and Biological Systems, Tuscany, Italy, June 26–30 (1989), E. BONABEAU, M. DORIGO, G. THERAULAZ, *Swarm Intelligence: From Natural to Artificial Systems*, Oxford, 1999; H. MARSH, *Binding Chaos: Mass collaboration on a global scale*; in E. BONABEAU, Eric, *Special issue on Stigmergy*. Artificial Life, Cambridge, 5; M. J. DOYLE, L. MARSH, *Special issue: Stigmergy in the Human Domain*, Cognitive Systems Research, Elsevier., 2, March 2013, 1-74.

⁴ R.L. DOTY, *The Great Pheromone Myth*, Baltimore, 2010.





The classes of pheromones together with the features are the basis of the collective behaviour that eases the generation of an organization. The system is similar to the building of an anthill by termites, using tracing pheromones to add "bricks of mud".

The individual behaviour generated by pheromones can modify the environment in a decentralized way, and, in this case, this phenomenon is called *Stigmergy*⁵.

Stigmergy is not limited to animals but can also be observed on the *Internet*, even on centralized systems, for example with regard to the interactions that can occur through a communication system in a shared environment (leave messages in a newsgroup, bulletin board system, etc.).

The examples are numerous, starting from *wikis* like *Wikipedia*, or in an *open source software project*: the structure and development of available information is comparable to a termite nest, with a first user who leaves the sketch of an idea that attracts other users who continue to add ideas and changes until they arrive at a complex and elaborate structure, but on the basis of a simple instruction (writing on a *wiki*), with specific response (idea of change), predictable behaviour (proposed modification) and without any level of learning (only basic computer skills).

Stigmergy relies upon pheromones and upon interactions through a communication system and in the Web these interactions could become easier and the modification of the environment faster due to its virtual nature.

Obviously, the concept of stigmergy and pheromones must be adapted to the virtual environment. So, it is possible to identify the virtual pheromone in the part of the *code* that (i) allows individuals to communicate among each other without central control or an organized structure, and (ii) induces certain behaviours.

The virtual pheromone eases the interaction between users, and if the interaction generates common coordination among the users, creating a network, even unstable, the modification of the virtual environment has happened and virtual stigmergy took place.

This new system could live with evolution and adaptation or die, but the stigmergy did exist with the birth of the system.

The capacity of survival of the new organization that modified the virtual environment is the key factor of its success, but from a theoretical point of view, the basic element is its birth, the existence. The instruction contained in the code is simple, easy, and without any explicit design of the system but the virtual activity put in place, induces others in acting: the instruction is the unifying element, the *virtual pheromone* that allows the interacting amongst individual.

The interactions move in an unpredictable and indeterminable way because it is impossible to understand the final network from the analysis of the code or on the behaviour at an individual level: it is like trying to understand a human being from the DNA.

The individual is neither aware of the global network nor of the contribution of the other individual parts not of his contribution to the network, acting without awareness but following the *virtual pheromone*.

It is possible to indicate the four typical ingredients for these phenomena:

⁵The term "stigmergy" was introduced by French biologist Pierre-Paul Grassé in 1959 to refer to termite behaviour. He defined it as: «*Stimulation of workers by the performance they have achieved*».



1. *Positive feedback*: they consist of "reinforcements" deriving from the execution of simple rules of behaviour. Such reinforcements can generate the creation of structures.
2. *Negative feedback*: they balance positive feedback and allow the stabilization of the system, such as limitation of resources, depletion of the source the tended behaviour, the disappearance of pheromones or competition between several rules of behaviour.
3. *Fluctuations of positive feedback*: the actors who follow these rules have a behaviour based on randomness that is often decisive for the discovery of new solutions or for recruiting new actors.
4. *Direct or stigmergic interactions*: they are indispensable for the production of deterministic results and for the appearance of durable structures.

In any case, these phenomena are not possible without a decentralized communication system.

2.2 The Bitcoin system

The *peer-to-peer*⁶ network allows a system of communication between individuals without a central body, without a platform owned by anyone, but based exclusively on a data exchange protocol.

The *virtual pheromone* is contained in the algorithm (*Bitcoin core*⁷) that generated imitative energy and allowed the organized development of the system, orienting the behaviour of individuals (nodes).

The actors involved are:

1. Users.
2. Nodes.
3. Miners.
4. Devs.

These actors follow the algorithm, putting the activity into place according to the limited instruction of the code.

The Bitcoin system auto-organizes the whole system around the longest chain and the trust generated in the decentralized environment as a result of the simple rules of behaviour.

Each individual acts following the *virtual pheromone* (like an ant following the path), starting a competition that generates a chain of blocks to make the chronology of transactions unalterable (albeit economically), without anyone participating in such a system to modify it but only to imitate and follow others.

Using the typical ingredients seen above, the positive feedback consists in the attribution of new *bitcoins* for the solution of the block computation problem, the negative feedback from the abandonment of the shorter chain of blocks, the fluctuations from the acceptance or not of the BIPs (protocol modification proposals / Bitcoin Improvement Proposal) and direct interactions, all conventions, meetings and the *community*.

It is undoubted that this form of an organization without organizer (or monopoly without a monopolist⁸) generates a totally new paradigm in which individual behaviour does not even have the

⁶ See: <https://en.wikipedia.org/wiki/Peer-to-peer> .

⁷ A.M. ANTONOPOULOS, *Mastering Bitcoin: Unlocking Digital Cryptocurrencies*, Sebastopol, Inc, 2014, 31-32.

⁸ G. HUBERMAN, J.D. LESHNO, C. MOALLEMI, *Monopoly without a monopolist: An economic analysis of the bitcoin payment system*, Research Discussion Papers 27/2017, Bank of Finland.

awareness nor the intention to act towards a scope but to participate to a system based on imitation or positive or negative reinforcement.

2.3. Forks, cryptocurrencies, and ICOs

Satoshi Nakamoto's paper⁹ and Bitcoin's chain of blocks gave evidence that it was possible to create a decentralized network and various actors started to try to improve or to maximize their utility. The decentralized system then evolved with forks, creation of new altchains and altcoins, modifications the script, the virtual pheromone. The modifications start from Devs that may suggest, on an open source philosophy¹⁰:

- A proposal for modification of the protocol that can lead to:
 - Acceptance of the modification;
 - Refusal;
 - Fork of the protocol with the birth of multiple chains as Ethereum and Ethereum Classic or Bitcoin and BitcoinCash.
- The creation of a new script (new system)
 - Altchain.
 - Altcoin.

The ecosystem evolves with a new form of virtual Darwinism with acceptance and consensus on some crypto-assets rather than others.

The difficulty to create a new decentralized system is increasing and to solve this problem tokens were built over an already existing system: a centralized system over a decentralized one.

The Token system starts with an Organizer, but the logic relies upon a decentralized system (Bitcoin, Ethereum, Ark, etc.) and the central part is the initial framework: after that, in many cases, the system is decentralized.

This step complicates the analysis, as it is possible to create a new system over another one in a decentralized manner, as experienced with Initial Coin Offerings (ICOs).

So, from the perspective of the origin of the crypto-assets, there are genuine crypto-assets and synthetic crypto-assets. The second ones are the tokens built over an existing platform.

3. Classification of the actors

The actors in this new paradigm must have a different classification because of the permissionless development of the system¹¹. The classification is mandatory to identify the impact of regulation and whether regulation could have an effect.

In the case of a pure decentralized autonomous system it is possible to divide actors in:

⁹ S. NAKAMOTO, *Bitcoin: A Peer-to-Peer Electronic Cash System*, 31.10.2008, <https://bitcoin.org/bitcoin.pdf> (last visit on 29.05.2020).

¹⁰ P. FRANCO, *Understanding Bitcoin: Cryptography, engineering and economics*, Chichester, West Sussex, 2014.

¹¹ EUROPEAN CENTRAL BANK, *Virtual currency schemes*, Oct. 2012, <https://bit.ly/2XPlp40> (last visit on 29.05.2020), EUROPEAN CENTRAL BANK, *Virtual currency schemes – A further analysis*, Feb. 2015, <https://bit.ly/2YsfuRy> (last visit on 29.05.2020).

1. Primary Actors or Essential Actors.
2. Secondary Actors or Native Actors
3. Tertiary Actors or Metamorphic Actors

The awareness of the tasks performed, the connection to the system, and the control on that part of the system are the features that generate this classification.

Essential Actors must exist in order for a cryptocurrency system to exist and to be maintained. Therefore, they can be identified in those actors that are vital for the system: the absence or the weakness of only one actor causes the risk of collapse of the entire system.

Native Actors are inborn in the new system, they are not vital, and they perform tasks or provide services that are useful for Primary Actors, with two limitations: they cannot exist and they cannot perform tasks or provide services outside these systems.

Metamorphic Actors provide services to Essential or Native Actors but the only innovation is the use of these systems because their activity is similar to those performed by analogous actors outside this system.

3.1. Primary (Essential) Actors

Primary Actors are not aware and do not control the part of the system they interact with. They are mechanical performers that follow the virtual pheromone and act without any awareness of the final configuration.

In a pure permissionless system, Primary Actors are:

1. Users
2. Nodes
3. Miners
4. Devs.

Users belong to this category because their activity is limited only to the utilization of the system even if their activity is useful and/or necessary to the system.

Nodes, in the permissionless ecosystem, are free to participate or not and their activity is only of data transmission, a mere conduit.

Any computer that connects to the network is called a node. In Bitcoin, nodes that fully verify and fully enforce all of the consensus rules are called full nodes.

The nodes enforce the consensus mechanism on which there is an agreement, but from a practical perspective, they receive and broadcast data, following algorithmic rules no matter what.

This activity is a mere conduit scheme, exempt from liability under most laws around the world because the nodes: (i) do not initiate the transmission, (ii) do not select the receiver of the transmission, and (iii) do not select or modify the information contained in the transmission.

Miners are particular full nodes that process the addition of transaction records to the public ledger of past transactions: the activity consists only in solving a mathematical puzzle to receive cryptocurrency as a reward. The activity is only data processing, without being interested in data contained in a block except for the amount of fees contained in the transactions.

Miners strictly follow rules, because nodes will accept only compliant blocks and in the case of refusal the miners will not receive any rewards.

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Devs work for the improvement of the software, but the software is based on an open source logic so the proposal can be accepted or rejected by the nodes. In this way, Devs can only propose without any other possibility of intervention.

The behaviour of Essential Actors is realized because of the virtual pheromone. They cannot be regulated because of their role and of the unawareness of their activity. They must follow and be compliant with the code because in this case, the sentence “code is law” is absolutely true and must be obeyed. Any failure in doing this will conduce to the total uselessness of the performed task.

Essential Actors follow virtual pheromones and they obtain the virtual reward, that is valueless even though it can have an economic value that is not intrinsic in the protocol, but external and elsewhere.

3.2. Secondary (Native) Actors

Secondary Actors are a new form of business that is built on these networks or on Primary Actors.

The Secondary Actors are not necessary for the working of the permissionless ecosystem but they exist only in this industry. This means that these actors are born only in cryptocurrency system and they cannot perform any services outside of this context.

These actors can provide services to Primary Actors and they mainly receive payments for their services in cryptocurrency.

Mining Pools, some wallet providers (desktop, mobile), provider of software and dAPP, Airdrop, Mixing services, Oracles, are activities that could be performed only in these systems¹².

These kinds of activities are subject to the code, but they do not rely upon it and the compliance could be not so strictly.

Some forms of smart contracts¹³ related to mining or mixing services can generate Native Actors, that usually provide services and obtain rewards or fees in cryptocurrencies.

Regulation must merge with “rule of code” to succeed.

In the case of mining pools (Proof-of-work or PoW), individuals found out that they could work for a long time without finding a block and receiving any reward for their mining efforts. To equalize their income miners started organizing themselves into pools so that they could share rewards “pooling” their resources (hashing power). Mining Pools split the reward according to various reward schemes. All consensus systems other than PoW (Proof-of-stake, Delegated Proof-of Stake, Masternode, etc.) have these features determining a need for composing the code with regulation.

3.3. Tertiary (Metamorphic) Actors

Metamorphic Actors provide known services in this new world in a different way and actual rules are designed in such a way that they cannot be applicable and/or enforceable.

Exchangers, ICOs, Custodian Wallet Providers, Mixing Services, that could be provided to crypto users or to users of other assets: the only differences are the particular features of crypto-assets.

¹² For a particular case see: SECURITIES AND EXCHANGE COMMISSION, *Report of Investigation Pursuant to Section 21(a) of the Securities Exchange Act of 1934: The DAO*, Release No. 81207, 25.07.2017, <https://bit.ly/2XOq2vk> (last access on 29.05.2020).

¹³ N. SZABO, *Formalizing and Securing Relationships on Public Networks*, in *First Monday*, 2, 9, Sept, 1, 1997



It is quite clear that the particularities of crypto assets affect the enforceability of the rules because of the virtuality, ubiquity, and disintermediation.

“Code is law” principle does not affect Metamorphic Actors because they have only the particularity that their business uses cryptocurrencies, therefore, relevant laws could not be applicable due to the ambiguous nature of bitcoin, but their activity has characteristics of normality (buy and sell, deposit, and so on).

4. Regulating the actors

The classification is useful to understand the impact and the success of regulating the actors¹⁴, with the awareness that some of these actors are strictly ruled by the code and they cannot behave in a different manner.

This perspective of analysis leads to a better comprehension of the implication and the effect of imposing chunks of legislation on the actors. We must bear in mind that the only law that defines virtual currencies is the Fifth AML Directive¹⁵, limited to the scope pursued therein.

Not any rule can affect Essential Actors and modify their behaviour because they cannot deviate from the code. The only activity they can perform is to follow strictly the code and obtain the virtual reward: therefore, it is possible to regulate only the economic effect obtained, setting rules about taxation, bookkeeping, and financial reporting, taking into account that these activities are permissionless.

To reach this scope, the preferable way is to define crypto assets under tax and accounting laws and introduce an ad-hoc framework for tax filing and reporting.

The Native Actors are different because the activity performed may be ruled by law due to the fact that they act knowingly. However, this might lead to a difference in the way their activity is performed or organized.

These actors operate in a no man’s land because their activity is similar to regulated activities or normal activities but they exist only in the cryptocurrency system and they obtain only crypto-assets

¹⁴ REGULATORY OBSTACLES TO FINANCIAL INNOVATION EXPERTS, *Final Report*, 13.12.2019 in <https://bit.ly/3dOL6r7> last visit on 29.05.2020).

P. PAECH, *The governance of Blockchain financial networks*, 2017, in *Modern Law Review*, 1073–1110, in https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2875487 (last visit on 29.05.2020).

¹⁵ On 19 June 2018 the 5th anti-money laundering Directive (Directive (EU) 2018/843), which amended the Directive (EU) 2015/849, was published in the Official Journal of the European Union. See https://ec.europa.eu/info/business-economy-euro/banking-and-finance/financial-supervision-and-risk-management/anti-money-laundering-and-counter-terrorist-financing_en (last visit on 27.05.2020). The Art. 3 is the following: «For the purposes of this Directive, the following definitions apply: [...] (18) “virtual currencies” means a digital representation of value that is not issued or guaranteed by a central bank or a public authority, is not necessarily attached to a legally established currency and does not possess a legal status of currency or money, but is accepted by natural or legal persons as a means of exchange and which can be transferred, stored and traded electronically.» See also: FINANCIAL ACTION TASK FORCE, *Guidance for a Risk-Based Approach – Virtual Currencies*, June 2015, <https://www.fatf-gafi.org/media/fatf/documents/reports/Guidance-RBA-Virtual-Currencies.pdf> (last visit on 29.05.2020), FINANCIAL ACTION TASK FORCE, *Glossary of the FATF Recommendations*, October 2018 in <https://www.fatf-gafi.org/glossary/u-z/> (last visit on 29.05.2020).



in exchange for their services. Also, the application of indirect taxes, like VAT, is questionable because some activities could be considered as services under Directive 112/2006/EC with consequent VAT liability. In this case, it could be very hard to identify the customer that is obliged and liable to pay VAT, as the services are performed in favour of the entire network and the payment is received autonomously.

In this situation, relevant regulation could be addressed in two directions: (i) clarification of falling outside the scope of certain regulation (i.e. VAT), and (ii) regulation of the economic effect, taking into account that these activities could be performed in a permissionless way and without physical premises.

The Metamorphic Actors use cryptoassets in their activity and their ambiguous and hybrid nature makes actual legislation unfit. The presence of a central entity and the technological system of the distinction of the object from the transaction constitute the axioms in which actual legislation is built with definition and notion that do not include cryptoassets.

The Metamorphic Actors perform activities that will fall under actual legislation but the presence of cryptoassets makes their activities fall outside the scope of the main directives enacted for consumer protection, investor protection and market integrity.

The possibility to intervene on these actors could follow two different lines:

1. Introducing new definitions in old legislation to extend some existing regulations to new actors (V anti-money laundering directive, directive UE 843/2018), extending the scope and including these new activities.
2. Introducing new laws to regulate these new actors taking into consideration the features of these systems (ICOs issuers, Exchangers).

5. Conclusion

This theoretical framework could help understand the dynamics of a distributed ledger system, its logic, and the difficulty to apply rules and laws written for centralized systems.

The key point is the lack of awareness of the individuals that take part in the maintenance of the system, primarily because these persons are not knowingly acting for the system, but according to a behaviour induced by a virtual pheromone.

A decentralized system that is also autonomous is hard to understand and regulate because there is neither a central point of intervention nor a particular actor to regulate. These systems do not need anything else from the external world but only a community that trusts the code.

The taxonomy of actors involved could be useful to understand the impact and the effectiveness of possible rules, even though some new service providers (wallet service providers, exchangers, token issuers, custodian wallet, etc.) are giving rise to new issues, fostering the need of intervention to fix them¹⁶.

¹⁶ See R. HOUBEN, A. SNYERS, *Crypto-assets – Key developments, regulatory concerns and responses*, Study for the Committee on Economic and Monetary Affairs, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg, 2020 in <https://bit.ly/2MPGuVG> (last visit on 29.05.2020).