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Article

Social emergence in cryptocurrency systems and their open, self-organized development

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Abstract: Being supposedly the ground for an exchange system that does not depend on central, top-down regulation, cryptocurrencies increasingly need new algorithmic and policy-driven rules to maintain their trustworthiness and capacity to exhibit empirically supported growth. The present paper offers a conceptual and philosophical discussion on whether and how cryptosystems could be able to generate resilient development in a way that is coherent with a non-reductionist view of positive economics. As proposed, a plausible way to understand them can be achieved considering their complexity and their concrete, local features, which have to be grasped both in terms of formal and material specificity.

Keywords: cryptocurrencies; economic growth; social technology; emergence; complexity

1. Can cryptocurrencies express growth in an empirical sense

A key aspect of how the infrastructure of cryptocurrency operates is that it strongly depends, following a commonly accepted characterization, on nodes that are strictly functional to the particular computational network. So, besides being anonymous, so-called bitnodes are not distinguished with regard to whether they represent businesses, individuals or miners, for example. They are mainly conceived as data processors part of the cryptocurrency network—in other words, as users.

According to a study by Saiedi et al. (2021), the adoption of cryptocurrency infrastructure depends on how broad are the financial practices and habits in a society. Countries with greater financial culture tend to implement cryptocurrencies more effectively. Also, according to their research, the use and infrastructure of cryptocurrencies will depend on the level of competition within the banking market. This may seem surprising, considering the idealized assumption that competition should generate attractive financial offers that would deviate the attention from decentralized economic alternatives. However, following Saiedi et al. (2021), a lack of trust in the centralized financial system—no matter how competitive—may be correlated with an increase in risk willingness, which leads to investment in cryptocurrencies. Thus, the distrust in an environment produces exploratory tendencies. Now, exploration must stop when agents feel sufficiently safe again. And this is another fundamental principle (partially) explained in their study: In order to be implemented, the cryptocurrency infrastructure still needs an important trust component. This is partly secured by so-called consensus mechanisms, which are program-based procedures that guarantee agreement between the nodes in any exchange (e.g., proof-of-work mechanisms). In fact, these kinds of mechanisms are required by the seminal ground rules of the cryptocurrency architecture (Nakamoto, 2008). Currently, many of those programs have been proposed as purely theoretical

and are not in use; they are, however, valid in principle, fundamentally because they would contribute to the trust infrastructure of the network dynamics, which is the essential aim of a consensus mechanism.

The fundamental relevance of trust within crypto infrastructure leads us to an important question regarding the grounding bricks of mainstream economics, which since the work of John Neville Keynes (1891) follows a tradition of distinguishing between a normative and a positive branch. While positive economics is understood as a body of knowledge systematically built on empirical economic facts (on what is), normative economics is a body of knowledge concerned with how certain rules and means allow economic agents to achieve specific goals (with what ought to be). With this in mind, how can the facts of crypto transactions fit into a framework of positive economics, given that, as already claimed, a cryptocurrency infrastructure depends fundamentally on trust-ensuring mechanisms? Well, of course, this question generalizes easily to all kinds of market transactions. However, normative aspects seem to have a more central role in cryptocurrency than in idealized transactions defined mainly in terms of the pragmatics of supply and demand. This is because, in the case of cryptocurrencies, such normative aspects take a form of algorithmic, top-down rules of interaction. Arguably, the central aspects of normativity in cryptosystems depend essentially on the features related to anonymity and not much on decentralization, which requires by default an important degree of transparency. Although there are no in-principle conflicts between privacy and cryptographic transparency in blockchain technologies (De Filippi, 2016), it is still possible to suggest that such an interplay trades authoritative trust reinforcement for algorithmic normativity. Interestingly, this has a particular influence on the resilience of an economic system involving cryptocurrencies, given the tension between the special regulations and computational mechanisms that seem to be necessary to guarantee the fast recovery from crises, as well as their avoidance (Clack, 2018; Dixit et al., 2022).

In the realm of human social relations, personal trust is a result of past interactions but is also ensured through tradition, rules and habit. Historically, these norms and regularities have been expressed through more or less stable encodings, oral and written. I am assuming here a distinction between this kind of rule codification and algorithmic normativity, where the latter may have a greater autonomy and may be almost fully private or even impossible for humans to reproduce once the algorithm starts operating. This is why I prefer, for the sake of the argument, not to consider it as capable of reinforcing trust in an authoritative way, being sometimes rather closer to authoritarian rule imposition. Naturally, non-computational rules may be authoritarian too (no one gives full credit to banks either). So, the reason I have for assuming the distinction has more to do with how algorithmic normativity is socially implemented than with its basic, formal principles.

What I would like to defend in the present work is mainly the following. If the implementation of cryptocurrencies fails to distinguish carefully the normative and positive aspects of an economic system or even to clarify their interrelations, it may imply a disconnection between theory and empirical reality. As shown below, such a disconnection can take the form an analytic circularity with regard to the concept of growth and its microfoundations.

2. The circularity of growth and the need for concreteness

In this section, I would like to briefly present some assumptions associated with the concept of economic growth. In particular, I intend to examine some factors that may affect the compatibility between growth and cryptocurrencies, as well as their compatibility with a resilient form of development.

As one of the most fundamental concepts in mainstream economics, understanding the concept of growth should be crucial to tackle questions about how cryptocurrency systems may contribute to development. According to a very general way of expressing the traditional neoclassical conception (Solow 1957), the growth of an economy is defined in terms of production increase, characterized by some production function where capital and labor are the main inputs. Of course, how we understand capital and labor within a crypto infrastructure is of great significance in answering questions that connect cryptocurrencies and growth. But we do not have to get now into specific definitions of those notions to detect a problem that is mainly analytical in nature, namely a problem of conceptual circularity:

a) *Analytical circularity of growth.*

a.1 Growth is defined as increase of production.

a.2 Production is defined in terms of supply and demand.

a.3 But at the same time, supply and demand depend on production.

a.4 Therefore, the definition of growth is analytically circular.

This sort of circularity may turn out not being vicious because the economic processes that instantiate premises a.2 and a.3 correspond to different phases of cyclic fluctuations or (arguably) different phases in the production process. Furthermore, note that in a.3 I take the relation of dependence rather than the relation of definition, as in the two previous premises. This has two main reasons. First, the distinction indicates that although the orthodox definitions of the concepts of supply and demand are not provided based on the notion of production, their definitions still implicate, considering a broader and stricter picture, that supply and demand are grounded on production and thus, can be characterized as concepts that are indirectly defined in terms of production. So, here, "to depend on" does not exclude "to be defined in terms of". Also, the expression of the form "*x* is defined in terms of *y*" means, more strictly that the concept of *x* is defined through terms that refer to *y*. Second, the distinction allows to imply, regarding premise a.2, that even if production does not strictly depend on supply and demand, its definition in terms of capital and labor has to involve ways to measure those variables, which—in the dominant model—is market price.

The specific theoretical way out of this problem would depend on how close and how far a theory of economic production is from the different schools, mainstream or heterodox. For example, the Austrian School tends to consider economic cycles as artificial. Under this assumption, the analytical circularity is broken by recognizing in some sense that it is production the main dependent factor, which is determined by value (through variations in the interest rate) rather than conceiving price-value as the main dependent factor, being based (mainly) on production.

But solving the issue through the acceptance of arbitrariness of economic cycles may be seen as a move that, first, fails to maintain the distinction between positive and

normative economics and, second, does not necessarily touch upon the concrete elements that ground the abstract circularity. On the one hand, the latter aspect is central for cryptocurrencies, considering their conformity with usual debt dynamics (Zhang et al., 2021), which is essentially based on abstract features such as incentive percentages and loan ratios. On the other hand, the first aspect—closely related to the second, of course—would imply not only that there are blurred lines between norms and facts within a system of crypto transactions but also that abstract norms are more fundamental than matters of fact. This is more than peculiar for a system that is supposed to be free from hierarchical norms.

Since positivism must be characterized as a perspective that seeks both precision in the analysis and empirical groundings allowing for concrete, inter-subjective testing procedures, a treatment of cryptosystems within the framework of positive economics cannot be adequate without escaping the circularity problem and tackling relevant questions with regard to their concrete foundations. By concrete foundations, I do not mean ones that are only specific in their descriptions or just accurate in their modelizations (which by the way may include mainly simulations). Rather, concreteness should be understood as richness of content. And since content can be both material and formal, appropriate empirical ways of achieving concreteness will thus be in line with materialist as well as with information-theoretic accounts. (In particular, information delimits material production and vice versa.).

Another important point that we should have in mind is related to the comparison between how the circularity of growth occurs within economic systems operating with regular currencies and how it occurs in cryptosystems. Since the problem is fundamentally an analytical one, coming from particular assumptions of neoclassical economics, its theoretical aspects would transport naturally to any system in which currencies are presumed to play the role of a measurement unit satisfying premises a.2 and a.3. Thus, the issue may become more acute in the case of cryptocurrencies as long as they operate more in the form of commodities than in the form of measurement units. This is actually the case of cryptocurrencies, mainly because of their decentralization, meaning that their supply is not directly controlled. Anyhow, non-direct mechanisms of supply control can be found in cryptocurrency networks. For instance, hash-rates keep the mining velocity under a given arbitrary limit. Another example is the taxation role of inflation (Bailey et al., 2021), as well as the anti-inflationary rule called halving. Further in the centralization spectrum are central bank digital currencies, which technically are not cryptocurrencies and behave fundamentally like fiat money. However, it is of great importance to analyze how different digital currencies with different degrees of centralization interact (Helmi et al., 2023). It is usually claimed that neither fiat money nor cryptocurrencies have intrinsic value; their value is determined externally by different forms of normativity. However, even if this aspect distinguishes them from commodity money, which does have intrinsic value, fiat money and cryptocurrencies may behave as commodities under a perspective of debt and finance dynamics, as well as considering their concrete structural foundations. In principle, assuming that intrinsic value could be either primitive or derivative, the latter may emerge in a system, given appropriate interactions between parts of it that have primitive intrinsic value.

Now, regarding the analyticity of the circularity problem, let us pose it in the

following form, considering, instead of the relations of dependency and definition, the function relation, which is more general:

b) *Functional circularity of growth*.
b.1 Growth is a function of production.
b.2 Production is a function of price, i.e., of supply and demand.
b.3 Both supply and demand are functions of production.
b.4 Production is a function of price and price is a function of production.

Premise b.2 could be decomposed as "Production is a function of capital and labor" but for the sake of the argument we can characterize production as a function of price, given that, according to the dominant model, both capital and labor are measured based on the market laws.

As already claimed, typical solutions to the circularity problem assume either a distinction between price and value—together with the acknowledgment that cycles are artificial—or that premises b.2 and b.3 represent different stages in the production process. A special case of both of these kinds of solution would be to characterize the concept of supply in terms of a notion of quantity that is independent of price. Murialdo and Cifuentes (2022) develop an account that tackles this challenge, offering a value metric based on conditions of high information processing power and complexity. Also, related to the issue of intrinsic value, Murialdo and Belof (2022) propose a coin that would stabilize in correlation with electricity (rather than through a correlation with fiat currencies or other debt dynamics), thus arguably not depending on emergent values. This does not seem to be possible for market-oriented models. Either way, a solution would involve fundamental normative assumptions. On the one hand, if we let all economic value to be defined as price, any decision that influences supply and demand in a top-down way can be seen as normative. The design of consensus mechanisms implies such kind of decisions. On the other hand, supposing that we assume a way of distinguishing market-based value from other kinds of value, we have at least two alternatives: We may either select only non-price values that are supposed to be factual, i.e., non-normative (which is already a normative constrain), or we may open the way for normative values as fundamental economic values. One of these values could implicitly give intrinsic value to the cryptocurrency itself, as when it appears that the fundamental aim of the cryptosystem is to replace fiat currencies or just to increase the number of users. (Similarly, regular monetary systems may conduce to the aim of just having or accumulating money. This fetishization of money is actually a more general feature of capital.) These considerations should make clearer how the circularity problem of growth may exacerbate the issue of the failed neoclassical distinction between the normative and the positive.

In general, my argument pends on the following. The lines between norm and facts are blurred as a result of the circularity problem of growth, which may be more dramatic in cryptosystems because of the nature of algorithmic normativity. As defenders of cryptocurrencies claim, no central authority is needed in their system; just the main basic rules. However, these rules still allow (and even demand) endorsing different trust-securing mechanisms, as well as certain changes that may impact the system's stability and wealth distribution. This makes it particularly difficult to

distinguish between the economic facts of cryptosystems and the economic norms associated with them. Along this, the issue may become more acute with the analytical circularity of growth, especially if cryptocurrencies fail to behave as non-commodities and if their concreteness is not adequately accounted for.

Having all this in mind in the face of circularity, it seems plausible to explore an answer that connects the abstract features of cryptosystems with their concrete infrastructure (including the production of hardware, on the material side, and consensus mechanisms, on the side of the formal). In order to give a conceptual sketch of how we could go towards that exploratory direction, I would like to briefly present in the remaining sections some ideas on the concept of emergence, together with a take on cryptocurrencies that conceives them as sociotechnical ecosystems.

3. Social emergence: Benign self-organized loops

It is a broadly accepted idea that economies and transaction systems in general behave as complex systems, i.e., as systems that exhibit, at least in part, types of behavior that involve randomness, self-organization and the arising of novel properties that cannot be reduced to the behavior of the vast number of parts and system-constituting interactions. Take, for instance, the different possible global patterns of self-organization that may emerge in an economy from a great number of local interactions that are mainly based on resources and needs, i.e., supply and demand (Krugman, 1996). Notably, the emergence of economic self-organization depends neither only on the number and variety of interactions nor on a global structure constraining them. Supply and demand fall short of expressing economic complexity. Beyond them, characterizations of complexity depend on content, on meaning. By meaning as content I am not supposing characteristics that are fully opposed to the formal. Rather, the dependence of complexity on meaning can be formal, as in the case of rule-dependent notions of complexity (such as algorithmic complexity) or other notions that depend on any sort of regularity. Rules and regularities determine content. Not being necessarily subjective, characterizations of complexity depend—more or less directly—on how individuals attribute meaning to their environments and to those interactions, on inter-subjective symbolic sense-making and on a sociological understanding of economics (cf. Sawyer, 2005).

On this basis, in order to understand growth in terms of how cryptocurrency technologies develop and of how they respond to their associated business cycles, it is crucial to analyze the goals of their developers and shareholders, both in general and locally. As other features of cryptosystems considered in this work, many features associated with their business cycles are not exclusive of them. They are common to the great majority of economic systems at stages of great technological and social challenge. The present argument taken as a whole oscillates between showing properties that might seem special and exclusive of cryptocurrencies and showing how those very properties are expressions of the organic development of capital in particular periods of human history.

It is also essential to study how cryptosystems interact with centralized markets and other parts of the global economy, as well as with different aspects of social life, including ethical, political and environmental ones. The particular complexity of that

combined system taken as a whole cannot be grasped assuming a single horizontal level of description—like purely microeconomic descriptions or plain algorithmic descriptions—from which everything else purportedly arises. However, if we want to maintain explanatory power and empirical concreteness, there still has to be a way of conceiving those kinds of horizontal descriptions as fundamental in some sense. Trying to explain any market's behavior only in terms of macro-level structures usually ends in losing track of those epistemological aims.

Thus, an adequate way would be to define self-organization in terms of a contextual notion of emergence (Bishop and Atmanspacher, 2006; Céspedes, 2020). As I propose, such a notion would demand finding, first, a relevant context in which some of the self-organizing properties can be reduced to some lower-level description; second, a relevant context where those self-organizing properties are strictly irreducible to lower-level descriptions; and third, a context that exhibits a drastic change of complexity correlated with the appearance of self-organization. The first two conditions allow us to break a vicious analytical circularity between macro- and micro-levels (such as the circularity related to growth). (As is well known since classical economics, capital tends to increase its circulation velocity thanks to technology. Now, we may escape the viciousness of the circularity of growth regarding its analytical aspects. But even if we manage to analyze in a non-vicious way and in concrete terms how growth circularity develops, such a development may exhibit other kind of vices, such as ethical or political ones. The third condition guarantees the diachronic, gradual (although abrupt) arising of the properties in question, dismissing arbitrary top-down regulations as a main cause.

Regarding cryptocurrency systems, a contextual account of emergence would be adequate to tackle some of the general issues already mentioned. It could provide conceptual tools to understand in which sense economic growth is possible within a system of transactions based on blockchain technology and to understand, as well, whether it could be sustainable and resilient under the current conditions and definitions. It could also help us characterize the concrete aspects of cryptocurrency infrastructure taken as a whole, i.e., not only conceiving bitnodes as the only fundamental parts but also conceiving the concrete features of the technologies involved. As argued, the kind of concreteness that adjusts to a genuine positivist understanding of economics would imply contexts attending to material conditions, such as hardware production and physical resources, along with formal conditions, such as information and algorithmic structures.

4. Crypto systems as sociotechnical ecosystems

According to a work by Shin and Rice (2022), blockchain technologies in general and, as such, cryptocurrency systems, should be characterized having in mind their complexity and connections to other social systems. They defend the idea that cryptocurrencies constitute ecosystems that cannot be studied merely in terms of their financial aspects and propose a broader level of analysis which encompasses technical and non-technical conditions. As I would like to show, this kind of wide-focus analysis is perfectly in line with the notion of contextual emergence introduced above.

Basing their study on the case of how cryptocurrency has been implemented in

Dubai, Shin and Rice note some problematic circumstances due to the particular cultural and political conditions, such as weak privacy and lack of trustworthiness related to lack of information about how blockchain technology works. These and other social phenomena have led to new regulations, which include measures like the obligation to be present in Dubai to carry on businesses that involve virtual assets.

Shin and Rice (2022) propose three basic set of conditions that should be fulfilled to have a sociotechnical understanding of cryptocurrencies. First, the practices and knowledge associated with them, including their ethical and cultural effects, should be accessible to the potential user's everyday life. This means making knowledge accessible at and from different levels of explanation, including technology-oriented, sociological and even ecosystemic angles. Second, as a sophisticated network infrastructure, the foundations of a cryptosystem cannot be constrained and stabilized in terms of a one-time policy but have to be constantly under scrutiny and study. Now, this does not mean that its constant maintenance should depend only on top-down, state and federal policies. In combination with the first condition, a resilient crypto-infrastructure would have to involve self-organized forms of normativity, driven by education, culture and socio-ethical reflection. Third, and related to this last aspect, Shin and Rice (2022) argue that policymakers will have to be particularly focused on ethical approaches and on how these combine with technological implementation. A key feature shared by all of the three conditions is that they reinforce an epistemology that implies application and implementation, not being mainly intellectual and theoretical. This differentiates sociotechnical understanding from other types of knowledge.

It is especially decisive for the discussion I am proposing that these conditions are essentially based on context-dependent ways of identifying sociological properties and, as such, on context-specific methods towards the implementation of crypto-infrastructure and its sustenance. Note that the conditions proposed by Shin and Rice for their sociotechnical account of cryptocurrency do not exclude its technical and financial aspects, which are still fundamental. This is compatible with the first condition regarding contextual emergence, as outlined earlier: There must be a relevant context (or a set of relevant contexts) in which economic self-organizing behavior is conceived as reducible to some set of low-level descriptions. So, demand-based and growth-based analyses subject to mathematical functions, law-like idealized behavior and algorithmic restrictions are still fundamental in some contexts.

Cultural, political and ethical features in Shin and Rice's characterization are captured by the second condition of contextual emergence: There must be a relevant context that renders economic self-organizing behavior as irreducible. This explains the need for the constant sociotechnical evaluation of cryptocurrencies. It is also related to the fact that a sociotechnical view sees cryptocurrency systems as open systems that are in permanent interaction with a diversity of other sociopolitical systems, which means that sooner or later, crises will come, and abrupt changes in complexity are going to occur (third condition of contextual emergence). It is crucial to understand how abrupt they can be. Only a broad sociological point of view will allow for a clear insight into adequate adaptive behavior to those abrupt changes and proper anticipation of their negative impacts.

Let us go back to the issues regarding the analytical circularity of the neoclassical

concept of growth. In order to guarantee a healthy growth structure generated by crypto markets and a resilient development of crypto infrastructures, it is not necessary to completely break the co-determination between production and value-generating dynamics. What is needed is an adequate set of methods to identify the context-dependent ways in which production and value are concretized, which in the particular case of crypto economic systems imply the cultural and sociological understanding of practices, together with the relevant financial and top-down normative features, of course, but also with non-algorithmic and macroeconomic normativity.

Thus, the way out of the analytical circularity trap is not letting it be a purely analytical circularity but grasping it as concrete as possible, as empirical as possible (assuming a non-reductive notion of experience, of the empirical). It means grasping the appropriate circularities of a system that, under the wide scope, is extremely complex. According to what I have proposed, these circularities are neither fundamentally analytical nor abstract but rather consist in feedback and feedforward loops involving constant observation and careful action.

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