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Sustainable Blockchain or Blockchain For Sustainability: Blockchain Technology As A Digital Enabler For A Sustainable Supply Chain (A Preliminary Analysis)

Paper in progress

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Abstract:

Since the introduction of bitcoin and other cryptocurrencies, Blockchain and distributed ledger technologies have been widely adopted in several domain areas. The current studies regarding this technology highlight the promising benefit in the disruption of the functioning of the whole business models. However, many technical challenges are threatening the full introduction of this technology to the organizations. One of the biggest weaknesses of blockchain technology is that it consumes more energy than any decentralized system. Proof of Work (*PoW*) is always pointed to be a “waste” energy consensus protocol and thus makes some blockchain platforms unsustainable. However, just because a blockchain consumes energy does not make it unsustainable. Indeed, in the context of supply chain management (*SCM*), blockchain can improve traceability and product tracking through information sharing, enhance transparency in processes, and ultimately contribute to sustainability of the supply chain. Blockchain has the potential to improve the current systems and infrastructures and make them sustainable.

Keywords: *Blockchain, PoW, Sustainability, SCM*

Introduction:

Supply chain is one of the classic application areas of blockchain technology. Supply chain represents a huge ecosystem as it includes several stakeholders and may be very complex in terms of management. During the manufacturing process of a product, from the manufacturer to the end consumers, many challenging events could occur during the process. For example, physical damages and defects, delays, costing (energy and labor)... Failures in supply chain influence all stakeholders in the ecosystem economically and in terms of image. In addition to the traditional challenges of generalized supply chains related to transparency and tracking, some Supply chains face several peculiarities that make them more difficult to manage, i.e. counterfeit products and the suspicious provenance of products. Blockchain can bring benefits to supply chain systems. It may improve the supply process, ensure the quality of products and prove their provenance (Tian, 2017). These characteristics could not only improve the performance of blockchain in terms of its technical issues (Scalability) but also lead to its sustainability.

Blockchain is the emerging technology behind the bitcoin appearance (Nakamoto, 2008). This technology cleverly combines a set of well-known technologies such as cryptography, databases and peer-to-peer networks (Dhaoui, 2021). In other words, Blockchain is a distributed database that stores and records data in blocks securely using cryptographic algorithms. Given the significance of its industrial potential, blockchain is touted to disrupt not only the financial domain but also many other application areas, i.e. Supply chain Management, healthcare, education ... However, several researchers and practitioners are still skeptical regarding blockchain technology applicability (Zheng et al., 2020). One of the major challenges in the blockchain industry is sustainability as it has an environmental cost. Moreover, three main technological issues are repetitively identified which are **scalability, authorization and security, and an excessive consumption of energy** (Abu-elezz et al., 2020).

Blockchain technology consumes considerably power because of what we call consensus protocols (Chaudhry & Yousaf, 2018). To verify transactions, some blockchain platforms require computers and algorithms to solve complex mathematical problems in order to reach consensus (e.g. Bitcoin). This mining method takes a lot of time and energy to record a transaction. Thus, this feature presents the unsustainable character of the blockchain technology. However, what is sustainability? Moreover, how does blockchain affect sustainability? Is blockchain a digital enabler for sustainable development?

Sustainability refers to the capability (capacity+ ability) to maintain or manage a process continuously over time. Therefore, a sustainable blockchain means a blockchain which uses a sustainable consensus protocol and which enables to sustain the management of a process. However, it is important to highlight that blockchain has the potential to reach sustainability in several domains despite the implemented protocol through the circular economy (Esmaeilian et al., 2020). It is the paradox of sustainable blockchain or blockchain for sustainability. To be more explicit, industry and innovation are essential to achieve economic sustainability. Therefore, the question remains to know if blockchain technology is able to achieve the three main pillars of sustainable development, which are environmental, economic and social sustainability (Purvis et al., 2019), and how does it manifest itself in supply chain management?

In this study, we intend to explore the following paradox: Sustainable blockchain or blockchain for sustainability. In order to properly clarify the existing discrepancy, we raised the following main research question: What are the main blockchain features and characteristics that enhance Supply Chain sustainability? Our main objective is to investigate which characteristics do concretely help to achieve sustainability and observe how it can be applied in practice. A case study is used to investigate and bring preliminary findings to this research.

This research study is a work in progress and still need extra research and deep analysis to reach relevant findings.

Blockchain as a disruptive technology for SCM:

In this section, we first introduce the consensus protocols of blockchain, which are directly related to the sustainable blockchain. Then, we present the concept of sustainable supply chain and finally summarize the main characteristics of blockchain for a sustainable supply chain.

Consensus protocols of blockchain: A sustainable protocol for a sustainable blockchain

A consensus protocol is a process for finding agreement on a single data value between distributed processes or systems. It's an important feature of blockchain because, when consensus is reached in a blockchain, it leads to a successful implementation of a smart contract and thus an appropriate execution of a transaction (Dhaiouir & Assar, 2020).

Concerning our research, when we tackle the sustainability topic, we should probably refer to the consensus protocols. For instance, Proof of Work (PoW), which is known as one of the most “unsustainable” consensus protocols (Shoker, 2017), is no longer a judicious option because of its numerous latencies; the high energy consumption and the poor performance scalability (Vukolić, 2016). In fact, the choice of the appropriate consensus protocol would determine incentive mechanisms, authentication, and verifiability, fairer distribution among the network stakeholders, as well as to rationalize the consumption of power and thus improve scalability in terms of time and storage. Proof-of-Stake (PoS) or proof-of-activity (PoA) could be reasonable protocols to reach sustainability. Moreover, Proof-of-exercise (PoX) (Shoker, 2017) is introduced as a new consensus protocol that represents a sustainable alternative of PoW. A sustainable consensus protocol is a crucial condition for sustainable blockchain.

Sustainable Supply Chain (SSC):

Sustainable Supply Chains or green supply chains have become a foundation to any organization that seeks to fulfill the three pillars of sustainability: environmental, economic and social (Purvis et al., 2019). A SSC can be defined as “management of material, information, and capital flows as well as cooperation among companies along the supply chain while taking goals of all three dimensions of sustainable development, i.e. economic, environmental and social, into account which are derived from customer and stakeholder requirements” (Prasad et al., 2020). A supply chain is sustainable when it meets these three conditions (Prasad et al., 2020) :

- 1) Ensure a complete collaboration between all the stakeholders of the SC
- 2) The complete achievement of the three pillars of sustainability
- 3) Recognize the roles and responsibilities of each stakeholder of the SC

It is important to draw our attention to the second condition, which states that the achievement of the three pillars of sustainability (Environmental, economic and social) is essential to reach SSC.

Blockchain features and characteristics for Sustainable Supply Chain

Blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network using cryptography (Ferreira et al., 2019). It is a consensus, unanimous decentralized and secure system to store transactions.

From the above, it can be inferred that these concepts make blockchain a very transparent and efficient system for recording transactions as all relevant stakeholders maintain some level of equality and access in tracking the process. These features make blockchain a veritable choice for a secured and trusted system for a Sustainable Supply Chain.

The application of blockchain technology in supply chain management is a new approach that has been widely explored by researchers. Previous work include the use of blockchain in order to create new business models and enhance performance and competitive advantages in SCM (Wamba et al., 2020). Blockchain has the potential to enhance supply chain sustainability standards especially in developing countries (Kshetri, 2021) . Blockchain is expected to ensure **transparency, effective traceability, responsive supply chain, and accountability** (Yadav & Singh, 2020). These four characteristics will be used in our empirical research. Another concept to highlight the transparency side of blockchain is : “The Supply Chain Has No Clothes” (Francisco & Swanson, 2018). In this research paper, Blockchain may bring supply chain transparency to a new level because it can lead to new ways of control in terms of exposing the bad practices in manufacturing (Child labor, raw materials provenance ...)

Despite these benefits and potentials for SSC, most empirical researches that have been done in this application area do not show promising impact. To some extent, adopting Blockchain to improve the performance or the sustainability of supply chain still grapple with various issues that make the SSC process very challenging.

Research methodology: Case Study

In the earlier parts of this study, the problem statement that we seek to address through this preliminary work was clearly presented. In addition, with the current literature on the reviewed subject and the very

important highlighted gaps, there is the need to conduct an empirical research to fill these gaps. However, conducting only few interviews within an organization or several is clearly not the most clear-sighted path to follow to study this phenomenon.

Case Study selection:

In this work, we use the case study methodology. It is considered as one of the most appropriate approaches that enables to investigate in-depth a specific and complex real-world topic, which is in our case; Blockchain-based supply chain sustainability. We choose the single case study approach introduced in (Irani et al., 1999) as we intend to deeply investigate the following paradox: Sustainable blockchain or Blockchain for Sustainability by exploring the first findings of the main research question.

Research question:

As stated at the beginning of this study, the main objective of this research was to investigate and analyze which blockchain features and characteristics lead to a SSC. To achieve this main objective we need to understand the current existing gaps in the literature and especially evaluate the “appropriate” sustainable features or characteristics that enable to reach sustainability. From these observations, the research will be looking to answer this main research question: What are the main blockchain features and characteristics that enhance Supply Chain sustainability?

Data Collection procedure:

In our research, we will be combining a direct data collection procedure through semi-structured interviews with document reviews from related sources. **1) Documents analysis (Secondary data):** For this study, we have relied heavily on the use of various documents related to the subject matter from sources ranging from hackathons, organization’s publications and organization’s sources. Due to some of the limitations encountered with the analysis of documents, we have gone a step further to conduct semi-structured interviews to collect primary data on the phenomenon. **2) Semi-structured interviews:** For this research, we choose to start the case study by doing interviews because we will be combining a direct data collection procedure through semi-structured interviews with document reviews from related sources. The following sub-questions are inserted in the semi-structured interviews and are valuable in drawing preliminary findings:

- 1) What are the main feature/characteristics of blockchain in the supply chain?
- 2) Which of these features/characteristics were used in your project in order to reach sustainability?
- 3) What are the Barriers, and Challenges in the use of Blockchain for Sustainability in the Supply Chain?
- 4) Which of these challenges were faced in your project? (For future work)
- 5) What were the adopted solutions to overcome them? (For future work)

Preliminary results, discussion and implications:

In our study, we are investigating in a big organization of blockchain, which has been working in SSC projects since 2020. The main objective is to create a sustainable infrastructure for the SCM application domain using the features and characteristics of blockchain technology. Only two semi-structured interviews were conducted for now (with the project manager and the chief editor), and several internal documents and files were analyzed to get these two preliminary findings:

Sustainable blockchain: Blockchain features and sustainability

The interviewees stated that the association of the terms “blockchain” and “sustainable” would say that certain blockchains are not sustainable. However, it is not because a blockchain expends energy that it is not sustainable. We must go further. Giving the example of Bitcoin (A consuming energy platform because of the use of *PoW* protocol consensus) , which represents a major innovation on a planetary scale, is secure because it expends energy. It has never been hacked since 2008 and many blockchains are now based on its model. The right question to ask: is the service offered worth the energy expenditure? Moreover, bitcoin has a big value today (1 Bitcoin = 19 913, 15 euros). Therefore, blockchain features could be unsustainable only for the environmental pillar of the sustainable development.

Another feature was pointed out which is the ledger type. In private blockchains, organizations set their standards to ensure security. However, the problem remains enormous, as private blockchains are not as much as decentralized as public blockchains that can be problematic regarding trust between stakeholders. Moreover, creativity is very limited due to the private closed structure of the blockchain with the limited cooperation and collaboration between the stakeholders. To achieve sustainability, public blockchains are highly recommended.

The interviewees and the organization files cited a new feature that was not introduced in the literature, which is Scalability. Scalability means the ability of an organization to scale and to grow. A scalability without a sustainability model can have negative impact on the business growth and in the economy. These findings can be summarized in the following table:

Blockchain features		Sustainability Pillars		
		Environmental	Economic	Social
Consensus protocol	PoW	High ¹	High	Medium to High
	Other	Low		
Ledger type Permissioned	permissioned	High	High	Medium to High
	permissionless	Low		
Scalability	Low	Low	Low	Medium to High
	Medium	Medium	Medium	
	High	High	High	

Table 1: Blockchain features' impact on the three pillars of sustainability

Blockchain for Sustainability: Blockchain characteristics for SSCM

According to the interviewees and the organizations files, Blockchain technology has the potential to make possible the valuation of the supply chain by presenting it as a key function of the company, which makes it possible to clean up its operation. The supply chain is in full transformation. The requirements of consumers and regulatory authorities control in terms of **transparency**, quality and traceability are increasingly important. Blockchain is a technology that participates to provide full process visibility. Through its **responsive characteristic**, it allows having **certified data**, which will **create trust**. All these characteristics are promising to have a big impact on the three pillars of sustainability. These findings can be summarized in the following table:

Blockchain characteristics	Sustainability pillars		
	Environmental	Economic	Social
Transparency	Low to High	High	High
Effective traceability	Low to High	High	High
Responsive SC	Low to High	High	High
Accountability	Low to High	High	High

Table 2: Blockchain characteristics' impact on the three pillars of sustainability

As it can be noticed, few information derived from this preliminary research. The list of blockchain characteristics is not exhaustive and the measured impact was not clearly defined. As well as the social sustainability pillar was not investigated. A complete advanced research is highly recommended to finish this work in progress, which seems very promising according to the first findings.

Conclusion

In this research, we tried to explore the paradox of sustainable blockchain and blockchain for sustainability. We emphasized on the concept of sustainable supply chain to illustrate. However, the literature is pushing us forward out of bias and our first convictions. Because sustainability is a whole system, which is based on three main, pillars (environmental, economic and social). The impact on these three pillars is different from a blockchain feature to a blockchain characteristic. Indeed, contrary to what might sometimes be believed, an unsustainable blockchain could lead to SSM according to the economic and social pillars. These first observations and preliminary findings enhance us to go beyond the four blockchain characteristics defined in the literature and tested in the case study. Broadening the scope impels us to question the real impact of blockchain characteristics on the economic and social sustainability. Which characteristics work and which doesn't? Alternatively, even go further and maybe too far tricky: Is blockchain able to enhance environmental sustainability?

¹ Low, medium and high refer to the impact, the impact could be negative or positive, we used the green color for + and red color for -

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