Unveiling the Digital and Sustainability Convergence: Leveraging Blockchain for Grand Challenges Oriented Business Model Innovation

Davide Moiana, Jacopo Manotti, Antonio Ghezzi and Andrea Rangone
Politecnico di Milano, Department of Management, Economics and Industrial Engineering, Via Lambruschini 4B, 20156 Milan, Italy

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Abstract: Social and ecological challenges are increasingly threatening the world, asking for concrete actions from all the actors and sectors of our society. Broad social and environmental problems have been collected below the definition of "Grand Challenges" (GCs), to represent their wicked nature and tough resolution. In order to advance these goals, the United Nations in 2015 ratified the so-called 2030 Agenda for Sustainable Development, which includes 17 Sustainable Development Goals (SDGs). This new imperative implies firms to shift towards new sustainable practices and innovate their business models. Management research has identified in emerging technology one of the most powerful means for Business Model Innovation (BMI). In this regard, blockchain is claimed to have the ability to drastically restructure firms' business structures and markets. By way of an inductive multiple-case study analyzing 4 start-ups in the Voluntary Carbon Market (VCM) field, this research proposes a conceptual model summarizing three actionable characteristics (Asset enabler, Trust machine, Collaborative and coordinated action enhancer) through which blockchain technologies can drive BMI, making it clear on how they enable to embed GCs in the business model components.

1 INTRODUCTION

The critical social and environmental issues world is facing nowadays have been called "Grand challenges" (GCs), which are wicked issues with complex, no clear and unequivocal solution (Ferraro, Etzion, & Gehman, 2015; George, Howard-Grenville, Joshi, & Tihanyi, 2016). The United Nations' 2030 Agenda for Sustainable Development outlines 17 Sustainable Development Goals (SDGs) aimed at achieving social, environmental, and economic objectives. To address these goals, governments, businesses, and individuals must work collaboratively (Grodal & O'Mahony, 2017; Howard-Grenville & Spengler, 2022). Firms must also adapt to the evolving definition of their role in society, shifting towards generating shared value for all stakeholders. This requires transitioning towards sustainable practices, facilitated by technological solutions (Foss & Saebi, 2017; George et al., 2016), including blockchain, which we examine in this research. Through an inductive multiple case study in the Voluntary Carbon Market (VCM), we identify blockchain's potential as an asset enabler, trust machine, and enhancer of coordinated and collaborative action, proposing a theory of strategic business model design for Grand Challenges. Our research contributes to the convergence of the digital and sustainable imperative and advances the understanding of technology's impact on business models.

2 THEORETICAL BACKGROUND

George and colleagues (2016), describes GCs as "*formulations of global problems that can be plausibly addressed through coordinated and collaborative effort*" (George et al., 2016; Howard-Grenville et al., 2019). Namely, GCs call for a coordinated and consistent effort from a wide range of stakeholders from different levels of organizations and society, for alterations in the way economic

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activities are planned and carried out and for advancements in tools and technology (George et al., 2016; Griggs et al., 2013; Muzio & Doh, 2021). For profit businesses, alone or in conjunction with governmental and non-profit organizations, are relevant actors in this regard, as they represent a "locus of innovation" and they can play a central role in fostering social impact collaboration (Bode, Rogan, & Singh, 2019; Wang, Tong, Takeuchi, & George, 2016).

Business model innovation (BMI) is increasingly recognized as a key driver to deliver greater social and environmental sustainability in the industrial system, as it entails holistic changes to how business is conducted on multilevel and multistakeholder dimension (Bocken et al., 2014; Klein, Spieth, & Heidenreich, 2021). Zott and Amit (2010) define the business model as an architecture of value that can be described as a network of activities, activities and transactions that involve internal and external stakeholder that can be described in terms of content, structure and governance. An activity system is also characterized by different dominant logics to achieve value creation: Novelty, efficiency, complementarities and lock-in (Zott & Amit, 2010).

Sustainable business model innovation is defined as the incorporation of heterogeneous logic within business, considering the so-called economic, environmental and social "triple bottom line" (Bocken et al., 2014; Stubbs, 2017). According to Cohen & Winn (2007), sustainable business models should aim to tackle market inefficiencies such as imperfect competition, negative externalities, and information asymmetry. However, implementing sustainable business models can be challenging due to six managerial problems that pose significant obstacles to achieving sustainable change, identified by George and colleagues (2021): knowing, valuating, communicating, coordination and trust, access and reach and institution.

Emerging technologies have the potential to enable sustainable-oriented business model innovation (BMI) (Foss and Saebi, 2017; Teece 2018). Emerging technology–enabled BMI can have a profound impact on stakeholders in the ecosystem, including customers, suppliers, and strategic partners, creating new needs and leading to novel resource configurations (Amit & Han, 2017; George et al., 2021).

Blockchain, an electronic ledger system that enables secure and transparent transactions without the need for intermediaries, has emerged as a particularly interesting technology to study due to its potential for disrupting various industries. It fulfills the five parameters identified by Rotolo, Hicks, and Martin (2015) to define an emerging technology: radical novelty, fast growth, coherence, prominent impact, uncertainty, and ambiguity. However, these properties are not fundamental actionable characteristics, but rather factors that explain the diffusion and impact of a technology, allowing it to be classified as "emergent" and advancing the consolidated work on technology diffusion (Tushman & Anderson, 1986; Utterback & Abernathy, 1975).

Recognizing the emergent nature of blockchain and the possible consequent implications in terms of BMI and GCs, the research questions investigated in this study is *"How blockchain enables the design of Grand Challenge-oriented business models?".*

3 METHODOLOGY

The unit of analysis aim of this research are the technological features of blockchain that enable new sources innovation in the business model design elements proposed by Zott & Amit (2010) in their activity-system view, and how they tackle the managerial problems formulated by George and colleagues (2021).

Blockchain impact on sustainable business models is a research field still unexplored, from which new theory can emerge (Bansal & Corley, 2011; Eisenhardt, 1989). As a result, it is advantageous to proceed with qualitative research (Gartner & Birley, 2002). More specifically, it was chosen to conduct an inductive multiple case study (Eisenhardt, 1989; Yin, 1984). This approach is preferred over a single case study due to its robustness and ability to enable comparisons between different manifestations of the phenomenon, thereby increasing the generalizability of results (Eisenhardt & Graebner, 2007; Meredith, 1998).

3.1 Empirical Setting

Climate change is one of the most critical challenges facing humanity, as it is widely considered a significant threat (Pörtner & Roberts, 2022). The primary issue with climate change is the rising concentration of greenhouse gases in the atmosphere, which causes global warming. However, in most industries, there is no penalty for causing air pollution.

Carbon markets can be an effective tool for addressing the negative externalities associated with greenhouse gas emissions. Voluntary Carbon Markets (VCM) are non-regulated markets where

organizations participate based on self-imposed emissions reduction goals. Actors can offset their impact by purchasing carbon credits generated through the development of mitigation projects that follow international methodologies, verified and certified by external accreditation entities such as Verra and Gold Standard (Ieta, 2021).

Voluntary carbon market should increase by a factor of or more by 2030 and by a factor of up to 100 by 2050. However, the market faces several challenges that impede it to scale up, including measurement technical issues, heterogeneity and illiquidity of carbon credits, greenwashing concerns, opaqueness and fragmentation, entry barriers and lack of regulation (McKinsey, 2021).

The use of blockchain technology is becoming increasingly popular among practitioners who are determined to combat climate change and promote decarbonization of the global economy. This growing interest is apparent in the astonishing number of new companies that are emerging, offering innovative solutions that leverage blockchain for carbon markets (Morgan Stanley, 2022; Southpole, 2022).

3.2 Case Sampling

To ensure appropriate theoretical reasoning and high-quality case study research, a theoretical sampling approach was utilized to select cases for this multiple case study with potential to offer theoretical insights (Goffin, Ahlstrom, Bianchi & Richtner; 2019; Eisenhardt & Graebner, 2007).

Pitchbook, a subscription-based website covering private capital markets such as venture capital and private equity, was the primary source for identifying blockchain-based startups for case selection. Searches were conducted using keywords such as "Blockchain" AND "Sustainability" or "Blockchain" AND "Environmental services." Once a sufficiently large initial sample was gathered, the cases were filtered to select the most notable examples for examination, ensuring the heterogeneity logic and alignment with the thesis's goal. As a result, the final sample consisted of four blockchain-based startups: Company A, Company B, Company C, and Company D.

3.3 Data Collection and Analysis

The research employed a data triangulation approach to ensure robust results for the qualitative research. Multiple sources of information were used, including primary and secondary sources, such as semi-structured interviews with founders and C-levels, as well as information from the companies' websites, whitepapers, and third-party articles. (Yin, 1984; Bonoma, 1985).

The researchers conducted eight semi-structured interviews over two distinct waves, with each session lasting between 31 and 76 minutes. The informant for each company remained the same during both rounds. For both the rounds, all sessions lasted between 31 and 76 minutes. A total of 380 minutes of material was recorded, and the results were transcribed into 107 pages. To improve the overall rigor of the case study, as recommended by Eisenhardt (1989) and Yin (1984), the final outcome of primary data was triangulated with secondary sources.

The study's research question was used to create a consistent protocol for the pilot interview. The first set of questions focused on understanding the business models in terms of design elements and themes (Zott & Amit, 2010)., while the second set of questions investigated the sustainability contribution through the lenses of GCs managerial problems (George et al, 2021), with a particular emphasis on the contribution of technology for the resolution of those problems. The second round of interviews allowed for a deeper investigation of specific blockchain applications and topics that were overlooked in the first phase (Yin, 1984).

After the data collection phase, the data analysis was carried out. The recordings were transcribed, and a within-case study data analysis was performed in accordance with Eisenhardt (1989). Ground theory methodology (B. Glaser & Strauss, 1967; Strauss & Corbin, 1998) was adopted to study each case according to an open coding practice, allowing to investigate complex phenomena using labels, thus generating theory from interviews. The collected data allowed the generation of in-vivo codes dataset and the analysis following constant comparative method (Gioia et al., 2013). Subsequently, a comparison of codes from the different cases was carried out to obtain the formulation of first-order concepts. The second-order codes were then aggregated into two major overarching dimensions: (1) *Business model design themes* routed in Zott & Amit (2010) seminal work; (2) *Grand Challenges managerial problems*, based on George and colleagues (2021) work.

In the cross-case analysis, similarities and differences at different abstraction levels were looked at to compare the differences between the four cases, allowing for novel findings (Eisenhardt, 1989). The correlation between Grand Challenges managerial problems and design themes was investigated, and the final result was graphically represented using coding trees (Gioia et al., 2013).

4 RESULTS

The cross-case analysis, carried out triangulating primary data coming from interviews with secondary data, has been the foundation for the conceptual framework described in figure 1.

Overarching Dimension 1: GCs Managerial Problems.

The GCs managerial problems described by George and colleagues (George-et-al, 2021), are routed in the business model design elements identified by Zott & Amit (2010). Namely, the first two problem - *problem of knowing* and *problem of valuating* – are associated to *design content*, being the knowledge and the valuation of natural and social capital, fundamental to act within sustainability domain. The *third* and *fourth problem* – problem of communicating and problem of coordination and trust – are tied to *design structure*, as they entail the reshaping of links between actors in the market and changes in the way they communicate. Finally, the last two problems – *problem of access and reach* and *problem of institutions* – concern design governance, as they deal with actors' access and the institutions' role in the activity system.

Our cases reveal that blockchain seems not to cover a role in addressing the technical difficulties in obtaining an accurate and reliable measurement of a project's impact (*problem of knowing*). Being blockchain a distributed ledger, it has significant implications for how data is managed and shared among actors, but not for how data is obtained (for which other technologies can be leveraged, i.e., oracles such as sensors or satellites).

According to the findings, blockchain can successfully contribute by addressing the heterogeneity and illiquidity issues of carbon markets (*problem of valuating*) – while allowing to tokenize and fractionalize carbon credits. As described by Company C CIO: "*The liquidity has to do with creating baskets of tokens on chain where we take a certain quality of token. There will be a third party that will just determine which tokens would be allowed into the basket; in that way, you can have literally millions of carbon credits in the basket and a single tradable token can be traded on centralized or decentralized exchanges*." Carbon credit baskets aggregate credits from comparable carbon offsetting initiatives, boosting the homogeneity of the supply of carbon credits. Increased liquidity results in correct price discovery for each credit class: *"The current illiquid system can work for a company buying a bunch of credits. But, if you want to have traders in the market and people who are longing carbon credits, you need to have much larger liquidity"* (CIO, Company C).

Concerning *problem of communicating*, blockchain represent a reliable mean to tackle greenwashing. In the distributed ledger, all information about each carbon credit is shared and accessible: "*when somebody buys one of our carbon credits, they are not only buying a net 0 carbon reduction. They're also buying ESG reporting data*" (CEO, CAS).

All the startups evaluated addressed the VCM's opaqueness and fragmentation issues (*problem of coordination and trust*). Within a blockchain distributed ledger system, retiring a credit involves the burning of the underlying smart contract. This eliminates the possibility of double-counting, which can occur when a credit is sold and then resold through a broker or trader. Moreover, the peer-to-peer nature of blockchain technology can promote higher degrees of disintermediation within the activity-system, where brokers, traders, and merchants no longer play a vital role in the market. As described by Company A CEO: "*we're basically disrupting the brokers, traders and exchanges; we're shortening the value chain"*. Furthermore, blockchain's decentralization features enable the proposal of a new methodology for carbon offset verification through a DAO, where token holders can vote on its implementation, creating a decentralized governance mechanism.

As a result, blockchain can help by providing the tools for removing entry barriers (*problem of access and reach*). Blockchain-based startups are leveraging the technology's benefits to reduce transaction costs and improve financing opportunities for carbon credit projects. These startups are combining blockchain with other measuring technologies, such as sensors and satellites, to develop new digital measurement, reporting, and verification methodologies. This approach significantly reduces verification costs for project developers, making it more efficient and less time-consuming than traditional manual methods used by standard organizations such as Verra and Gold Standard. As described by Company C CEO: "*The process of sequestering carbon is still going to be at the same speed. It works at the speed of biology. But hopefully the process to validate and verify and collect data will be perhaps quicker and more inexpensive than in other projects"*.

Finally, blockchain may fill the institutional failures (*problem of institutions*) of traditional voluntary carbon markets; Blockchain can serve as a global distributed platform infrastructure for

transacting carbon credits, without heavy reliance on trust intermediaries. As highlighted by Company A CEO: *"[stakeholders] They don't have to trust a close service report [standards' organizations services]; you can trust a much more distributed and decentralized validation of the proof of your carbon purchase or offsetting*".

Overarching Dimension 2: Design Themes.
The cross-case analysis suggests that blockchain's *novelty* is primarily through tokens. Governance tokens enable new forms of decentralized governance (i.e., Decentralized Autonomous Organizations), while utility tokens represent on-chain carbon credit revival. Regarding these digital artifacts, Company D whitepaper affirms: "*Tokens have multiple advantages over legacy offsets, including full transparency, programmability and fractionalization"*.

The tokenization of carbon credits allows for more *efficient* and transparent transactions, as the use of smart contracts on a decentralized ledger eliminates the need for intermediaries and automates trustless transactions. This leads to a decrease in transaction costs and information asymmetry, improving the overall efficiency of carbon markets. Additionally, the use of tokens as a representation of carbon credits allows for fractionalization and increased accessibility for smaller investors, further promoting the efficiency and democratization of the market.

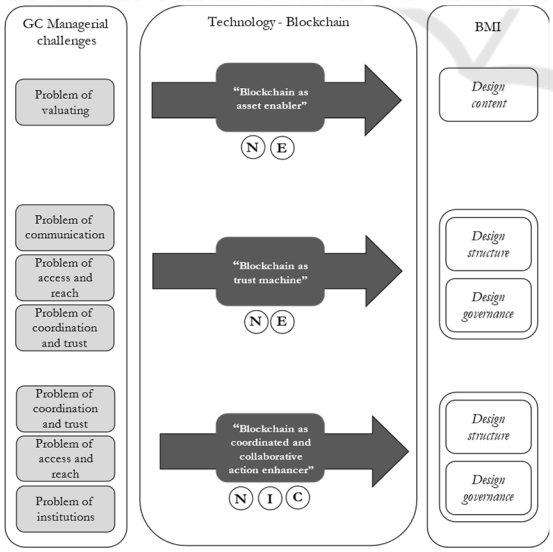

Figure 1: Conceptual Framework.

Concerning the value source of *complementarity*, two main insights emerge. First, the application of blockchain is empowered with the usage of a combination of other emerging technologies to innovate the measurement phase (i.e., oracles): "*There are complementarities from a technological point of view, with the convergence of IoT, Remote Sensing, Satellite's image and blockchain is possible to develop D-MRV methodologies"* (CIO, Company C). Secondly, blockchain's open-source logics facilitate cooperation among various actors, leading to composability and encouraging innovation in the carbon market. Governance tokens and DAOs allow investors to participate in decision-making and share profits, generating new *lock-in* mechanisms.

5 DISCUSSION AND CONCLUSIONS

This study contributes to the call by Bocken, Heidenreich, Spieth, Tucci and Zott (2022), who asked researchers to investigate business model innovation as a mean to address Grand Challenges. By drawing on the case of voluntary carbon market, we get to explore how blockchain can contribute to the improvement of sustainable issues. In particular, our contribution is twofold.

First, we provide a theoretical contribution to the BMI and GCs literatures by studying business model innovation as a means of addressing Grand Challenges. In particular, we shed light on the so-called "*digital and sustainability imperative convergence*" (George-et-al, 2021). Building on the business model construct proposed by Zott & Amit (2010) in their activity-system view, our framework (fig.1) illustrates three features that characterize blockchain as enabler of novel forms of design content, structure and governance; specifically, blockchain acts as *asset enabler*, as *trust machine* and as *coordinated and collaborative action enhancer*.

Feature 1: Blockchain as Asset Enabler.
Blockchain acts as an *asset enabler* as it offers new ways to design and create digital and real-world assets. Ownership is a fundamental attribute that blockchain adds to the internet we use today, which allows for the emergence of new asset classes. Governance tokens are a prime example of asset classes that are built natively on-chain and govern the consensus mechanism of blockchain protocols and projects. These tokens offer new forms of stake, rights, and participation (F. Glaser, 2017; Trabucchi, Moretto, Buganza, & MacCormack, 2020). Additionally, tokenized assets are digital twins of current real assets that are represented and

transferrable on the distributed ledger (Gan, Tsoukalas, & Netessine, 2021; George et al., 2021).

The emergence of tokens as a source of design content creates new activities that are related to token design (i.e., defining the conditions under which participants can earn new tokens for contributing resources to the network and defining the rights associated with token ownership) (Catalini & Gans, 2020; Forman et al., 2019; F. Glaser, 2017).

Tokens also contribute to sustainable development by addressing the problem of valuation. As our research confirms, tokenization transforms natural capital into precise, manageable, fungible, or non-fungible, tradeable units for which new markets can establish prices. By using tokens, it becomes possible to assess and value ecological and social assets in new ways. This creates opportunities for individuals to gain access to asset classes and risks that may have been beyond their capacity (George et al., 2021; Santos, Pache, & Birkholz, 2015).

Feature 2: Blockchain as Trust Machine.

The *trust machine* property is linked to the nature of its distributed ledger and consensus mechanism. Smart contracts enable multiple parties who do not trust one another to engage in exchanges of value when certain conditions are met (Catalini & Gans, 2020; Forman et al., 2019; Murray, Kuban, Josefy, & Anderson, 2021). The distributed ledger and consensus mechanism of blockchain technology have significant implications for reducing transaction costs. These costs are associated with intermediaries and their related expenses, including verification, searching, and coordination costs, which traditional and digital intermediaries have emerged to address (Bailey & Bakos, 1997; Clemons, Reddi, & Row, 1993; Malone, Williamson, 1993; Yates, & Benjamin, 1987; Zott et al., 2011). Our study shows that blockchain technology enhance trust and transparency by reducing costs and time for validating trading partners. By shifting trust to the consensus algorithm rather than to a central entity, blockchain enables actors to trade in a large-scale decentralized fashion, without the need for a trustworthy intermediary. This allows participation for actors who were previously excluded from existing activity systems, opening new possibilities for economic and social participation Santos et al., 2015). Building trust is essential in various domains of sustainability, especially when exchanging goods or services that have a social or ecological impact. A transparent distributed ledger can enhance trust by preventing information asymmetries and opportunistic behaviors (George, 2021).

Feature 3: Blockchain as Coordinated and Collaborative Action Enhancer.

The definition of Grand Challenges provided by George and colleagues (2016), emphasizes the need for "*coordinated and collaborative effort*". However, traditional organizational structures may not be suitable for GCs as they lack centralized control over their participants, as argued by some researchers (Ferraro et al., 2015; Howard-Grenville & Spengler, 2022; Luo, Zhang, & Marquis, 2016). Blockchain protocols pave the way to new distributed governance paradigms, incentives systems, and new open-source collaboration mechanisms. These can serve as a mechanism for designing new forms of rewards aimed at achieving alignment in addressing Grand Challenge. This aligns with Adner's (2017) definition of "ecosystem-as-a-structure," which characterizes ecosystems as the structural alignment of multiple partners who must interact to realize a central value proposition. In the context of Grand Challenges, a social or environmental challenge may represent the central value proposition that a set of partners collectively tackle with their efforts.

Blockchain, Value Creation Logics and Technological Convergence.

Prior literature has highlighted the importance of synergy across value logics to achieve good designs (Amit & Zott, 2001). We find not only that blockchain based business model exhibit all the value creation themes (novelty, efficiency, complementarity and lock-in), but also that there is strong inter-relationship among them. Specifically, we show how the "asset enabler" and "trust machine" properties of blockchain promote efficiency and novelty logics, while the "coordinated and collaborative action enhancer" property stimulates novelty, complementarity, and lock-in logics. Additionally, building upon Teece's (2018) argument on technological convergence, we observe that the composability within different Blockchain protocols, as well as their integration with other consolidated and emerging technologies (i.e., oracles, including remote sensing and satellites) play a crucial role in unlocking the emerging technology's full potential.

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