THE JBBA THE JOURNAL OF THE BRITISH BLOCKCHAIN ASSOCIATION®

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Proceedings of Blockchain Associations Forum, 4th Annual Summit, September 2024

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TABLE OF CONTENTS

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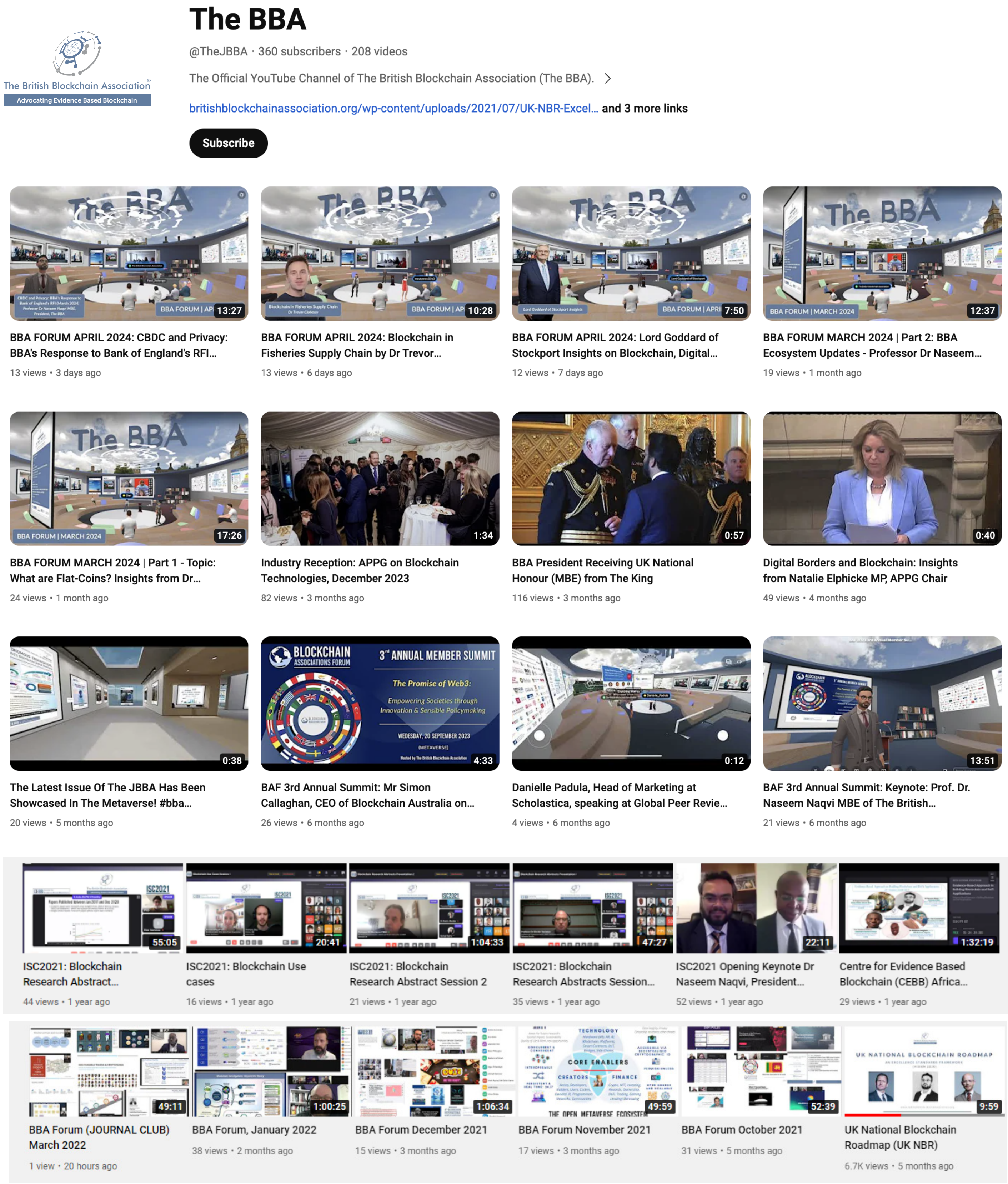

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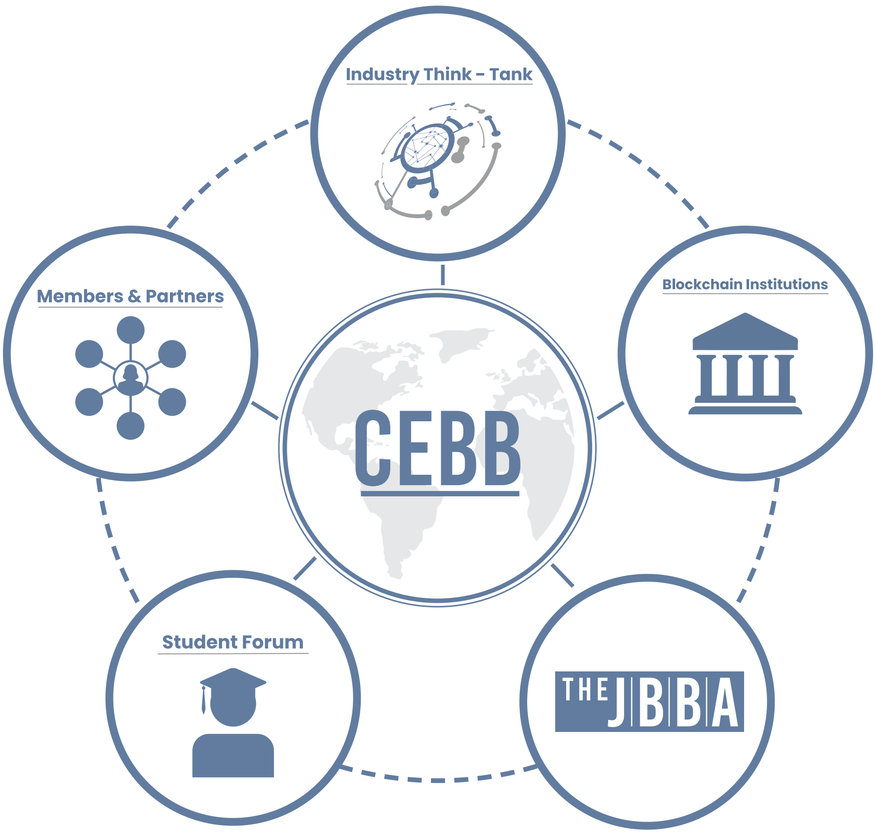

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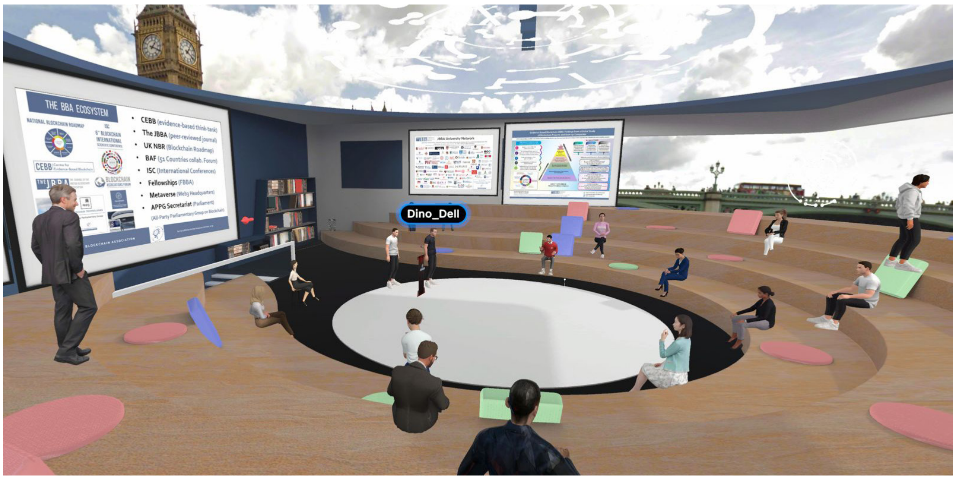

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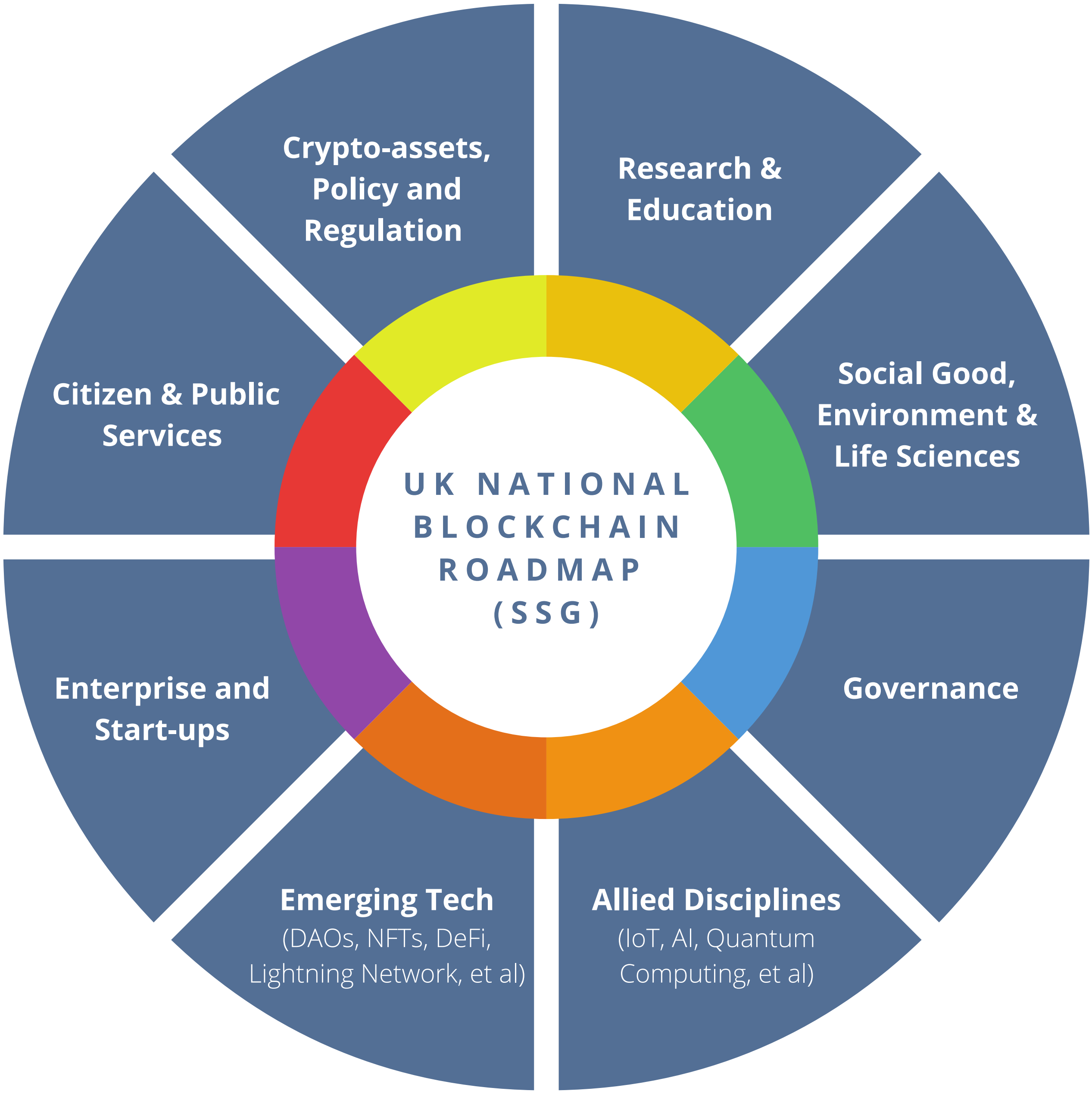

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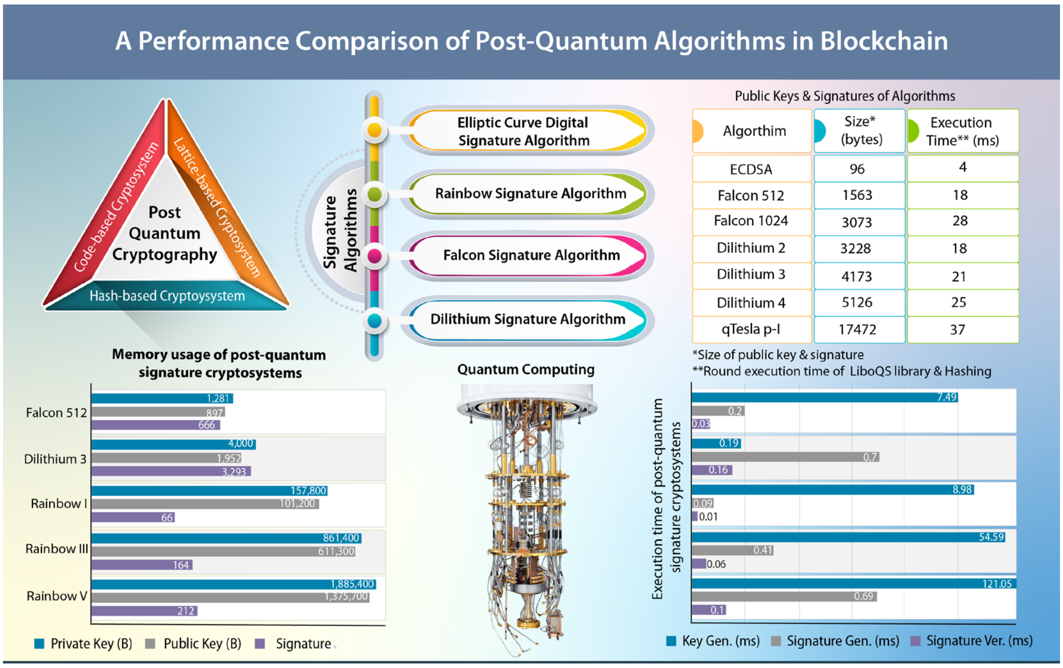
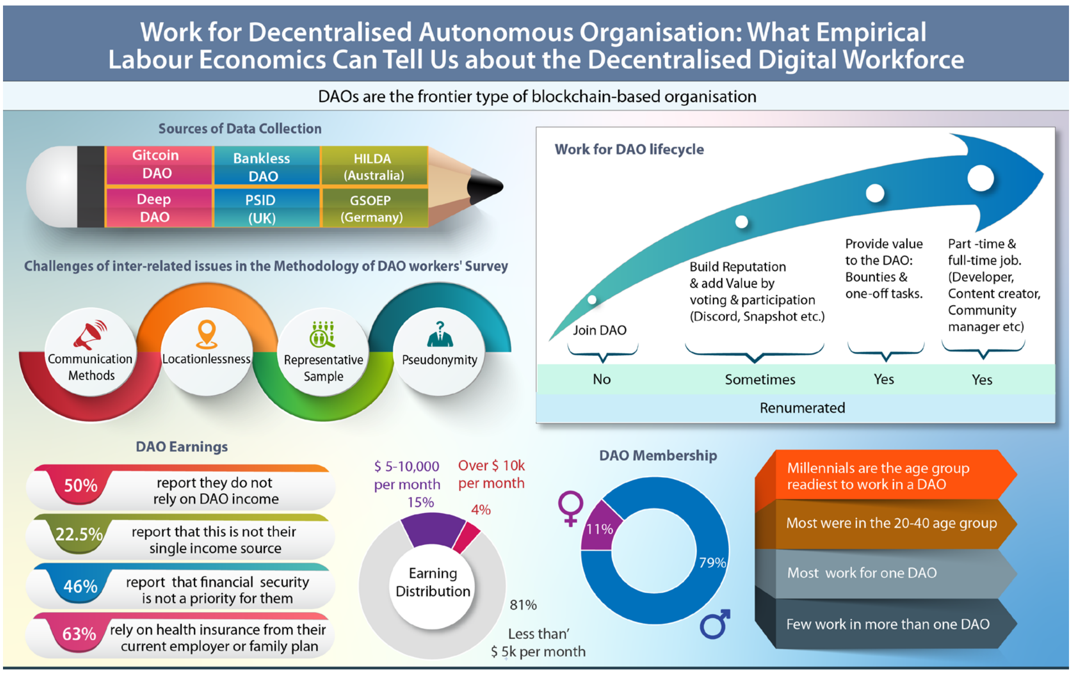


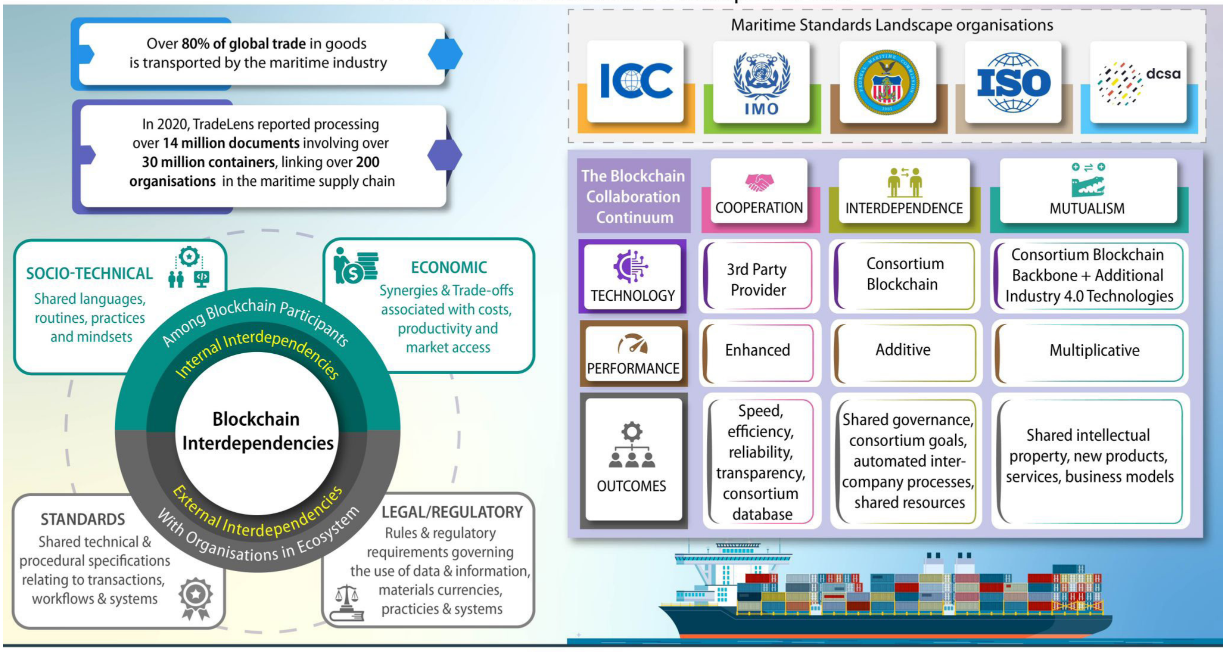
Lu Gan and Bakhtiyor Yokubov (2022)
DOI: 10.31585/jbba-6-1-(1)2023



Nataliya Ilyushina (2023)
DOI: 10.31585/jbba-6-2-(2)2023

The Role of Interdependencies in Blockchain Adoption:
The Case of Maritime Trade

A Framework of Blockchain Interdependencies



Melissa M. Appleyard & Kristi Yuthas (2022)
DOI: 10.31585/jbba-5-2-(6)2022

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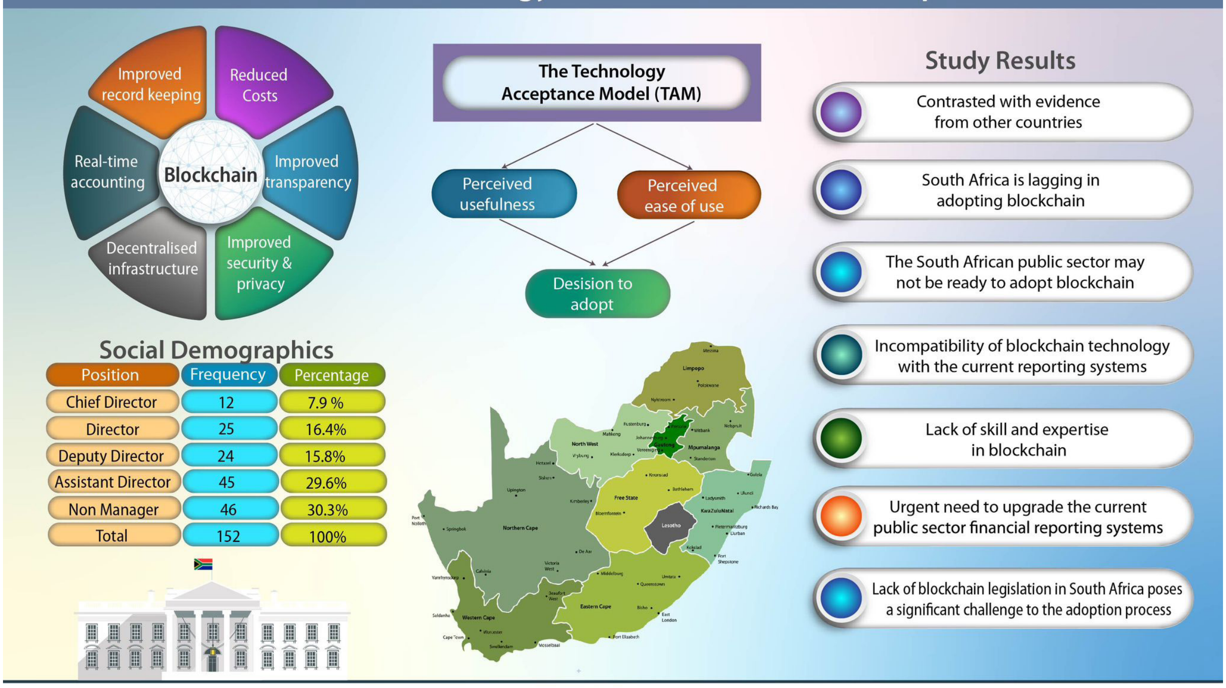

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Beatah Sibanda, et.al.
DOI: 10.31585/jbba-7-2-(1)2024

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The Editorial Board of The JBBA gratefully acknowledges and thanks the reviewers fortheir time and expertise. The following is the list of reviewers who contributed to the peerreview process for the current (14th) Issue of The JBBA (November 2024).

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EDITORIAL

It gives me great pleasure to present to you the *14th* issue of *the Journal of the British Blockchain Association (The JBBA).*

The theme for this edition, **"Efficient Blockchain Markets for Sustainable Development,"** could not be more timely. The articles within this issue collectively explore the intersection of blockchain technology and its capacity to create more equitable, transparent, and efficient systems. From carbon trading systems in Africa to cryptocurrency-based fundraising, each piece offers a unique insight into how blockchain innovations can reshape industries and align with the United Nations' Sustainable Development Goals (SDGs).

A standout in this issue is the article from BBA Fellow, Professor Kristi Yuthas FBBA, titled ***"An NFT Framework for Innovation and Sustainable Development Goals",*** which takes a closer look at how non-fungible tokens (NFTs) can foster not only digital creativity but also contribute to achieving sustainability. By presenting a framework where NFTs are linked to real-world impact, this work signals how innovation can bridge the gap between technology and global responsibility. Similarly, the paper ***"An Architectural Design of a Pioneering Blockchain-Powered Carbon Trading System in Africa"*** illustrates the transformative potential of blockchain in environmental stewardship, providing a model that could be replicated across the globe.

Ethereum, one of the most widely adopted blockchains, is at the forefront of another pivotal shift explored in this issue. ***"Ethereum 2.0 Hard Fork: Consensus Change and Market Efficiency"*** delves into the profound implications of Ethereum's transition to Proof of Stake (PoS). By significantly improving market efficiency and reducing the carbon footprint of blockchain operations, Ethereum's evolution aligns closely with the theme of sustainability.

Equally intriguing is the forward-looking exploration of governance by BBA Fellow Professor Sinclair Davidson FBBA, in ***"Can DAOs Innovate Governance beyond Hierarchies?"***. Decentralised Autonomous Organisations (DAOs) promise to democratise decision-making by eliminating hierarchical structures. This article asks crucial questions about the future of governance, not only in blockchain spaces but in broader organisational contexts. It serves as a blueprint for how blockchain can facilitate more inclusive, transparent governance models.

Blockchain's potential to foster innovation is further evidenced by this paper from BBA Fellow Professor David Lee FBBA, et al, entitled ***"The Evolution and Future of Cryptocurrency-Based Fundraising Mechanisms."*** The article offers a historical overview while exploring new possibilities for crypto-financed projects, giving us a glimpse into the future of fundraising in an increasingly decentralised world.

Our cover theme highlights the importance of creating *efficient blockchain markets* that are aligned with sustainable development goals. As blockchain matures, market efficiency becomes crucial—not just for economic reasons but for its potential to drive systemic change. Whether through energy-efficient consensus mechanisms, like Ethereum's transition to PoS, or carbon credit systems, blockchain's ability to streamline processes can significantly impact the sustainability of markets worldwide. Efficiency in blockchain markets is not just about faster transactions or reduced fees but also about achieving long-term social, environmental, and economic impact. By integrating these technologies into global systems, we can support a more sustainable and fair future for all. I hope the readers will find the papers in this issue enlightening, informative and futuristic.

On a different note, we are delighted to host the *Scholars in Blockchain International Symposium* (#SIBIS24), the world's first global symposium dedicated to blockchain scholarship. This event will bring together leading minds from around the world – professors who are providing quality blockchain research and education opportunities for their students. It is a historic milestone, and I look forward to this unique global gathering of innovators, scholars, and thought leaders.

As always, none of this would be possible without the tireless efforts of our dedicated team of editors and reviewers. Their expertise and commitment ensure that the JBBA continues to be a beacon of academic and practical discourse in the blockchain space. We extend our heartfelt thanks to all who contribute to this ever-growing body of knowledge, helping to drive blockchain toward its full potential in creating a sustainable and efficient world.

Professor Dr Naseem Naqvi MBE
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NFTs at the Nexus of Innovation and Sustainability: A Framework Aligning NFT Affordances with the Sustainable Development Goals

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Abstract
The United Nations' Sustainable Development Goals (SDGs) are goals associated with the most significant global issues, which include climate, health, security, and poverty. The goals are part of an agenda for making progress on environmental, social, and economic issues while ensuring peace and leaving no one behind. Meeting these goals requires effort and innovation on all fronts, including technology. Information and communication technologies have long contributed to these efforts, and more recently, blockchain for good projects have begun to bear fruit. Non-fungible tokens (NFTs), which are, in essence, certificates of ownership stored on a blockchain, can also contribute to sustainable development. However, to this point, they have been underutilised. NFTs have inherent capabilities that can make them ideally suited to contribute towards the SDGs. Their unique capacity to validate ownership, identity, claims, and history of events makes them valuable for a variety of purposes. To date, NFTs have been employed primarily for trading digital assets such as collectibles, in-game items, digital art, and event tickets. However, their affordances—the actionable properties NFTs offer to users—make them suitable for use in ways that can significantly affect the health and well-being of humans and the planet. This article provides a framework for linking NFT affordances with the SDGs and examples of how NFT use cases are addressing, or could address, these urgent global needs.
Keywords: *Digital Assets, Non-Fungible Tokens, NFTs, Affordances, Sustainable Development Goals, SDGs, Sustainability*
JEL Classifications: *L31, L86, 014, O19, O33, O34, Q01, Q55*

1. Introduction

In 2015, all 193 member-states of the United Nations developed and agreed to 17 Sustainable Development Goals (SDGs) that address the world's most important and challenging problems. The SDGs set out specific targets for global progress in climate, health, security, poverty, and other critical areas of development, to be achieved by 2030. The world is not on track to meet these targets. Experts argue that there is a need for far-reaching efforts to achieve these goals [1]. Collaboration and innovation on approaches and solutions are urgently needed.

Blockchain and distributed ledger technologies (hereafter "blockchain") have been employed for a variety of use cases targeting social impact. The World Food Programme, for example, has used blockchain for cash transfers and access to food assistance [2]. Non-Fungible Tokens (NFTs), however, have received little attention in this realm, and yet they offer vast, untapped potential. This article addresses the research question: Can NFTs provide utility in achieving the SDGs?

To answer the question, I begin by exploring academic and professional literature for consensus on the inherent qualities of NFTs. Building on these qualities, I define four affordances, or functionalities, that NFTs can offer. They can signify identity, establish ownership, institute claims, and convey history. These affordances imbue NFTs with the potential to promote the SDGs in ways that cannot be replicated using other technologies. I build a framework intersecting these affordances with the development goals and then explore numerous current and potential use cases that demonstrate how the affordances can be realised within each of the SDG categories. The framework presented in this article provides a starting point for using NFTs for social change.

Comprehensive studies provide taxonomies that purport to define the full range of potential uses for NFTs (e.g. [3, 4–6]). Such taxonomies have largely ignored or overlooked the potential for NFTs to contribute to social impact. The studies tend to examine extant and adjacent use cases, usually with an eye towards commercial and investment potential. Although some use cases address important social impacts, such as privacy of medical records and rights to intellectual property, sustainable development has not been a focus. While taxonomies can contribute significantly towards understanding the potential of this technology, I do not review them here. Instead, I explore how NFTs can be used in a much broader range of contexts and for social and environmental purposes.

As I will demonstrate, NFTs have a powerful role to play in creating social change. Even in the hands of highly skilled designers and users, the effectiveness of NFTs is a function of the broader sociotechnical systems within which they are embedded. Exploring their potential for social impact provides a foundation for multi-layered interventions that can address global challenges.

2. Sustainable Development Goals

The United Nations' 17 SDGs and the 169 specific targets associated with the goals comprise part of a global agenda to be completed by 2030. This agenda "provides a shared blueprint for peace and prosperity for people and the planet, now and into the future" [7]. The goals were formed over a three-year period with input from hundreds of organisations. Nonet et al. [8] consider the SDGs to be "the most all-encompassing, ambitious, as well as action-oriented agenda for progress on a global scale, ever agreed upon by humankind."

Figure 1: The United Nations' Sustainable Development Goals

People—Eliminate hunger and poverty in all forms, guarantee dignity and equality for all human beings

- SDG 2: Good Health and Well-being: Ensure healthy lives and promote well-being for all at all ages
- SDG 4: Quality Education: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- SDG 5: Gender Equality: Achieve gender equality and empower all women and girls.
- SDG 6: Clean Water and Sanitation: Ensure availability and sustainable management of water and sanitation for all.

Planet—Protect the planet's natural resources and climate for future generations;

- SDG 11: Sustainable Cities and Communities: Make cities and human settlements inclusive, safe, resilient, and sustainable.
- SDG 12: Responsible Consumption and Production: Ensure sustainable consumption and production patterns.
- SDG 13: Climate Action: Take urgent action to combat climate change and its impacts.
- SDG 14: Life Below Water: Conserve and sustainably use the oceans, seas, and marine resources.
- SDG 15: Life on Land: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss.

Prosperity—Ensure prosperous and fulfilling lives in harmony with nature;

- SDG 1: Zero Hunger: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
- SDG 7: Affordable and Clean Energy: Ensure access to affordable, reliable, sustainable, and modern energy for all.
- SDG 1: No Poverty: End poverty in all its forms everywhere.
- SDG 8: Decent Work and Economic Growth: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
- SDG 9: Industry, Innovation, and Infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
- SDG 10: Reduced Inequalities: Reduce inequality within and among countries.

Peace—Promote peaceful, just and inclusive societies which are free from fear and violence

- SDG 16: Peace, Justice, and Strong Institutions: Promote peaceful and inclusive societies, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.

Partnerships—Implement the 2030 Agenda through solid partnerships

- SDG 17: Partnerships for the Goals: Strengthen the means of implementation and revitalize the global partnership for sustainable development.

The 17 goals cover five overlapping themes: social, environmental, economic, peace, and partnership (see Figure 1). Descriptions of the 5Ps are from Richiedei and Pezzagno [9]; descriptions of the SDGs are from the United Nations [10].

The intention of the SDGs is to mobilise social change. Stakeholders at every level and across sectors are called to contribute investments and strategies [11]. When commercial initiatives and organisations use the concepts covered by the SDGs, they often focus on reducing negative social and environmental impacts rather than making positive movement towards the goals. Nonetheless, their impacts can be significant [12]. Businesses have been called to evaluate their performance, align business activities with relevant goals, and report outcomes [13] as a means to monitor and improve progress. Technology can play an essential role in these processes [14], and as will be discussed, the impact of NFTs could be profound. In the remainder of the paper, I refer to topics addressed by the SDGs as "social issues" and to outcomes relating to these issues as "social impacts."

3. Non-Fungible Tokens

Broadly speaking, NFTs are digital files that function as certificates of ownership, typically for digital or physical assets. They enable the holder to prove their ownership as well as the provenance of the certificate. NFTs are stored in digital wallets and can be transmitted between owners through blockchain transactions. Blockchains, in this context, are lists of transactions that are timestamped, validated, and stored in multiple locations, providing assurance that the transactions have not been modified or deleted. NFTs are typically governed by smart contracts—small programs that define the features and functions of the NFT. These contracts are also stored on blockchains. NFTs often take the form of static tokens that include the URL of the location where an associated digital asset, such as a .jpg file, is stored. NFTs can have more complex features. For example, high-value NFTs themselves can be tokenised [15]. Some types of tokens are dynamic. Their contents can change based on conditions specified in the smart contract or on events occurring outside of the contract [5]. The versatility of NFTs will continue to increase over time, expanding their potential roles in social impact creation. Greater depth on NFTs and their technological underpinnings can be found in [16–18].

4. Research Method

Addressing the research question of how NFTs can provide utility in the achievement of the SDG involved four steps. The first was a systematic literature review (SLR), described below. The SLR approach is appropriate in this context because the article seeks to push the knowledge frontier by conducting exploratory research on a topic for which little established theory exists [19]. I began the literature search using Web of Science (WoS) and the term "non-fungible tokens" as a starting point, following citations forward and backward. Further details are described in the next section.

I explored the professed qualities or characteristics of NFTs and summarised these characteristics using narrative review and synthesis. Next, I researched NFT use cases associated with the SDGs. I searched WoS and Google Scholar for academic research and used Google and Brave to search for grey literature. I included publications by the United Nations and other multilateral agencies, international non-governmental organisations, and global consulting firms with blockchain practices. I expanded the search terms beyond NFTs to include blockchain and information and communication technology (ICT). These technical terms were combined with sustainable development, SDGs, and individual goals such as poverty and peace, as well as with terms related to social impact in the business press: environmental, social, and governance, corporate social responsibility, and sustainability. I used meta-narrative techniques [20] to extract themes for categorising use cases along SDG dimensions.

5. NFT Characteristics

NFTs share inherent characteristics that differentiate them from other technologies. As a result of these characteristics, NFTs can perform functions and solve problems that cannot be effectively addressed using alternative technologies, whether centralised or decentralised. Significant differences exist in the characteristics attributed to NFTs by different authors. Core characteristics are important in the context of SDGs because they position NFTs to contribute in unique ways towards the achievement of positive social impact. Identifying a set of consensus characteristics began with a thorough review, analysis, and synthesis of claims made about NFTs.

A WoS search using "non-fungible tokens" as the key term returned 139 publications, the majority in computer science, engineering, and telecommunications. Beginning with eight publications classified as review papers, and 58 having multiple citations, I selected papers that directly identified and described inherent characteristics of NFTs, most notably [21], [22–24]. There is still relatively little academic research on NFTs, and much of the existing analysis is focused on the economic potential for creators, investors, and traders [21]. Most review articles present a narrow perspective on the relevant characteristics of NFTs; for example, Taherdoost [24] focused on digital scarcity. The domain covered by these papers was also narrow. Bao and Rouboud [21] and Nadini et al. [25], for example, focused on economic and finance domains and considered a limited scope of NFT use cases, primarily focusing on collectibles, artwork, and gaming.

The academic literature was expanded and validated using trade publications (e.g. [16, 17, 26, and 28]). This yielded a comprehensive list that I then synthesised into four core NFT characteristics. NFTs gain some of their attributes from the underlying qualities of the blockchain, and the characteristics listed here are also common to many types of blockchain tokens and ledger entries [29].

Four foundational NFT characteristics resulted from this process. They are uniqueness, ownership, transferability, and authenticity.

1. Uniqueness: NFTs are non-fungible; they can't easily be exchanged with other assets. Distinct from cryptocurrencies and other fungible tokens, each NFT has a unique identifier that is included in its metadata. It can therefore be differentiated from every other token, even if it is one in a series of tokens that appear to be identical. This is akin to limited-edition prints, where numbers are used to uniquely identify individual prints.
2. Ownership: An NFT resides in a single wallet and is therefore associated with or "owned by" whoever controls that wallet. The owner is likewise said to own the digital asset to which the NFT refers or the physical asset represented by the title, deed, licence, or other form of ownership to which the NFT refers. Depending on the asset and its community of interest, ownership conveys value in various forms that include status and access.
3. Transferability: NFTs are typically transferable from one owner to another. Because the capabilities of NFTs are governed by code, rules for transfer can be embedded. For example, the number of times an NFT can be transferred or the allowable wallets the token can be transferred to can be programmed in. Because they reside on blockchains, NFTs can be transferred directly, securely, and rapidly, as is the case with cryptocurrency. In some cases, interoperability exists, and NFTs can be transferred from one blockchain platform to another.
4. Authenticity: The origin, evolution, and transmission of NFTs are often fully transparent and can be found through simple searches using free software such as Etherscan. Because NFTs reside on blockchains, they are essentially immutable and cannot be deleted. Once the NFT is recorded on the blockchain, its location and state can be viewed and tracked throughout its lifespan. If the validity of the entity(ies) responsible for creating the asset and minting the NFT can be trusted, the ability to establish subsequent authenticity is a valuable attribute.

Many studies included scarcity and/or rarity when enumerating attributes (e.g. [24, 29–31]). These are directly related to uniqueness but are not inherent to NFTs. Instead, creators intentionally mint a limited supply of similar or identical items, often to increase their exclusivity and market value, but the quantity need not be limited. Most studies did not include programmability, a function of smart contracts that has not been heavily researched in this arena but which gives them profound advantages in a variety of contexts [26], [22]. This feature can unleash potential for social impact beyond that discussed in the examples provided here.

In addition to capabilities, the literature review uncovered a litany of problems, including transfer of copyright and other rights, legal status of NFTs, know your customer (KYC) and privacy regulations such as GDPR, loss of or damage to the digital or associated physical asset, and errors or fraud in the smart contract code. These are significant concerns that are not well understood by participants in NFT markets, and that will take time to resolve. Further discussion of these issues can be found in [21, 18, 32–34, 35].

Also significant, particularly when stakeholders include the world's most vulnerable populations, are concerns about security of private data and biometrics, the digital divide that puts Web3 technologies out of reach for many, and the "first mile problem" of ensuring that the code, data, assets, and validators for NFTs can be trusted. These and other issues present challenges for blockchain implementation in developing countries [36] and will need significant attention for the potential of NFTs to be realised.

6. NFT Affordances

As a result of their fundamental capabilities, NFTs have affordances that make them uniquely valuable in the pursuit of the SDGs. Different from inherent properties, affordances represent the potential; they are realised when technology is applied by humans to appropriate uses [37]. For example, an affordance of a meal is to reduce hunger when eaten. In an entrepreneurship context, affordances of a particular technology enable its use in creating and capturing economic value [38]. Affordance here will refer to the potential of NFTs to address problems or opportunities that advance the SDGs.

Chalmers et al. [29] describe NFT affordances as the potential to enable users to perform new actions or perform old actions differently. They identify two general affordances enabled by NFTs: ownability, which confers value for digital assets, and verifiability, the ability to evaluate and validate asset ownership [29]. In this section, I explore affordances in depth within the context of sustainable development, focusing on the potential of NFTs to create, deploy, and capture social value.

Beyond ownability and verifiability, NFTs have affordances that position them to make significant contributions towards the SDGs. I propose four critical affordances: NFTs can signify identity, establish ownership, institute claims, and convey history. As a result of their unique attributes and capabilities, NFTs can play a profound role in promoting the goals and generating social value.

6.1 Signify Identity

The identity affordance refers to the use of NFTs to uniquely signify the identity of persons and things. These things can include digital assets, such as files, domains, transactions, or data. NFTs can replace paper records that identify physical assets, such as land, machines, or Internet of Things (IoT) devices. Identity can also be assigned to digital representations of physical identifiers such as passports and land titles. Because NFTs are unique and tamper-proof, they can reliably and durably represent individual identities. When identities are linked to persons, they are typically associated with access to passwords ("something they know"), biometrics ("something they are"), physical devices ("something they have"), or a combination of the three. For privacy and security, personal information may be stored in a manner in which it can be accessed and shared only by the person, a model known as self-sovereign identity [3, 23, 39].

6.2 Establish Ownership

Identity provides the foundation for ownership to be established. Digital assets and digital representations of physical assets identified by NFTs can be said to be owned by whoever controls them, typically a wallet address or a person or organisation with an identity. NFTs typically reside in digital wallets that are owned by individuals, but they can be owned by groups, organisations, or other entities. What makes NFTs unique is that ownership claims can be publicly verified, and in the absence of human fraud or coercion, they cannot be erased or stolen [3].

6.3 Institute Claims

Claims here refer to rights and credentials conferred to the holder of a token. Claims can be instituted through information about who the holder is, what they own, or what they have earned, purchased, or been given. For example, a token held by a verified citizen may entitle them to vote; a token representing a ticket may entitle its holder to enter an event. NFTs can also be used to represent credentials earned by the holder, such as certificates of attendance, diplomas, and licences, or to provide documentation of work performed or payments made. NFTs representing credentials may confer rights, such as entitling the owner to hold a certain job or practice a profession. Rights can be given to NFT holders by outsiders. For example, food aid might be awarded to NFT holders located in a region experiencing drought. Rights can be attached to NFTs through their smart contracts, and these rights can change based on events and conditions. For example, crop insurance may pay out based on weather.

6.4 Convey History

The term "history" is used here to refer to the historical record of NFT states that can be conveyed through records on the blockchain. An NFT's history typically includes its provenance—the conditions under which it was created along with its original owner and rights—and a record of all events that have occurred since that time. For static NFTs, this is simply a record of each transfer of ownership. Each transfer is timestamped, and the sending and receiving entities are known. For dynamic NFTs, histories can include almost anything, as the nature and attributes of the NFT can evolve over time. The tamper-proof, time-stamped record of events imbues NFTs with the affordance of verifying history. In addition to the history of the NFT, the history of a wallet, and by extension, the individual holding the wallet, can be verified. For example, NFTs representing signed invoices or receipts for payments held in a wallet can be used as evidence of creditworthiness. NFTs representing medical procedures and receipts could be used as evidence of health status.

Through these four affordances, NFTs can be used to generate trust—trust that someone is who they represent themselves to be, that an object is owned by its purported owner, which a person does possess valid claims, and that events have occurred as attested. While I separate them for analytical purposes, these affordances intersect and complement each other. For example, a person owning land has claims to the use of that land as evidenced by historical records.

7. Illustrative Use Cases

The introduction of NFTs has spurred an explosion of entrepreneurial activity, particularly in 2021 when crypto markets were booming and sales of NFTs were exceeding expectations and creating new markets. In addition to sales, collection, and speculation, there have been efforts on many fronts to begin to use this new technology for the pursuit of social and environmental goals.

To date, the most visible and impactful use cases have been associated with fundraising for charitable organisations that issue NFTs, which are purchased by donors. [40]. Many artists, celebrities, investors, and others have developed new approaches to raise and funnel cash to organisations committed to social change. For example, in 2023, several NFT collections were designed to draw attention to and raise funds for earthquake victims in Syria and Turkey [41, 42]. A web search for NFT and charity renders thousands of projects, which are associated with all of the SDGs. UNICEF, for example, launched a 1,000 NFT project to raise funding for a school connectivity project [43]. Even Charity Navigator, an organisation that evaluates the effectiveness of US charities, touts the potential fundraising benefits of NFTs [44].

Efforts to employ NFTs for direct use in pursuing social goals are far less common. However, a broad range of use cases is now being pursued or considered. These use cases provide a breadth of insights that can be applied creatively in a variety of settings. These efforts are illustrated through two exemplar projects: Ripple's carbon trading efforts and Everest's humanitarian work. These projects serve as case studies of innovative uses of NFTs and adjacent technologies. Each promotes progress spanning SDG categories and delivers on multiple affordances.

7.1 Ripple

Ripple is a technology company that uses blockchain, crypto, and tokens to provide finance solutions that enable safe, economical, and sustainable exchanges of value. Ripple's carbon trading initiative is enabled by its XRP ledger (XRPL), a public, permissionless blockchain. The XRPL platform and its consensus mechanism, the protocol that ensures that copies of the ledger are synchronised, enable high-velocity transactions with very low financial and environmental costs [45]. Ripple has made significant commitments to support companies building climate infrastructure by providing functionality and tools for XRPL that optimise the ledger for carbon trading [46]. Carbon trading plays an important role in compliance with the Paris Agreement, a binding, multilateral treaty on climate change [47]. Carbon offsets can be earned in two primary ways, through avoidance of emissions, such as through switching to efficient or renewable sources, or through removal, such as through reforestation and sequestering. Self-regulation, incentives, and lack of government oversight result in a market overwhelmed with poor-quality or "junk" credits that do not achieve the claimed reductions [48, 49].

Ripple and its partners use NFTs to represent carbon credits. NFTs can improve the quality of credits by exposing claims about these credits and the authorities making them. This helps to solve problems that have plagued carbon trading markets—in particular the lack of transparency and verifiability that reduces trust in claims relating to the source and validity of credits [50]. With the transparency and security provided by NFTs, carbon markets can function more effectively, and the auditability of sustainable finance is improved. Efficient markets can significantly reduce trading costs, freeing resources for emission reduction efforts [71].

To reduce the cost of compliance, firms can purchase high-quality credits and build portfolios of carbon credits that help achieve sustainability goals [51]. The identities of both the parties that mint NFTs and those that validate the NFTs can be established, which helps to ensure that the credits are original and authentic. The ability to accurately track the identity of purchasers and the timing of the purchases serves to establish ownership of the credits and rights to use those credits in climate reporting. The visible history of purchase and deployment of the credits helps to ensure that they are not re-sold or double-counted.

Efficient and trustworthy carbon markets play an important role in carbon management and reduction. The progress in climate affects all life on the planet and provides differential advantages to populations in lesser developed countries. On the whole, these populations are much more vulnerable, personally and financially, to the impacts of climate change relative to populations in other regions. Ripple and its collaborators, by establishing markets and facilitating credit trades on XRPL, harness the multifaceted benefits of NFT technology, effectively championing the People, Planet, and Prosperity objectives outlined in the United Nations' SDGs.

7.2 Everest

Everest provides a platform for combining biometric identity with a digital wallet using NFT technologies. The platform offers users the ability to verify identity, transfer value, and access financial services. Everest's humanitarian projects are built around their novel identity solution that cannot be "lost, stolen, denied or transferred" [52]. Biometric data is used to uniquely identify individuals who may not possess an ID card, certificate, or cell phone or other connected device. Biometric data can be combined with other information to provide a richer identity story that can confer additional rights. Information such as membership in a family, village, or tribe, for example, can be established using a variety of triangulation methods for verification and can be reinforced by birth, school, and other records. With identity information stored privately in a wallet that only its owner can open, individuals are able to access a variety of critical humanitarian services while their privacy is protected [53].

Tokens representing rights and entitlements can be delivered to these wallets by agencies and organisations supplying resources. The tokens can be transferred directly and immediately to authorised wallets. Clients can identify themselves to agents who scan clients' biometric data using their own devices. Clients can then exchange their tokens for material or financial resources or for access to services.

One project in Indonesia used Everest's ID and token system to deliver vouchers for fuel tanks. Because the blockchain-based system ensured that tokens were distributed to and exchanged only by recipients entitled to fuel subsidies, fuel resources were directed to their intended purpose. This greatly reduced fraudulent access to fuel and improved accessibility for valid recipients. The natural gas fuel subsidies were used to replace kerosene, a cheap but dirty fuel that damages the health of its users and the environment [53].

By enabling more efficient allocation and delivery of fuels to the people who are entitled to it, Everest used the affordances of NFTs to create social good. Such efforts contribute to furthering the People, Planet, and Prosperity categories of the SDGs.

8. Framework: NFT Affordances and the SDGs

The framework presented in Table 1 showcases a variety of additional use cases that highlight the potential of NFTs to promote the SDGs. The rapidly evolving NFT landscape includes both implemented and proposed applications that serve as examples of how foundational NFT and blockchain technologies can be leveraged within development contexts. These use cases demonstrate the diverse ways in which the unique properties of NFTs can be utilised to address and advance global development objectives.

Table 1: Framework: NFT Affordances and the SDGs

	Signify Identity	Establish Ownership	Institute Claims	Convey History
People	Birth and citizenship records	Proof of livestock ownership	Storage of medical records	Combatting drug counterfeiting
Planet	Smart cities	Community energy	Plastic recycling	Biochar credits
Prosperity	Access to finance	Tokenised leasing	Locally grown coffee	Credit history

8.1 People

Within the people category, NFTs can contribute to goals relating to the provision of basic needs such as sufficient food, clean water and sanitation, education for all, affordable and accessible healthcare, and gender equity. Examples of NFT use cases in this theme include birth and citizenship records, proof of livestock ownership, storage of medical records, and combatting drug counterfeiting.

Birth and citizenship records. A basic need of people everywhere is the ability to prove their identity and citizenship. According to the World Bank, birth registration is less than 50% in many African countries [54]. Proof of identity is needed for accessing services, such as healthcare and education. Lack of access can have devastating personal and social consequences. Everest's Ever ID, discussed above, is designed to address the specific needs of low-income regions. Self-sovereign identity systems give individuals greater control over their personal information [55]. Birth registration and passport information stored via NFT could have further benefits in contexts of war, unstable government, or disaster, where identification may be needed to cross borders or access aid. Wallets and NFTs are also used in developed markets. For example, the UAE, a leader in blockchain and NFT technology, also uses wallets to validate the identity of token holders and uses NFTs for KYC compliance.

Proof of livestock ownership. NFTs for livestock have been proposed for use in the United States, enabling cattle owners to verify the healthcare status and genetic traits of cattle they plan to sell [56]. In developing countries, where many rely on livestock for their primary form of sustenance, NFTs could be used to help people prove their ownership for sales or to aid in recovering stolen cattle. Farmers in South Africa alone have lost tens of millions in USD to livestock theft. Even small losses can be devastating for resource-poor ranchers [57], whose risks may be higher as a result of nomadic seasonal grazing patterns. NFTs could be used to store data from images or hair samples that could be managed and verified by farming authorities.

Storage of medical records. Recent experience with COVID has familiarised the developing world with the importance of proving health or vaccination status. In developing countries, proof of health status may be necessary for travel and access to services, and it is also valuable information for determining additional healthcare needs. For people living without an easy way to store and maintain paper records, NFTs could be used to record health information linked to decentralised systems and could be accessible to any health provider with access to the internet and permission from the patient. This could improve treatment choices and health outcomes. VeChain has developed an eNFT vaccination certificate that is verifiable worldwide and has partnered with the state of San Marino as its first client [58].

Combatting drug counterfeiting. The World Health Organization [59] reports that "an estimated 1 in 10 medical products in low- and middle-income countries is substandard or falsified." NFT use in supply chains could help in the tracking and tracing of legitimate pharmaceutical supplies. By embedding token-linked IoT devices, manufacturers can establish provenance and provide for traceability of products through the pharmaceutical supply chain. Authena.io has developed one solution using NFTs. The company reports that smart contracts associated with these NFTs ensure that all participants adhere to agreed-upon terms and conditions for product movement [60]. Through improved tracking security of medical products, NFT technologies can play an important role in global health.

8.2 Planet

In the planet theme, NFTs can be used to promote and support sustainable cities, sustainable consumption and production, climate action, and conservation of life below water and on land. Because air, water, and land systems are tightly interconnected, improvements in one region of the world can have impacts elsewhere. Impoverished regions are among those most heavily impacted by climate change and degradation. Economic and social well-being in these regions is tightly interwoven with environmental health. Examples of NFT use cases in this theme include smart cities, community energy, plastic recycling, and biochar sequestering.

Smart cities. Efficient mobility and transportation in cities are associated with reduced energy consumption, and effective vehicle management plays an important role [61]. Smart city paradigms use IoT devices and artificial intelligence to help manage city functions, including traffic congestion, energy consumption, and emissions [62]. IoT devices need unique identities. In smart cities, NFT-based identification can be used in a number of ways. Ren et al. [63] propose using NFTs to gather intelligence relating to connected autonomous vehicles and to exchange data with other NFTs, thereby reducing the energy cost of networking. Schaar and Kampakis [64] and Li and Chen [65] argue that NFTs can be used for strategic business model expansion. Musamih et al. [61] propose using NFTs for increasing the use of rideshare vehicles. NFTs could be used as simple access keys and, more importantly, could store detailed information about vehicles or users. Improving the efficiency, ease, and quality of vehicle and ride sharing processes could reduce the use of private vehicles and the need for parking spaces.

Community energy. Energy cooperatives, which fill service gaps in rural regions, also operate in urban regions, promoting use of renewable energy through management of solar panels, energy storage devices, and other systems. Researchers from a Brazilian energy institute have developed a framework that uses NFTs to tokenise the emissions of energy generators, register them as NFTs, and include them in energy portfolios that can be used to manage efficiency [66]. Viable peer-to-peer energy trading models, in which excess electricity is tokenised and traded with neighbours and community members, have been demonstrated by LO3 Energy [67] and Power Ledger [68]. The model enables coops and other purchasers to target the energy characteristics that align with their missions. Increased visibility, transferability, and consumer voice can promote the use of renewables and further the United Nations' climate goals.

Plastic recycling. Ocean-borne plastic waste is damaging to plants and animals in the ocean and on land. Nozama's Plastiks platform provides an NFT marketplace that promotes ocean waste recycling [69]. Recyclers are awarded NFTs when they produce invoices for the plastics they have retrieved and sold. Recyclers can sell these NFTs to parties seeking to reduce or offset waste. Producers such as Gravity Wave, which makes products from recycled plastic, can use the NFTs to certify the recovered plastic. This innovation incentivises plastic clean-up and reuse [69].

Biochar credits. BiocharLife teaches smallholder farmers who would otherwise engage in open field burning to sequester biochar. This removes CO2 from the atmosphere and improves soil health [70]. Farmers are awarded certified carbon sink certificates and can sell them on The Blue Marble platform (thebluemarble.io), which has been supported by the Stellar Community fund. The certificates, which can be stored as NFTs, capture and validate detailed histories of biochar activities. Through this process, farmers improve the air quality and health in their locations, improve their crop yields, and earn extra income from carbon credits.

8.3 Prosperity

Prosperity refers to material and financial wealth and security, particularly in less developed regions. Themes include hunger, affordable energy, poverty, decent work, infrastructure, and inequality. Use case examples in this category include access to finance, lease to own, product claims, and credit history.

Access to finance. In 2017, the World Bank estimated that 1.7 billion adults are unbanked, lacking access to savings and other basic financial services [71]. Savings is often difficult and risky, as individuals lack safe ways to store cash. Informal savings services have arisen to address this problem. For example, in Ghana, susu collectors charge an upfront fee of 3%; money is saved an average of 15 days. Although expensive, this is a valuable service not widely available globally. NFTs for proof of identity, issued by banks and held in customer wallets, could be used by customers to open accounts and deposit or withdraw savings at multiple locations. Biometric systems tied to individual banks and retail networks have been tested in places like Malawi [72].

Lease to own. Empowa, a partner of Mercy Corps Ventures, uses NFTs to make affordable, climate-smart housing more accessible [73]. In most developing countries, housing represents half of the wealth of the household, and the World Bank has called for new approaches to lending [74]. Through tokenisation, NFTs representing property titles for housing units can be held by real estate companies or could be purchased by impact investors or donors. Renters of these properties would gradually purchase their units through rent payments [75], which can be used to repay investors or fund future housing aid. Tokenisation has also been proposed as a method for making real estate investment accessible to small investors [76].

Product claims. Producers and distributors of some products produced in developing countries can make claims about these products that enable them to capture greater returns than they might otherwise. Products in developing regions may be grown organically or in a region associated with desirable qualities, for example, Blue Mountain Coffee [77]. The inability to validate claims can cause producers to compete with others making false claims, which can dilute the market and damage reputation. NFTs can be used for awarding or storing certifications, making it possible to demonstrate the provenance and characteristics of the products. EverLedger has been a pioneer in this area, using NFTs for holding digital twins and chain-of-custody histories of diamonds, enabling support for the claim that diamonds were mined in conflict-free zones [78].

Credit histories. In low-resource economies, many people lack credit histories, which limits their access to personal and business loans. In subsistence marketplaces, customers lacking the ability to demonstrate creditworthiness are often at the mercy of vendors and other lenders. It is common to be temporarily unable to pay for the food and other resources needed for their families, farms, or small businesses. It is not unusual to pay interest rates of 100% to short-term money lenders [79] or to take on risk by co-guaranteeing group members' microloans [80]. Through the use of NFTs by microlenders or marketplace managers, lending and repayment histories could be stored, and customers could use them to reduce the cost and risk of credit and other ills resulting from the temporary lack of funds. Using blockchain transactions and NFTs to build and demonstrate credit history is being tested in developed markets [81].

SDG 16, which focuses on peace, justice, and strong institutions, and SDG 17, which encourages international partnerships, are broad goals that cannot be addressed easily by individual companies or governments. However, there are a number of NFT uses that could be employed to address these categories as well. For example, Tracr tracks diamonds to ensure that they are sourced from conflict-free zones [82]. NFTs can be used as digital diamond certificates to ensure transparency of custody and proof-of-ownership [83]. Similar projects could address other conflict minerals and promote peace by reducing financial flows to warring factions in conflict zones. NFTs can promote international partnerships, such as collaboration on humanitarian aid. NFTs can be used to represent physical aid and relief items as well as associated digital manuals, distribution targets, and other information, which can be attached to the NFT. The increased ability to track and manage resources across agencies and organisations can support joint efforts of these entities in the pursuit of social goals.

9. Concluding Remarks

NFTs stand at the frontier of technological innovation, holding vast untapped potential. Mobilising this potential for the advancement of the

SDGs can catalyse significant and lasting societal advancements. The inherent attributes of this technology, including uniqueness, ownership, authenticity, and transferability, create potential for addressing problems in new ways. They enable NFTs to be used to signify identity, establish ownership, institute claims, and convey history.

The framework developed here provides a structure for exploring how each of these affordances can be employed in the service of the SDGs. The numerous use cases illustrate how NFTs can be used to promote sustainable development. The examples provide insights into how this tool can be applied in a broad range of contexts. This article thus provides a foundation from which innovative and impactful use cases can be envisioned and ultimately actualised in a way that contributes to positive social change. As progress is realised, the impact on the world's most vulnerable communities and on sustainable development in general can be profound.

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Ethereum 2.0 Hard Fork: Consensus Change and Market Efficiency

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Abstract

This study investigates the impact of consensus mechanism changes on cryptocurrency markets within the framework of the efficient market hypothesis, focusing on Ethereum's transition from Proof-of-Work to Proof-of-Stake consensus, known as the Ethereum 2.0 'The Merge' update. Two main hypotheses guide the enquiry: (i) 'The Merge' update will significantly enhance market efficiency and (ii) Ethereum's updates will have a greater impact on market efficiency compared to other cryptocurrencies. Using the Hurst exponent's R/S statistic, changes in Ethereum's long-term memory characteristics before and after major hard forks are quantified. The analysis reveals substantial improvements in Ethereum's market efficiency following the Ethereum 2.0 hard fork, attributed to the introduction of Proof-of-Stake, which enhanced transaction speed and built trust. These findings suggest a positive trajectory towards improved efficiency in Ethereum's market, particularly with 'The Merge' update. In conclusion, this study contributes to understanding the role of consensus mechanisms in cryptocurrencies and provides insights into future market trends resulting from such changes.

Keywords: *Ethereum, Cryptocurrency, Hard Fork, Consensus Algorithm, Proof-of-Stake*

JEL Classifications: *C58 – Financial Econometrics, G14 – Information and Market Efficiency; Event Studies, G15 – International Financial Markets, G17 – Financial Forecasting and Simulation, D53 – General Equilibrium and Disequilibrium*

1. Introduction

1.1 History and Forks of Ethereum

Ethereum, introduced by Vitalik Buterin in 2014, is an open-source, blockchain-based platform that utilises decentralised technology to address challenges like high transaction costs and information disparities [1]. Smart contracts are central to this transformation, streamlining asset transactions and reducing reliance on intermediaries [2]. Ethereum requires computational resources for transactions and 'smart contract' execution, with fees denominated in Ether (ETH) [3]. Unlike traditional cryptocurrencies like Bitcoin, Ethereum enables the creation and execution of decentralised applications (DApps) [4]. While Bitcoin has consistently utilised the Proof-of-Work (PoW) consensus mechanism since its inception [5], Ethereum was designed to transition from PoW to a more energy-efficient Proof-of-Stake (PoS) consensus mechanism. Table 1 provides definitions of key terms used in this article.

The Ethereum network was launched on 30 July 2015. In June 2016, a security breach led to the unlawful appropriation of about 3.6 million ETH. The Ethereum community chose a hard fork to rectify the transactions and restore affected investors' assets. A 'hard fork' signifies a substantial modification to a blockchain's operations, leading to a significantly different protocol. These changes may generate conflicts, potentially causing a division within the blockchain. In contrast, a 'soft fork' denotes a less drastic alteration [6]. The decision faced resistance, causing a schism in the Ethereum ecosystem, resulting in Ethereum Classic and the restructured Ethereum, which differ in consensus mechanisms and governance.

Ethereum achieved a market capitalisation of over $20 billion in June 2017. The Byzantium hard fork in October 2017 improved smart contract security and reduced mining rewards. The Constantinople update in February 2019 optimised the EVM and delayed difficulty bombs, paving the way for Ethereum's transition from PoW to PoS. PoW assigns network participants the challenge of solving complex mathematical puzzles, where individuals with more computational power have a greater chance of forming new blocks [7]. In PoS, participants validate transactions and create blocks based on their cryptocurrency holdings. Validators stake a predetermined amount of coins and gain the privilege to authenticate new blocks, receiving rewards in the same cryptocurrency [7]. 'The Merge' occurred on 15 September 2022, a focal point of this study. Table 2 summarises key Ethereum network updates and their objectives [5, 8, 9].

1.2 Consensus Mechanisms of Cryptocurrency

The consensus algorithm within a cryptocurrency is pivotal for maintaining the blockchain's integrity and reliability in the context of technological evolutions and social acceptance [10]. See Table 3 for types of popular consensus algorithms.

It fosters agreement among network participants, ensuring the legitimacy of each block [11].

Consensus algorithms serve essential roles in blockchain networks. They support decentralisation by enabling collaborative interactions among nodes, preserve data integrity without relying on central authorities, and maintain trust by safeguarding against tampering [12]. They also function as governance and participation mechanisms, empowering cryptocurrency holders to engage in network activities and receive rewards, fostering community ownership [7, 13].
Efficient consensus algorithms offer benefits like improved transaction processing, enhanced performance, and increased scalability. The

choice of consensus mechanism depends on the network's purpose and characteristics [11]. PoW is the most popular, followed by PoS and Delegated Proof-of-Stake (DPoS) [14].

Table 1. Definitions of key terms used in this article.

Key Term	Definition
ETH	Abbreviation for Ethereum, the native cryptocurrency of the Ethereum platform.
DApps	Decentralised Applications that run on a blockchain network, not controlled by any single entity.
DAO	Decentralised Autonomous Organisation, a type of organisation controlled by members and not influenced by a central government.
DDoS	Distributed Denial of Service, a cyber-attack aiming to disrupt the availability of a resource.
PoW	Proof-of-Work, a consensus mechanism where complex computations validate transactions.
PoS	Proof-of-Stake, a consensus mechanism determining block validation by coin holdings.
EVM	Ethereum Virtual Machine, the runtime environment for Ethereum smart contracts.
ASIC	Application-Specific Integrated Circuit, hardware designed for specific tasks like mining.
EMH	Efficient Market Hypothesis, a theory stating that asset prices reflect all available information.
Block	A unit of data storage on a blockchain, recording transactions.
Difficulty Bomb	Mechanism in Ethereum to increase mining difficulty over time, encouraging a transition to PoS.
Gas Cost	The computational effort required to execute operations on the Ethereum network.
Hard Fork	A significant change to the blockchain protocol requiring all users to upgrade.
Soft Fork	A backward-compatible change to the blockchain protocol.
The Merge	Ethereum's transition from Proof-of-Work to Proof-of-Stake.
Stake	Holding cryptocurrency in a wallet to support blockchain network operations.
Validator	Responsible for storing data and adding new blocks in a PoS blockchain.
Economic Layer	The layer in blockchain architecture where economic incentives are defined.

Table 2. The major forks and updates to the Ethereum blockchain (https://ethereum.org/en/history/ and https://github.com/ethereum, accessed on 7 August 2023).

Date	Fork Name	Summary
30 Jul 2015	Ethereum (Frontier)	Ethereum blockchain launch.
7 Sep 2015	Ice Age (Frontier Thawing)	First (unplanned) fork, providing security and speed updates. Introduced the difficulty bomb to ensure a future PoS hard fork.
14 Mar 2016	Homestead	Enabled ETH transactions and smart contract deployment.
20 Jul 2016	The DAO	US $50 million stolen. Community hard forked to recover funds, leading to Ethereum Classic formation.
2016 ~	Ethereum Classic	Ethereum Classic split due to the DAO controversy.
18 Oct 2016	Tangerine Whistle	Response to DDoS attacks.
22 Nov 2016	Spurious Dragon	Response to DDoS attacks.
16 Oct 2017	Byzantium	Reduced mining rewards, delayed difficulty bomb, added non-state-changing contract calls.
28 Feb 2019	Constantinople	Ensured blockchain functionality pre-PoS, optimised gas costs, added interaction with non-existent addresses.
8 Dec 2019	Istanbul	Optimised the gas cost.
2 Jan 2020	Muir Glacier	Delayed the difficulty bomb (by increasing the block difficulty of the PoW consensus mechanism).
15 Apr 2021	Berlin	Optimised gas costs for certain EVM actions. Increased support for multiple transaction types.
5 Aug 2021	London	Reformed transaction fees (EIP-1559), changed gas refunds and Ice Age schedule.
9 Dec 2021	Arrow Glacier	Pushed back difficulty bomb.
30 Jun 2022	Gray Glacier	Pushed back difficulty bomb.
6 Sep 2022	Bellatrix	Prepared Beacon Chain for 'The Merge', updated fork choice rules.
15 Sep 2022	Paris (The Merge)	Switched from PoW to PoS.
12 Apr 2023	Shanghai	Enabled staking withdrawals on the execution layer.
12 Apr 2023	Capella	Enabled staking withdrawals and automatic account sweeping on the consensus layer (Beacon Chain).

Ethereum initially adopted PoW but was designed to transition to PoS [1]. After a series of upgrades, 'The Merge' successfully completed the transition on 15 September 2022.

Table 3. Types of popular consensus mechanism (https://crypto.com/university/consensus-mechanisms-explained, accessed on 2 October 2023).

Types of Consensus Mechanism	Description
Proof-of-Work (PoW)	Miners solve complex mathematical problems to add blocks, rewarded for being first. Used in Bitcoin and Ethereum.
Proof-of-Stake (PoS)	Validators stake cryptocurrency as collateral, chance to create blocks based on amount staked. Energy-efficient. Used in Ethereum 2.0, Cardano, Polkadot.
Delegated Proof-of-Stake (DPoS)	Similar to PoS, but with voted delegates creating blocks. Enhances scalability and speed. Used in EOS, Tron, Lisk.
Proof of Importance (PoI)	Considers transaction quality and reputation to determine block creation ability. Prevents centralisation. Used in NEM.
Proof of Capacity (PoC)	Uses storage capacity for mining. Miners plot nonce and block hashes before mining. Used in Burstcoin, Chia, Storj.
Proof of Elapsed Time (PoET)	Assigns random waiting times to miners, first to wake up creates a block. Used in Hyperledger Sawtooth.

Proof of Activity (PoA)	Combines PoW and PoS. Miners create empty blocks through PoW, holder with most coins adds transactions through PoS.
Proof of Authority (PoA)	Used in private/permissioned blockchains. Relies on participant reputation. Used in VeChain.
Proof of Burn (PoB)	Miners burn cryptocurrency, higher burn amount increases block creation chance. Used in Slimcoin.
Byzantine Fault Tolerance (BFT)	Focuses on consensus with malicious nodes. Regulates communication using cryptography. Used in Hyperledger Fabric, Zilliqa.

The shift from PoW to PoS carries profound technical, social and economic implications. Technically, it enhances scalability and energy efficiency by allowing users to participate in block creation through deposits [12]. Socially, it amplifies decentralisation by fostering wider participation, making the network more inclusive [15, 16]. Economically, PoS significantly reduces hardware and energy expenses compared to PoW, improving profitability for participants [15]. Moreover, the transition reshapes the token economy, an economic system where tokens serve as a versatile medium of exchange [17]. The token economy model design, which incentivises user participation, is crucial for sustainable business growth [18, 19]. PoS incentivises stakers who uphold network security and create blocks, altering token distribution dynamics and encouraging broader involvement [20, 21].

However, the potential market impact of Ethereum's consensus change through the hard fork must be acknowledged. Hard forks can result in new networks due to community disagreements, challenging compatibility with the existing virtual asset ecosystem and potentially impacting investor confidence and market stability [22].

1.3 Research Structure

This study delves into Ethereum's history of major hard forks, providing context for the Ethereum 2.0 transition and establishes the theoretical foundations of EMH and long-term memory. The research objectives and hypotheses are outlined, focusing on empirically validating the impact of Ethereum 2.0's consensus change, comparing it with other major updates, and examining the repercussions on other cryptocurrency markets. Data sources and analytical methods used to assess the impact of consensus changes on cryptocurrency markets using the EMH framework are explained. A comparative analysis of market trends before and after the Ethereum 2.0 hard fork is conducted to advance our comprehension of cryptocurrency dynamics and evolution. The findings are consolidated, emphasising the implications of the consensus change on cryptocurrency markets, and offering insights for policymakers and practitioners. Study limitations and potential avenues for future research are acknowledged.

2. Theoretical Background

2.1 Efficient Market Hypothesis and Long-Term Memory of Virtual Asset Markets

EMH posits that market prices rapidly integrate all available information, making it nearly impossible for investors to consistently outperform the market average return. EMH has been rigorously examined in various financial contexts, including stock markets, financial forecasting, capital markets, foreign exchange markets and cryptocurrency markets [23–30]. EMH offers three forms: (i) Strong form EMH assumes that all information, both public and private, is reflected in a security's current market price. This means that even insider information cannot be used to consistently generate abnormal returns. (ii) Semi-strong form EMH assumes that all publicly available information is reflected in a security's current market price. This includes not only past prices and trading volumes but also news announcements, financial statements and other publicly available data. In other words, fundamental analysis cannot be used to consistently generate abnormal returns. (iii) Weak form EMH assumes that all past prices and trading volumes of security are reflected in its current market price. In other words, technical analysis cannot be used to consistently generate abnormal returns [26]. Our study follows the weak form EMH assumption.

In time series analysis, long-term memory refers to a property where, following a disturbance, the autocorrelation function gradually diminishes but retains a lasting impact [31]. Identifying long-term memory in asset price changes implies historical shocks that persistently influence an asset's price, indicating market inefficiency. The presence of long-term memory in cryptocurrency price fluctuations suggests potential predictability of future returns, uncovering inefficiencies. Recent studies have probed these aspects in virtual assets:
Bartos (2015) initially observed that Bitcoin's price promptly responds to public information, implying market efficiency in swiftly reflecting known data. This observation suggests that Bitcoin behaves like a standard economic commodity, with its price determined through market supply and demand dynamics, a hallmark of efficient markets [32]. Urquhart (2016) scrutinised the efficiency of the Bitcoin market and noted its evolution from inefficiency to efficiency [33]. Bariviera (2017) also suggested that the Bitcoin market is not entirely efficient but has improved over time [34]. Nadarajah (2017) proposed a power transformation of Bitcoin returns satisfying EMH [35]. Khuntia and Pattanayak (2018) found Bitcoin's efficiency with exceptions during specific periods [36]. Mnif (2020) detected a positive impact of the COVID-19 pandemic on the cryptocurrency market efficiency [37]. López-Martín et al. (2021) investigated the efficiency of various cryptocurrencies and concluded that Bitcoin and Ethereum markets' inefficiency tends to diminish over time evolving to more efficient markets [38].

Comparatively, Mensi et al. (2019) discovered Bitcoin and Ethereum markets to be inefficient, with Bitcoin exhibiting slightly greater inefficiency overall, though the efficiency varies across subperiods [39]. Zargar and Kumar (2019) found informational inefficiency in Bitcoin returns at higher frequencies [40]. Gregoriou (2019) attributed cryptocurrency market inefficiency to investors obtaining significant returns [41]. Fidrmuc et al. (2020) suggested that Bitcoin, Ethereum and Litecoin markets displayed short-term inefficiency in 2017–2018 [42]. Fousekis and Grigoriadis (2021) proposed volume-to-returns predictability which indicates informational inefficiency in major cryptocurrencies' markets [43]. Yi et al. (2022) suggested Bitcoin's efficiency is lower than gold, USD and stock indices but not significantly different long-term [44].

The study of Ethereum forks holds pivotal importance in the cryptocurrency domain. Hard fork is anticipated to bolster Ethereum's network scalability and decentralisation, potentially yielding positive effects not only for Ethereum but also for the broader cryptocurrency market. However, consensus is lacking on cryptocurrency market efficiency [45]. In the field of capital market research, the EMH bears significance that extends beyond geographical and currency boundaries [46, 47] and remains relevant regardless of study time frames [48–50]. Notably, there is a shortage of research that delves into the precise implications of alterations in cryptocurrency consensus mechanisms on market efficiency.

2.2 Research Hypothesis

Decentralisation has a relationship with liquidity [51], and it can be inferred that liquidity and the number of active users may have a positive impact on market efficiency [52]. Extending EMH to the technical and intrinsic aspects of cryptocurrencies, our hypothesis suggests that the degree of decentralisation in a cryptocurrency, as determined by factors like liquidity and the number of active users, correlates with market efficiency.

Hypothesis 1: The efficiency enhancement effect induced by the Ethereum 2.0 'The Merge' update will be particularly pronounced. *This hypothesis aims to confirm that as Ethereum progresses towards achieving its decentralisation objectives, the associated efficiency gains will be notably pronounced.*

Hypothesis 2: Ethereum will exhibit a greater degree of efficiency improvement following updates compared to other cryptocurrencies. *If it is true, this hypothesis suggests that cryptocurrencies moving closer to decentralisation goals will see notable increases in market efficiency.*

3. Methods and Data

To assess the impact of decentralisation enhancements through changes in cryptocurrency consensus mechanisms, the analysis encompasses five cryptocurrencies: Ethereum, Bitcoin, Ethereum Classic, Ripple and Tether. These selections were based on criteria such as user base, market capitalisation, trading volume and general popularity.

Ripple functions as an international remittance currency aimed at expediting cross-border transactions involving traditional currencies. Unlike decentralised cryptocurrencies that permit broad participation as validators, Ripple adopts a more centralised approach, restricting validation authority to a limited number of pre-verified entities. This strategy enhances transaction verification speed. Ripple operates as a for-profit company, setting it apart from cryptocurrencies that adhere more closely to decentralisation ideology [53].

Tether, introduced in 2014, functions as a blockchain platform facilitating the digital spending of fiat money. Tether is a stablecoin, a type of cryptocurrency, with its value directly tied to real-world fiat currencies and tangible assets like gold, crude oil and legal tender. Tether serves as a foundational currency for acquiring other cryptocurrencies on various exchanges [54].

- Bitcoin and Ethereum Classic adhere to PoW, characterised by high energy consumption, limitations in scalability and transaction speed.
- Ripple deviates from decentralisation principles due to constraints on validators.
- Tether, in contrast to the overarching cryptocurrency philosophy of decentralisation, serves as a foundational currency tightly linked to centralised traditional finance.

3.1 Research Methods

This study employed the Hurst exponent, calculated through rescaled range (R/S) analysis, to assess the long-term memory of time series data. The Hurst exponent, developed by Hurst (1951) and evolved into a fundamental tool in fractal geometry, has found successful applications in various domains, including financial analysis [29, 44, 55], hydrological and climatological sciences [56–58], material science [59–61], control performance assessment [62–64], meteorology [65–67] and biosciences [68–70]. The Hurst exponent's versatility and effectiveness make it invaluable for investigating time series data, including our examination of cryptocurrency market efficiency.

R/S analysis is robust to heavy tails in the underlying process and does not need strict assumptions about probability distributions, supporting its adaptability across domains concerning long-term dependencies and complexity. We utilised the Python Hurst package to measure the degree of long-term memory in our data. R/S analysis has broad applicability, extending to fields like finance, environmental studies and signal processing. It is resilient to heavy-tailed distributions and doesn't require stringent assumptions about probability distributions [71], making it suitable for analysing long-term dependencies and complexity in various domains.

The R/S statistic calculates the range of values that average the deviation from the mean for each time series, rescaled by the standard deviation of the returns, and can be measured as follows [72]:

$$(R/S)_n = \frac{1}{S_n}\left[\max_{1\le t\le n}\left(\frac{1}{n}\sum_{k=1}^{t}(r_k-\overline{r_n})\right)-\min_{1\le t\le n}\left(\frac{1}{n}\sum_{k=1}^{t}(r_k-\overline{r_n})\right)\right]$$

where $\{r_1, r_2, r_3, \cdots, r_t\}$ is the return of the cryptocurrency at each point in time, $\overline{r_n}$ is its average $\left(\frac{1}{n}\sum_{t=1}^{n} r_t\right)$ and n represents the length of the time series. And S_n is the standard deviation of the return, which is calculated as follows:

$$S_n = \left[\frac{1}{n}\sum_t (r_n - \overline{r_n})^2\right]^{\frac{1}{2}}$$

Hurst (1951) found that the statistic is proportional to the H(Hurst's exponent) power of n. This relationship can be expressed as follows:

$$\left(\frac{R}{S}\right)_n = c \times (n)^H,$$

where c is some constant. Taking logarithms on both sides and summing them up, the following relationship is obtained:

$$\log\left(\frac{R}{S}\right)_n = \log c + H\log(n),$$

where a simple regression model with the calculated $\log\left(\frac{R}{S}\right)_n$ as the dependent variable and $\log(n)$ as the explanatory variables can be estimated using least squares to obtain a slope estimate, the Hurst index. Interpretation of the Hurst exponent is contingent on its values:

• $H > 0.5$: Signifies a persistent trend in the time series. This implies that either the existing uptrend will continue upward or the existing downtrend will persist downward.
• $H = 0.5$: Represents a completely random walk. In this scenario, no discernible predictive pattern for future volatility exists, aligning with the principles of the EMH.
• $H < 0.5$: Indicates an anti-persistent tendency in the time series. This suggests that the previous uptrend will lead to a subsequent downtrend, and conversely, the previous downtrend will lead to an ensuing uptrend.

This study employs changes in the Hurst index to assess Ethereum's updates in terms of their long-term memory effects and impact on market efficiency. By examining these changes before and after each Ethereum update, we aim to provide evidence regarding how each update has influenced the market efficiency of virtual assets.

3.2 Data

The study uses daily closing price data for Bitcoin, Ethereum, Ethereum Classic, Ripple and Tether, spanning from 1 January 2016 to 31 May 2023, obtained from coinmarketcap.com (https://coinmarketcap.com, assessed on 6 June 2023). These daily closing prices were then subjected to log-difference transformation to calculate daily returns. For the analysis, we utilised data from 26 July 2016 (the split between Ethereum and Ethereum Classic) to 31 May 2023, a total of 2,501 data points for each cryptocurrency.

The average log-differential returns for Bitcoin, Ethereum, Ethereum Classic, Ripple and Tether are 0.0015, 0.0028, 0.0014, 0.0017 and 0.0000, respectively. All of these values are positive, suggesting that these cryptocurrency markets exhibited an overall upward trend during the study period. The standard deviation is notably higher than the rate of return, indicating that the volatility in these cryptocurrency markets was significant throughout the study period. Both skewness and kurtosis values indicate

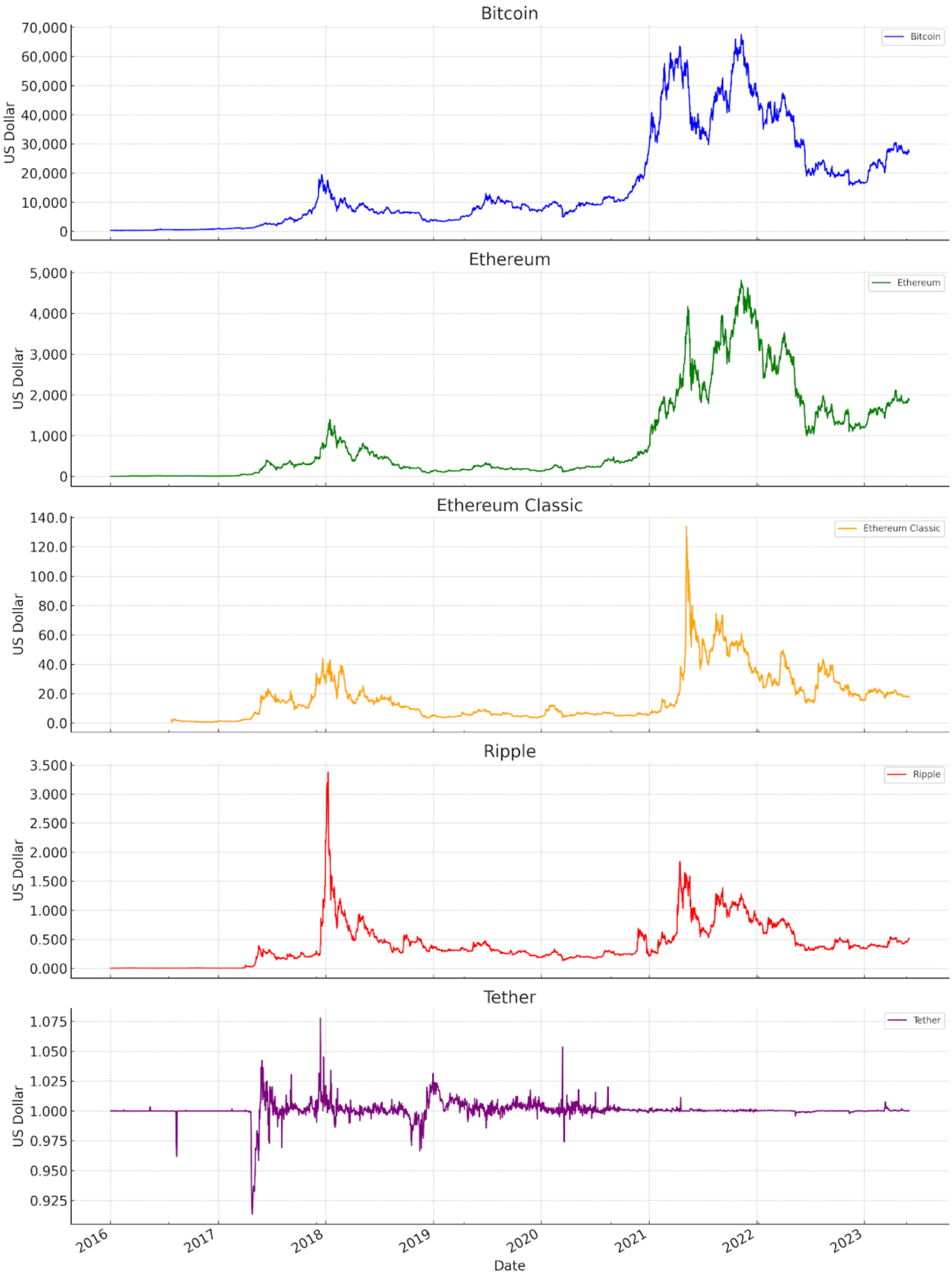

Figure 1. Price of five virtual assets during the entire period.

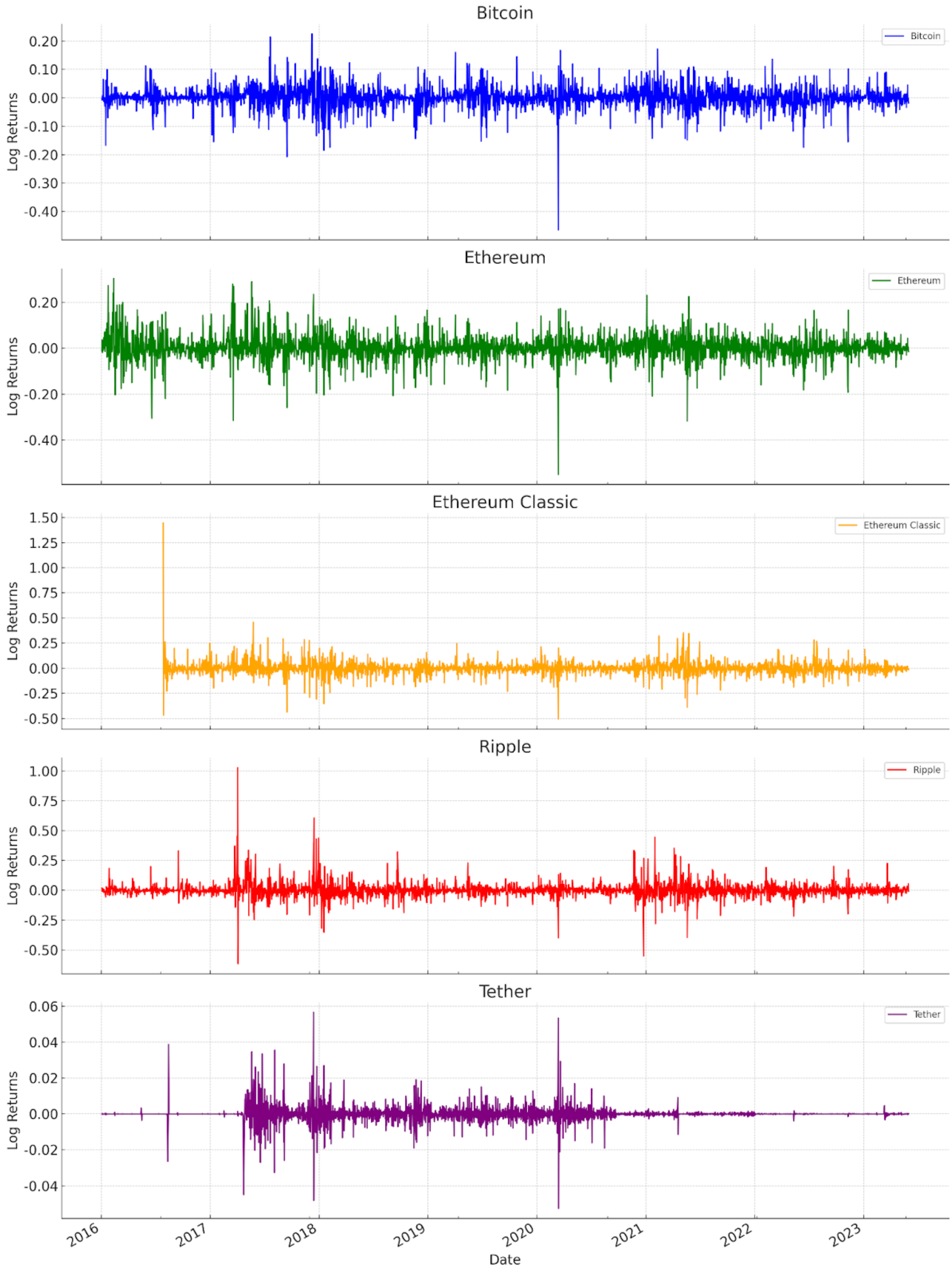

Figure 2. Log-difference rate of return of five virtual assets during the entire period.

that the returns of all five markets do not conform to a normal distribution, implying that they exhibit non-normal behaviour in their return patterns [73]. Refer to Table 4 for descriptive statistics of log-difference rate returns of five virtual assets. Figure 1 shows the price of these assets during the entire period, while Figure 2 illustrates their log-difference rate of return.

Table 4. Descriptive statistics of log-difference rate return of five virtual assets.

	Bitcoin	Ethereum	Ethereum Classic	Ripple	Tether
Count	2707	2707	2501	2707	2707
Mean	0.0015	0.0028	0.0014	0.0017	0.0000
Median	0.0018	0.0008	−0.0005	−0.0015	0.0000
Maximum	0.2251	0.3041	1.4443	1.0274	0.0566
Minimum	−0.4647	−0.5507	−0.5064	−0.6163	−0.0526
Std.	0.0385	0.0556	0.0708	0.0659	0.0047
Skewness	0.0018	0.0008	−0.0005	−0.0015	0.0000
Kurtosis	11.3393	7.8201	74.4897	36.4056	37.6493

4. Results and Discussion

4.1 Normality and Unit-Root Test

Table 5. Normality test of five virtual assets' log-difference rate return.

Normality Test	Bitcoin	Ethereum	Ethereum Classic	Ripple	Tether
Jarque-Bera	1.4680e4***	0.6901e4***	58.0677e4***	15.0836e4***	15.9404e4***
Kolmogorov-Smirnov	0.4482***	0.4319***	0.4265***	0.4334***	0.4888***
Anderson-Darling	59.5668***	50.4348***	92.3943***	134.7214***	311.2848***

* p-value < 0.1, ** p-value < 0.05, *** p-value < 0.01

Table 5 presents the outcomes of the Jarque-Bera, Kolmogorov-Smirnov and Anderson-Darling tests used to assess the normality of return probability distributions. The Jarque-Bera test checks if data follows a normal distribution based on skewness and kurtosis. The Kolmogorov-Smirnov test is nonparametric and compares data's distribution to the normal distribution. The Anderson-Darling test, based on cumulative distribution, detects departures from normality [74]. The results consistently reject the null hypothesis of normality for all five cryptocurrencies return time series. A high kurtosis in a distribution often suggests the presence of more extreme values or 'fat tails' compared to a normal distribution. These fat-tailed distributions may exhibit long memory characteristics, implying a persistent dependency over time in the data series [75, 76].

Table 6 summarises the findings from unit-root tests. The ADF test involves regressing the first difference of the time series on its lagged values and then examining the t-statistic of the coefficient on the lagged value. The PP test, similar to the ADF test, addresses serial correlation differently and employs a robust variance estimator for handling heteroskedasticity. The KPSS test is a two-sided assessment testing stationarity against a unit-root [77, 78]. The results indicate the absence of a unit-root in all five cryptocurrencies return time series. Both the ADF and PP test statistics yield significantly negative values, allowing us to reject the null hypothesis of a unit-root at the 1% significance level. Furthermore, the KPSS test statistics align with these results. Consequently, we can conclude that all five cryptocurrencies market return time series analysed can be considered stationary.

Table 6. Unit-root test results of five virtual assets' log-difference rate return.

Unit-root Test	Bitcoin	Ethereum	Ethereum Classic	Ripple	Tether
Augmented Dickey-Fuller (ADF)	-36.0853***	-9.7025***	-8.7511***	-11.1166***	-12.3097***
Phillips-Perron (PP)	-53.4699***	-53.6693***	-57.6344***	-54.5986***	-92.8047***
Kwiatkowski-Phillips-Schmidt-Shin (KPSS)	0.2578*	0.5432**	0.1825*	0.1979*	0.0075*

* p-value < 0.1, ** p-value < 0.05, *** p-value < 0.01

4.2 Hurst Exponent (R/S)

Table 7. Hurst exponent of five virtual assets according to test subperiods.

Event (Period)	Bitcoin	Ethereum	Ethereum Classic	Ripple	Tether
After Ethereum hard fork (26 Jul 2016 ~ 16 Oct 2017)	0.5887	0.7088	0.5950	0.6980	0.5850
After Byzantium update (17 Oct 2017 ~ 28 Feb 2019)	0.6311	0.6753	0.5487	0.6765	0.4718
After Constantinople update (01 Mar 2019 ~ 15 Sep 2022)	0.6021	0.6042	0.5976	0.5448	0.4404
After 'The Merge' update (16 Sep 2022 ~ 31 May 2023)	0.5781	0.5083	0.5694	0.5381	0.6275

Table 7 illustrates that Ethereum's updates generally influence the Hurst index of the cryptocurrency market. Right after Ethereum's split, the Hurst index of Ethereum stands at 0.7088, marking the highest within the entire observation period. However, as updates progress, Ethereum's Hurst index consistently declines. After 'The Merge' update, it experiences the most significant reduction, plummeting from 0.6042 to 0.5083, thus approaching a value close to 0.5.

Following the Ethereum split, all virtual assets display a persistent trend, with Ethereum exhibiting the highest index. Subsequent to the Byzantine update, the indices of Ethereum, Ethereum Classic and Ripple experienced slight decreases but still indicated a degree of persistence. Conversely, for Bitcoin, the index increased from 0.5887 to 0.6311, signifying a reinforced continuation trend.

Notably, after 'The Merge' update, Ethereum's Hurst exponent dropped from 0.6042 to 0.5083, indicating a reduction in long-term memory characteristics within the time series data. During the same period, the Hurst exponent of other cryptocurrencies decreased, approaching the 0.5 mark, suggesting a reduction in long-term memory effects. However, Tether exhibited a distinct pattern, with its index increasing from 0.4404 to 0.6275. Interestingly, the change in Ethereum's consensus mechanism had minimal impact on Tether, which stands out as the least decentralised cryptocurrency.

The analysis reveals that Ethereum's market efficiency has steadily improved with each update since its inception. Although there was a pronounced trend at the beginning, it gradually weakened over time, with the most significant reduction in long-term dependence occurring with the Ethereum 2.0 'The Merge' update. This implies a substantial improvement in the efficiency of the Ethereum market, aligning it more closely with the characteristics of an efficient market.

4.3 Ethereum Updates and Market Efficiency

The changes in the Hurst index provide insights into how each Ethereum update has impacted the market efficiency of virtual assets. Before the Byzantine update, both Ethereum and Ethereum Classic exhibited Hurst indexes exceeding 0.5, signifying a trend of market continuity. This implies that these markets might not have been fully efficient in incorporating available information. These inefficiencies could be attributed to the network divergence resulting from the community split. The newly forked Ethereum displayed an even higher Hurst index, indicating heightened confusion among participants during this transition. The split also introduced unforeseen vulnerabilities, underscoring its significant impact on participant behaviour and network security [79].

The Byzantium update in October 2017 aimed to improve smart contract functionality, enhance platform efficiency and introduce faster transaction speeds [80]. Following the Byzantine update, Ethereum's Hurst index dropped to 0.6753, signifying an enhancement in market efficiency.

The Constantinople update in February 2019 represented a significant stride in Ethereum's evolution as it moved towards transitioning from PoW to PoS. The primary focus was on optimising EVM operators' efficiency and mitigating the potential impact of the 'difficulty bomb'. After the Constantinople update, the Hurst index declined further from 0.6753 to 0.6042, bringing it closer to the 0.5 threshold. This shift indicated a weakening market trend and a transition towards a more balanced pattern in Ethereum's market dynamics. This result provides partial support for Hypothesis 1, which suggested that Ethereum's market efficiency would improve following major updates achieving its decentralisation objectives.

'The Merge' update in September 2022 marked a pivotal moment in Ethereum's evolution, as it aimed to transition the network into a more scalable and sustainable system. Following this update, Ethereum's Hurst index experienced the most substantial decrease during the study period, plummeting from 0.6042 to 0.5083. This reduction brought Ethereum's index closest to the 0.5 threshold among all virtual assets analysed. This significant decline in the Hurst index implies a notable improvement in market efficiency, consistent with *Hypothesis 1*.

4.4 Consensus Mechanism (PoW and PoS) and Other Cryptocurrency Markets

Beyond market efficiency, the transition from PoW to PoS through 'The Merge' update resulted in a significant reduction in Ethereum's energy consumption, ranging from 99.84% to 99.9996%. This shift has important implications from both social and business perspectives. From a social viewpoint, PoW-based cryptocurrencies like Bitcoin raised environmental and sustainability concerns due to their energy-intensive nature, while PoS-based cryptocurrencies are seen as more energy-efficient and eco-friendly. This could lead businesses and individuals concerned about environmental impact to favour PoS-based cryptocurrencies [9].

The choice between PoW and PoS consensus mechanisms has substantial implications for network governance and security. In PoS networks, security and validation are anchored in participants who hold stakes in the network. Validators have a vested interest in the network's success, as their holdings are at risk. This aligns network security with economic incentives. Conversely, PoW networks rely on miners who contribute computational power to secure the network. Security is directly linked to miners' capabilities and the computational resources they commit. The choice between PoW and PoS carries significant consequences for blockchain networks, impacting sustainability, governance and security. This decision should be carefully considered by cryptocurrency users, taking into account their objectives and values within the blockchain ecosystem [81].

Bitcoin and Ethereum Classic, both adhering to PoW, consistently demonstrate market inefficiency with Hurst indexes exceeding 0.5. Interestingly, in contrast to Ethereum, particularly after the Constantinople update, Bitcoin and Ethereum Classic's indexes exhibited striking similarity, highlighting comparable levels of persistence trend inefficiency. This lends support to *Hypothesis 2,* suggesting that the choice of consensus method significantly impacts market efficiency. Specifically, it suggests that PoS-type cryptocurrencies often foster more efficient markets compared to PoW-type counterparts.

Ripple, designed primarily for financial transactions with a high transaction volume and a substantial user base, displayed a consistent decline in its Hurst index over the study period. This indicates a shift towards market efficiency, potentially attributed to positive expectations regarding the outcome of the ongoing litigation with the U.S. Securities and Exchange Commission [82]. Despite variances in decentralisation compared to Ethereum, Ripple's market efficiency trends align with the broader trend observed. However, comprehensive investigation remains necessary to fully comprehend these trends, as they do not entirely align with prior research findings [53, 83].

In the case of Tether, the Hurst index displayed fluctuating patterns of inefficiency ranging between 0.4404 and 0.6275. It shifted from persistence to anti-persistence and back to persistence, indicating an inefficient market. This outcome aligns with previous research findings, suggesting that the Tether market may not be fully efficient [54, 84]. Furthermore, it can be inferred that the price trend of Tether, linked to the USD, can be highly volatile and unstable [85].

4.5 Ethereum and the Efficient Market Hypothesis

Vitalik Buterin's primary goal in conceiving Ethereum was to dismantle centralised systems through the transformative power of blockchain technology. The Ethereum White Paper introduced substantial improvements in computational efficiency, establishing an 'economic layer' for executing smart contracts while bolstering network security and the ecosystem as a whole [1].

Smart contracts broaden market access for investors, fostering a more transparent and inclusive financial environment. This transparency mitigates information disparities, empowering all stakeholders to make well-informed decisions [3, 86, 87].

EMH posits that financial markets are 'informationally efficient', meaning participants make decisions based on all available information, resulting in asset prices accurately reflecting their true value. Blockchain technology and smart contracts can be used to improve market efficiency by gathering more accurate and timely information [88, 89], and markets based on smart contracts have many similarities with the efficient market [90]. Smart contracts can potentially contribute to the democratisation of governance systems by enabling decentralised decision-making processes and coordination mechanisms [91]. We suggest that Ethereum's core functionality, namely smart contracts, democratises financial instruments. Although direct philosophical alignment between Ethereum and EMH is hard to find, it is possible to draw some parallels, i.e., both Ethereum and

EMH are based on the idea of decentralisation and the democratisation of financial markets.

5. Conclusions

5.1 Summary and Implications

This study examined the impact of Ethereum's updates on cryptocurrency market efficiency. Ethereum's journey, from inception to 'The Merge', demonstrated significant improvement in market efficiency, aligning with *Hypothesis 1*. Bitcoin and Ethereum Classic, using PoW, consistently exhibited market inefficiency, supporting *Hypothesis 2*, especially after the Constantinople update. Ripple displayed a transition towards market efficiency, potentially influenced by ongoing dispute. Tether's market exhibited instability. These findings underscore the significance of technological advancements in shaping market efficiency in the cryptocurrency landscape. Conducting interdisciplinary research is essential for a comprehensive understanding of these dynamics.

Our research yields critical insights into the cryptocurrency landscape. Ethereum's consistent market improvements, especially through 'The Merge', highlight the pivotal role of technological advancements in enhancing market efficiency. This underscores the cryptocurrency market's adaptability in rapidly incorporating new information into asset prices. The choice of consensus mechanism is a substantial factor in cryptocurrency market dynamics. The divergence in market efficiency between PoW-based cryptocurrencies, like Bitcoin and Ethereum Classic, and PoS-based Ethereum underscores the significance of these mechanisms. PoS-based cryptocurrencies tend to exhibit superior market efficiency, offering valuable guidance for investors and policymakers. Lastly, cryptocurrency markets are multifaceted; Ripple's journey towards market efficiency, despite its unique decentralisation model, demonstrates that resolving securities disputes positively influenced its stability and efficiency. Conversely, Tether's volatile behaviour exposes the instability of stablecoins. These findings emphasise the necessity for comprehensive investigations into linked assets like the USD, contributing to a deeper understanding of market efficiency within the stablecoin sector.

5.2 Limitations and Future Research

While this study offers valuable insights, it's important to acknowledge its limitations and suggest future research directions.

This research has data and methodological constraints, primarily relying on historical daily price data and the Hurst index with R/S analysis, potentially limiting the depth of insight. Future studies should consider broader datasets, various cryptocurrencies and extended periods before and after 'The Merge'. The impact of data frequencies on market efficiency also demands exploration. Incorporating Detrended Fluctuation Analysis (DFA) could enhance robustness, especially with small sample sizes. Alternative methodologies like Network Analysis, System Dynamics and Transformer algorithms could provide a more comprehensive perspective.

The lack of cross-market comparisons is another limitation. Examining market efficiency variations across different cryptocurrency markets, including altcoins and stablecoins, can illuminate unique dynamics and trends, enhancing our understanding of cryptocurrency interactions.
Causality and external factors are not considered, posing a major limitation. Establishing causality between Ethereum's updates and market efficiency remains challenging. Future research could explore how regulatory changes, other major markets or global events like the COVID-19 pandemic affect consumer behaviour during crises [92–94]. Controls in the experimental design could help clarify the causal relationship.

In summary, this study provides valuable insights into cryptocurrency market dynamics, focusing on Ethereum's updates and their influence on market efficiency. As the market evolves, smart contract-based algorithms for pattern recognition and AI trading could further improve efficiency. Future studies should build upon these findings to develop a more nuanced understanding of this ever-evolving market.

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Pioneering Emission Trading in Africa: An Architectural Design of a Blockchain-Powered Carbon Trading System

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Abstract

To achieve carbon neutrality by 2050 and reduce greenhouse gas (GHG) emissions to a range of 350–420 megatons of carbon dioxide equivalent, South Africa, the largest emitter of GHG in Africa, introduced a carbon taxation system in June 2019. However, within just 3 years, it has become evident that the system faces significant challenges, with less than 6% of the estimated tax returns reaching the government. This issue raises concerns about potential corruption and manipulation within the system. To address these challenges, this study presents a comprehensive framework for a carbon trading and taxation system leveraging blockchain technology (BCT). Designing this framework from the government's perspective ensures efficient monitoring and oversight. Notably, the proposed system operates automatically, eliminating the need for third-party intermediaries. This study also identifies a crucial research gap and lays the foundation for future studies. It empirically implements the system as a decentralised application) using the Hedera and Solana blockchain networks. Complemented by JavaScript for the user interface. Python, through Django, was used to handle the server-side system implementation. Thus, this research aims to address the shortcomings of Africa's current carbon taxation system through a novel, government-centric approach powered by BCT. The proposed system's potential to enhance transparency and efficiency justifies further exploration in future studies.

Keywords: *Blockchain, Blockchain Technology, Africa, South Africa, Greenhouse Gas, Carbon Taxation, Carbon Market, Carbon Trading System, Carbon Finance, Carbon Footprint.*

JEL Classifications: *Q4, Q53, Q54, Q55, P18, N7*

1. Introduction

Reports have indicated that South Africa is the largest emitter of greenhouse gases (GHG) in Africa and ranks among the world's top 20 emitters of the same. A substantial 86% of these emissions originate from the energy sector due to the country's heavy reliance on coal-fired plants for electricity generation. Without the implementation of necessary measures, this increase is projected to continue, as the GHG emission rate has risen by 67% between 1990 and 2019 and by 91% over the last decade [1]. Excessive emission of this gas has numerous adverse effects, including an increase in Earth's temperature, leading to acid rain, which can damage the atmosphere and the oceanic bodies [2].

To mitigate the emission rate and prevent the associated adverse effects, South African authorities have set a goal to reduce the emission rate to a range of 350 to 420 megatons of carbon dioxide equivalents (CO2e) and to achieve complete carbon neutrality by 2050. The action plan to accomplish these goals includes the introduction of carbon taxation in June 2019. Initially, this system seemed a practical step towards achieving the set goals, but its problems soon became apparent. In 2022, the government expected a return of R134 (≈$8) per ton of emitted GHG. However, the amount received was just R7 (≈$0.5) per ton of emitted GHG. This performance is deficient, representing only approximately 6% of the expected returns. Consequently, the purpose of carbon taxation is undermined as emitting entities (the companies) can still exploit manipulative and corrupt means to emit CO2e while avoiding the fees intended to regulate their emissions. These issues stem from the system being controlled by centralised authorities and institutions. These challenges are likely to escalate as the market value increases, particularly since the government plans to raise the price of carbon emissions per ton to $30 by 2030 and $120 by 2050 [1].

This potential for an exponential increase in market value necessitates an urgent solution to address possible manipulation and corruption within the system. Introducing a technology that ensures the system operates not only automatically but also securely, tamper-proof (immutable), and in a decentralised manner would be a novel solution [3]. These exceptional features are inherent to blockchain technology (BCT). BCT has demonstrated its dependability and usability in sensitive systems and is a technology that can be trusted [4]. Through its features, BCT is capable of curbing the corruption and manipulation present in the current conventional system, thereby shifting reliance and confidence from central authorities to system users and stakeholders [5].

To address the problems mentioned above, this study proposes and develops a framework for a blockchain-powered carbon trading system designed from the perspective of the South African government as a representative of the African governments. This approach ensures proper government monitoring and facilitates its adoption into the current African conventional carbon taxation and carbon trading system.

1.1 Background of Study

Carbon Tax: The carbon tax exemplifies a Pigouvian tax, which is a levy imposed by the government on businesses engaging in activities that have detrimental effects on the environment or public health, such as environmental pollution.

Consideration of South Africa's Carbon Trading Mechanism as a Sample of Africa's Carbon Trading Mechanism: South Africa not only is the largest emitter of GHG on the African continent but also ranks among the top 20 global emitters, having held the 12th position on the list. Its GHG emissions increased by more than 67% between 1990 and 2019, with the energy sector accounting for approximately 86% of total emissions. Other contributing sectors include industrial processes, agriculture, and waste. Consequently, by 2019, there was a nearly 91% increment in emissions over the previous three decades, primarily due to the energy sector's reliance on coal-fired power plants. South Africa is committed to reducing emissions to a range of 350–420 megatons of CO2e and achieving complete carbon neutrality by 2050. This objective is supported by a strategic plan to transition to a clean and resilient economy [1].

In an effort to mitigate GHG emissions, South Africa introduced carbon taxation in June 2019. This tax was levied on 90% of the country's GHG emission systems, making South Africa the first African nation to implement a carbon tax policy. Problems with the system began to emerge towards the end of 2022. At that time, the fee imposed on GHG-emitting systems was R134 (approximately $8) per ton of CO2e. However, the government received returns estimated at just R7 per ton of CO2e. Among other causes, this discrepancy can be attributed to the possibility of human-induced manipulations within the system, highlighting the need for a tamper-proof system such as BCT. Implementing BCT would not only decentralise the records but also make them immutable, ensuring that all tons of CO2e emitted by the responsible sectors are accurately accounted for, thereby making the entire tax fee payable to the government without any losses. This implementation is urgently needed before 2026 when the market value is expected to increase significantly due to the government's plan to raise the price of carbon dioxide to $20 per ton. However, the need for this technology will persist beyond 2026, as the market value of carbon trading is projected to grow exponentially, with plans to increase the value of carbon dioxide per ton to $30 by 2030 and $120 beyond 2050 [1]. Thus, BCT offers a scalable solution for the system.

Furthermore, the penalty proposed by the government for emissions exceeding the allocated carbon limit is a payment of $640 per ton of carbon dioxide emitted [1]. This fee can be avoided by companies through bidding for a carbon cap from other companies with excess quotas.

Overview of Blockchain Technology: As the name implies, blockchain is a chain of blocks linked together using cryptographic hashing. A block is structured data that records or maintains data initiated by and distributed across network entities. This record is not limited to financial information; it can also include sensor readings, diagrams from companies' applications, and government-imposed restrictions. Remarkably, it can also comprise executable source code, known as smart contracts [6]. Once the network entities reach a consensus to add a block to the chain, the information embedded within that block becomes permanently unchangeable [7]. Moreover, exact copies of the record are distributed to all network participants and kept up to date accordingly [8].

The distinctiveness of BCT lies in its capacity to enhance the security, immutability, and integrity of systems, among other exceptional, result-oriented characteristics [9]. It shifts reliance and confidence from central authorities such as institutions, governments, and companies to the system users or stakeholders [5].

The practical application of BCT in the carbon trading market is assured by its ability to secure data storage [10]. The absence of intermediaries and third-party entities facilitates secure and transparent interactions between two or more unknown parties [6]. Additionally, blockchain enhances system effectiveness by ensuring no single point of failure; entities within the network can exit and join at any time without disrupting the system's processes and the blockchain network [11].

2. Related Works

The practical application of BCT has been successfully implemented across various domains, including healthcare, identity management, and finance [12]. Its broad applicability extends to the energy and environmental sectors, which is directly related to our study, as a majority of GHG emissions are either directly or indirectly linked to the production and utilisation of energy [13]. In line with this, South Africa has set an ambitious target to achieve complete carbon neutrality by 2050 [1], underscoring the critical need to decarbonise the energy generation process in a digitalised and decentralised manner.

This context has led to the coining of the term "blockchain energy" by Teufel et al. [11], which refers to the application of BCT in the energy sector. According to the researchers, the scope of blockchain energy includes energy trading, energy record keeping, and the facilitation of energy transfer between entities. The benefits of a blockchain-powered system are evident in the independent trading of energy among small- and medium-scale prosumers, thereby mitigating the manipulation often associated with centralised authority systems.

Moreover, blockchain ensures that transactions within the system are traceable, allowing energy consumers to identify the source of their energy. The use of smart contracts enables automated agreements between multiple unknown parties, thereby eliminating the need for third-party intermediaries [5], [14]. This approach allows small- and medium-scale enterprises to participate alongside larger energy prosumers in the carbon trading market.

In a related study, Sadawi et al. [5] employed BCT to fulfil the original objectives of the carbon emission trading system, leveraging the technology's potential to design and develop an impartial and efficient carbon trading system. To facilitate government monitoring of the carbon trading market, most existing literature and studies in this domain have been developed from the government's perspective [15]. This approach enhances the system's originality and dependability, thereby reducing manipulation and corruption in carbon trading. To improve the fairness and effectiveness of the Australian carbon trading market, Hartmann proposed the integration of BCT into the carbon trading system [16]. Additionally, blockchain offers an optimised solution to the complexities of annual carbon cap allocation and system monitoring, ensuring proper revenue remittance and addressing information privacy challenges [5].

The time needed to gain mastery over BCT can be shortened if the pioneer carbon traders decide to speedily adopt the use of BCT into their system [17]. As Khaqqi [18] introduced, integrating reputation systems within blockchain operations and carbon trading gives preference to users with better reputations when allocating transaction quotas, thereby financially rewarding system users while ensuring system security.

The unique contribution of this study lies in presenting a framework for a blockchain-powered carbon trading system, proposed as a pioneering emission trading system for the African continent, with South Africa – the largest emitter of GHG – as the case study. This framework enables trade actions between prosumers and consumers without third-party intermediaries, ensuring a seamless process. By adopting a government perspective, this study designs a trustworthy carbon market system that facilitates proper government monitoring, thereby curbing manipulation and corruption associated with centralised systems.

3. Architectural Design

3.1 System Actors and Their Roles

The system comprises the governments, companies, and the system administrator. The system is targeted at aiding the company to be creative about different ways they can use to limit their emission, possibly by recycling it to generate power or sourcing for means of limiting the emission by utilising other avenues that are present at their disposal.

1. **The Government and Other Environmental Authorities:** The government, or the relevant authorities, will allocate a monthly carbon cap to each company within its jurisdiction. The volume of each company's monthly cap is determined by the annual carbon emission target, which is divided across the 12 calendar months to create smaller, more manageable goals.
2. **Companies:** Companies act as the prosumers of the carbon cap within the system, possessing the right to emit carbon within their allocated quota and to trade any surplus cap. Aware of their limited monthly GHG emission allowance, companies will be cautious about their emissions, promoting environmental responsibility. They will actively monitor and track their emissions using the company dashboard provided by the system. Should a company need to emit more carbon, it must either bid for additional carbon allocation in the market or accept an offer from another organisation with surplus carbon caps. This creates an incentive for companies to control their emissions creatively, as they can monetise any excess carbon cap in the digital carbon market. If a company exhausts its emission cap and fails to purchase additional rights from either the market or the government (at a higher cost than from another company), it will incur a tax or penalty greater than the potential market cost. The emission cap is monthly, but any unused or excess cap can be carried over to subsequent months. This allows companies to accumulate emission rights for future use, while those with deficits cannot reset their levels to zero without paying the necessary fees by acquiring quotas from the market or paying taxes to the government.
3. **System Administrator:** The system administrator possesses the technical expertise to build the system for end-users (the government and companies). The entire process is powered by BCT, moving away from conventional systems such as Microsoft Excel and centralised databases, which are susceptible to human manipulation and single points of failure, thus compromising the system's integrity. BCT is chosen for its tamper-proof and decentralised features, ensuring a transparent system where all entities involved can trust the processes. The system, programmed by the administrator, will include an alert mechanism that sends notifications to companies via SMS and email, informing them of their emission status at the end of each week, along with a summary at the end of each month.

3.2 Architecture of the Carbon Trading System

As inspired by Rachana Harish et al. [16], this consists of three primary layers, which include the blockchain-based carbon trading layer, the cyber-physical systems layer, and the information layer, as shown in Figure 1.

1. **Blockchain-Based Carbon Trading System Layer:** This component powers the entire trading system, enabling it to function as a decentralised platform. It is subdivided into three parts, which include:

   a. **Digital Access Tokenisation:** Tokens (digital assets) serve as the system's reward mechanism and medium of exchange. These digital assets can be stored for future use as cryptographic tokens, with ownership identity attached. Tokens facilitate the exchange of carbon emission rights within the decentralised system.

   b. **The Blockchain Network:** This manages peer-to-peer connections and communication among network nodes. Unlike centralised systems, storage here is distributed. In the absence of a central authority, consensus among nodes is required before accepting new records on the ledger. Additionally, the application automatically exchanges tokens as programmed, leveraging smart contracts.

   c. **The Blockchain Explorer:** The concepts mentioned above pertain to the backend logic of the application. To ensure a seamless user experience (UX) for non-technical users, a user interface (UI) is necessary. This UI acts as an intermediary between the technical components and the user, facilitating electronic trading and service exploration.
2. **Cyber-Physical Systems:** This layer integrates physical and virtual entities for the application's effective functioning. It encompasses human-induced operations such as emissions or energy purchasing decisions, machines (like the Internet of Things (IoT devices), and energy itself, that is, CO2e, along with the transaction fee known as gas, which is necessary for communication between system nodes. System performance is also crucial in this layer, as the proposed system aims to outperform existing conventional systems.
3. **Information Systems:** This layer provides users with data to make informed decisions. It includes an embedded email and SMS notification system, along with access to the electronic trading platform for allocating and monitoring emission rates, ensuring effective emission management.

4. Implementation Methodology

The designed system framework was implemented using the Hedera Blockchain Network, and the payment was powered by the Solana payment gateway system, which is also a decentralised technology. Hedera is an open-source, decentralised, proof-of-stake ledger powered by an asynchronous Byzantine Fault Tolerance hashgraph consensus algorithm. In its decentralised collusion-resistant platform, council, leading enterprises, universities, and Web3 projects are represented. Using Hedera's Ethereum Virtual Machine smart contracts, a real-time Web3 application and ecosystem can be created. It also provides cryptocurrency, file storage, smart contracts, and consensus services. Hedera differs from other blockchains in several ways. Through a robust codebase, high throughput, fast finality, low fees, predictable charges, and fair transaction ordering are ensured at every layer of the network infrastructure. For the purpose of preventing collusion, Hedera is governed by internationally recognised organisations. For writing smart contract programs, Hedera employs "Solidity.". This is an object-oriented and high-level programming language. It is also the core language used for the implementation of smart contracts on the network [20].

Furthermore, checking the execution of each of the transactions performed is done with the aid of Hashscan, which is an open-source tool used for the exploration of the performed operations on the chain. Among the other available tools, Hashscan was selected because it provides essential real-time analysis information of the Hedera blockchain simulation network, which includes details of the node and the prize of the transactions' used units. By the way, there is no need to register or make payments before assessing and using the platform. The only constraint of using it is that it enlists all the transactions performed on the Hedera network. So, to filter the transactions to the ones related to our smart contract, the account identification number (ID) of the smart contract test network deployment is connected [21].

To ensure a seamless experience for our "non-technical" system users while navigating the system, a UI connected to the Smart Contract was built. This UI was built using a popular programming language understood by the browser, which is known as JavaScript.

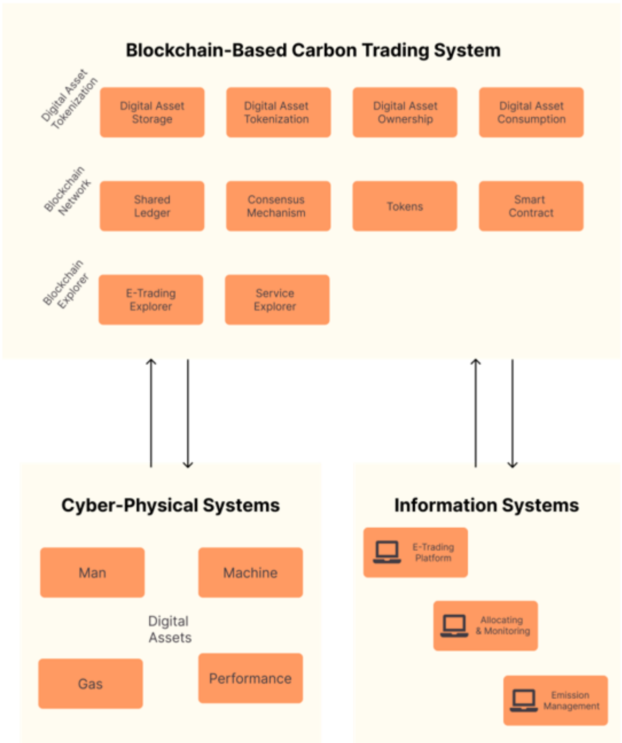

Figure 1. Architectural Design of the Carbon Trading System (Inspired by [19])

The data used for testing the system was randomly generated in the background using the Redis in-memory database. This was done to simulate carbon emission data that is generated in real time using an IoT-powered emission sensor. The development of the logic and the coding of the emission trading system powered by blockchain was implemented by following the following steps:

- First, samples of carbon emission data were checked using sources like ourworldindata.org/co2-dataset-sources, epa.gov/ghgreporting/data-sets, and cdp.net/en/investor/ghg-emissions-dataset. This helped us to get familiar with the format of a typical carbon footprint record. This knowledge was then leveraged to generate random emissions records in real time to reduce the carbon quota allocated to the emitting entities automatically.
- Second, the logic of the blockchain was developed. This step paid attention to the roles of each system actor and ensured that all the roles played by each of the entities involved in the system were strictly adhered to; that is, the system was made to work on an authorisation and authentication basis.
- Moving forward, the logic developed was then written using the Smart contract programs.
- The output obtained from the simulation of the system was then used to further enhance the system implementation to make it more effective.

After all the necessary checks have been done, the smart contracts will be moved from the Hedera blockchain's testing environment to the blockchain's main network.

4.1 System Operation Flow

An acceptable deliverable of the first version of the system was achieved when all use cases of the system were addressed, and it conformed to the following predefined conditions and workflow:

Based on the targeted annual emission volume, the system enables the government to allocate a carbon emission quota to each company or large emitting entity, considering their size and the taxes paid. During this allocation process, the government or environmental institutions ensure that a surplus quota is retained for contingency purposes.

Each company can monitor its emissions via a dashboard featuring user-friendly charts that compare its emissions against the allocated carbon quota. This is accomplished by using precomputed carbon records to generate random carbon footprints for each company on the system, which simulate real-time carbon footprints obtained through IoT carbon sensors.

Moreover, the system facilitates the trading of excess carbon quotas. Companies with surplus CO_2e quotas can offer them in the market. These offers can be updated at the company's discretion. However, once a buyer agrees to purchase an offer, the transaction becomes irrevocable. Similarly, a company nearing its allocated carbon quota and requiring additional emissions can bid for available offers in the marketplace.

If no offers are available for the bidder, the issue will be escalated to the authorities or government. If the government has a reserved quota, it will be sold to the company at a price slightly higher than the current market value but lower than the penalty fee. If the government does not have a reserved quota, the company must cease emissions for that month, even if it means stopping production. This scenario encourages the company to devise creative methods to continue production while reducing emissions. Alternatively, the company might choose to exceed its allocated quota without regard for the limitations. Exceeding the quota will result in imposing a high penalty fee corresponding to the excess emissions. Repeated violations of the emission rules by exceeding the quota without purchasing additional allocation will lead to the shutdown of the emitting entity's operations after three warnings.

The implementation methodology is illustrated in the flowchart shown in Figure 2.

5. Results

A decentralised ledger facilitates real-world trading conditions within the designed system. Additionally, the system was engineered to store, manage, and retrieve data to support users' decision-making processes. The operation of the blockchain-powered carbon trading system necessitates the use of a decentralised network, a server-side web programming language, and a client-side programming language.
The system was developed using six significant tools. The PostgreSQL database (version 15) is utilised for data recording, while Hedera blockchain technology stores the buy and sell orders. To develop the core application, Django (version 4.2.8), built on Python (3.12.1), was employed. Instead of generating real-time CO_2 emissions from IoT devices, random emission data is collected and entered into the system using Redis command line interface (CLI) powered by an Ubuntu runtime server/virtual machine. JavaScript was used for the front end.

5.1 Final Implementation Output

The designed framework was developed with a government-centric approach, implying that the government has full control over the system. The administrator interface makes it possible for the government to oversee the entire system process. From the point of creating large emitting entities, reducing payment through a decentralised approach, and allocating the genesis emitting block to the created emitting entities. The government or environmental institutions' authorities that are acting as the government delegate also reserve the right to maintain fair usage of the system, as they are the only system actors that can delete a sell order of a carbon quota that has been created if the seller desires to delete it or make a reverse on the move before any buyer shows interest of making the purchase.

Furthermore, after the emitting entities have been created, made payments, and allocated carbon quotas, they will then have full access to the system's functionalities. Despite granting full access to the system. At any time when the user wants to access the system, there is an authentication step that the emitter must pass through to access the system; this authentication step can be either through email and password, Google authentication, or Meta (formerly Facebook) authentication. Once the user has been authenticated, the emission dashboard will come up.

As shown in Figure 3, the emission below showcases the emission records of all participating companies instead of just showing the record of only the logged-in entity. This points to the fact that the emission reduction target is a collaborative effort of all companies in the region. This method fosters transparency, openness, and trust within the system. Moreover, it creates an environment where companies can compete to keep their emissions within the specified target.

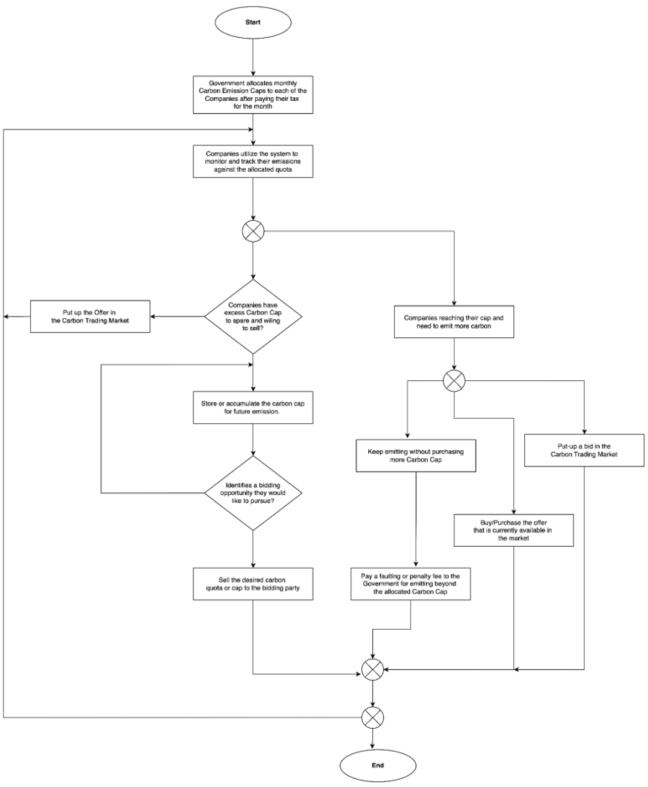

Figure 2. Carbon Cap Trading Process

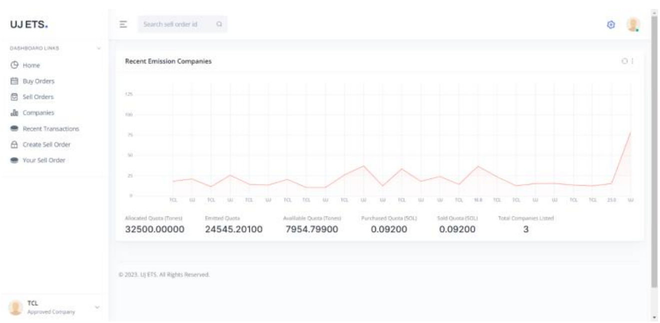

Figure 3. Emission Dashboard

The core functionality of the system is the exchange of excess carbon quota for monetary reward. This is only possible when entities are able to creatively limit the rate at which they emit and stay significantly below the allocated quota. Once a carbon quota has been listed for sale, a barcode will be generated and displayed at both the seller's and buyer's end of the system, as seen in Figure 4. This enhances the payment for the carbon quota by the buyer using the Solana wallet token storage known as Solflare. The payment process for the desired carbon quota sell order is illustrated in Figure 5. Upon successful and validated payment, the quota is transferred from the seller's allocation to the buyer's allocation.

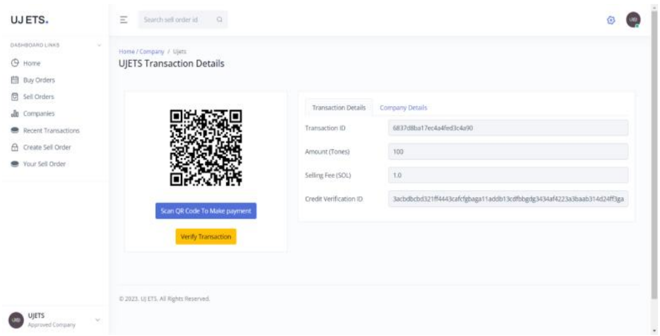

Figure 4. Carbon Quota Sell Order Creation

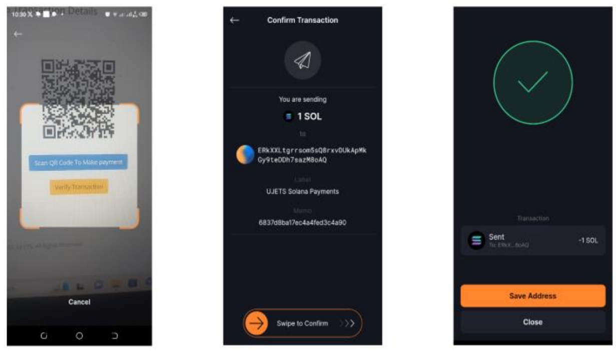

Figure 5. Payment Process using Solflare. https://solflare.com/

Moreover, the system uses smart contracts instead of conventional agreements. We used the Hedera Blockchain platform to power these smart contracts. Hashscan was utilised to monitor network transactions. By the way, Hashscan normally displays all transactions carried out on the Hedera Blockchain network; however, in this instance, the account ID number of our contract was linked to Hashscan, allowing the tool to display only transactions related to the contract.

5.2 System Performance Evaluation

The evaluation of the smart contract powering the system was conducted using Maian, a tool that uses an interprocedural symbolic implementation to identify contracts that are greedy, prodigal, and suicidal [22], as well as Semgrep [23], a code review tool that assesses the smart contract against standard practices. The findings of this evaluation are illustrated in Figure 8 and Table 1, which indicate that the smart contract is highly robust and does not exhibit any prodigal, suicidal, or greedy tendencies. The results obtained from Semgrep also reveal that the smart contract complies with 47 out of 48 Solidity rules, with the only violation being that the constructor is not payable. However, this has further established by Praitheeshan et al. [24] to pose a security risk if made payable.

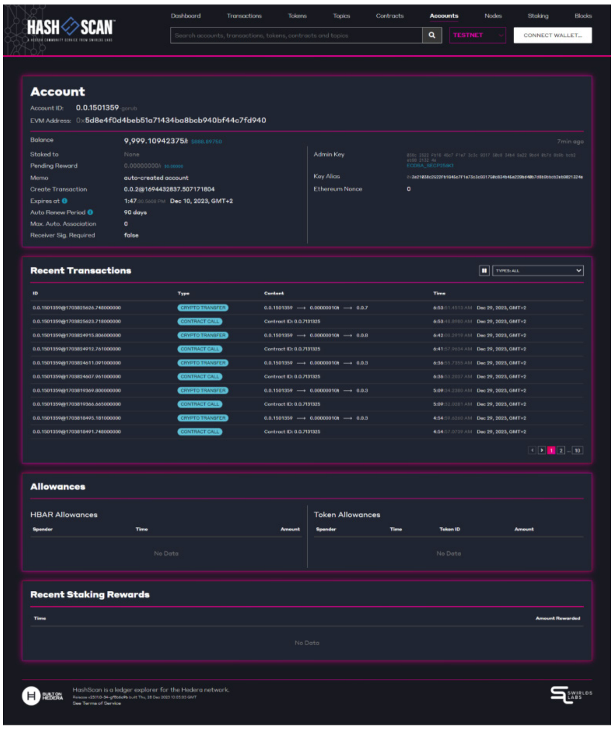

Figure 7. Tracking Smart Contracts Using Hashscan, https://hashscan.io/testnet/dashboard

Table 1. Analysis of the Smart Contract with Maian

Test	**Result**
Check if contract is SUICIDAL.	The code does not contain SUICIDE instructions; hence, it is not vulnerable.
Check if contract is PRODIGAL.	The code does not have CALL/SUICIDE; hence, it is not prodigal.
Check if contract is GREEDY.	No lock vulnerability was found because the contract cannot receive Ether.

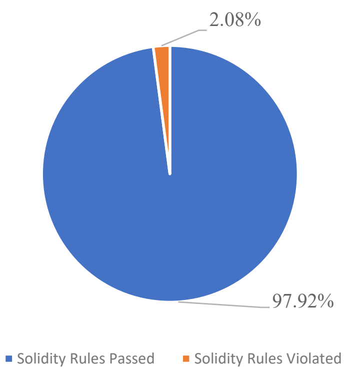

Figure 8. Analysis of the Smart Contract with Semgrep

Additionally, the system's source code was assessed using Bandit [25], generating a report that demonstrates a high confidence level and a low severity level for the code.

Table 2. Result of the Source Code Severity Analysis with Bandit

Low Severity	**Medium Severity**	**High Severity**
3,189 lines of code	551 lines of code	627 lines of code

Table 3. Result of the Source Code Confidence Analysis with Bandit

Low Confidence	**Medium Confidence**	**High Confidence**
233 lines of code	383 lines of code	3,751 lines of code

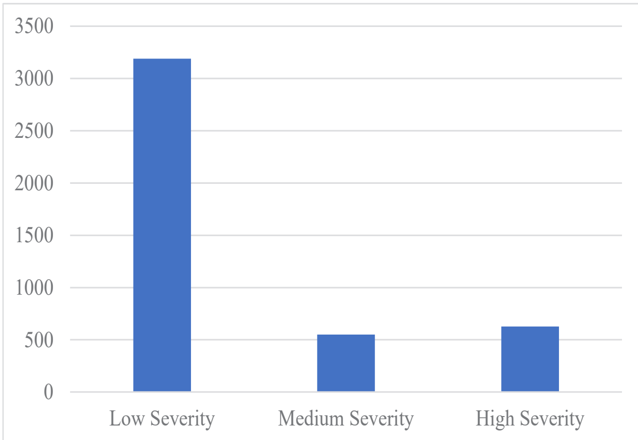

Figure 9. Result of the Source Code Severity Analysis with Bandit

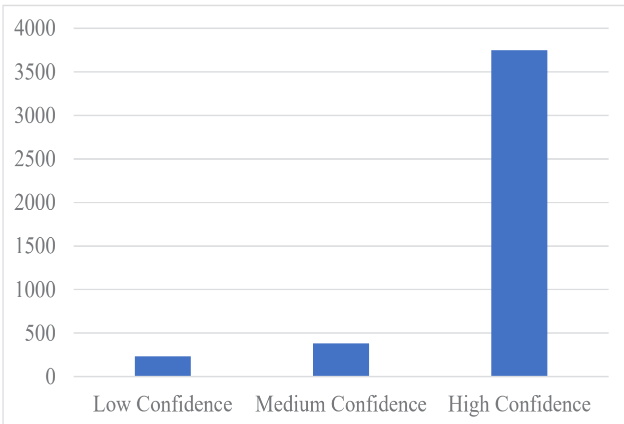

Figure 10. Result of the Source Code Confidence Analysis with Bandit

6. Discussion

6.1 Comparison of the Study with Related Works

Previous studies have explored the implementation of carbon trading systems using BCT. For instance, a study by Zhang et al. [26] demonstrated the potential of fostering a digital economy while reducing carbon emission intensity, highlighting BCT as an effective tool for this purpose. Similarly, research by T. Jiang et al. [17] established that BCT can intelligently automate carbon quota certification and payment, thereby reducing transaction costs and emissions through enhanced monitoring. Furthermore, the interoperability of the carbon trading market with other energy markets, such as the photovoltaic power market, has been validated through a decentralised architectural design [16].

This implementation, however, differs from the existing applications of BCT in the carbon trading domain in its focus and scope. First, it is fully automated, eliminating human interference from data capture to emission reduction within the allocated carbon quota based on proportional emissions. Additionally, the practical application to the African context has been considered, addressing the lack of such systems across the continent. The architectural design employed in developing this system is a decentralised architectural framework.

6.2 Limitations of the Current Study

These limitations are in place to encourage future research endeavours. First, the IoT data-capturing process of the system is simulated using random data that operates in the background through an in-memory database known as Redis CLI, running on an Ubuntu runtime environment. Second, the results are strictly focused on the emission trading system; future studies could explore the integration of a renewable energy trading mechanism into the system. Third, to enhance the system's alignment with the technological demands of the Fourth Industrial Revolution, machine learning and artificial intelligence could be incorporated to enable predictive analytics functionality. This would allow the system to utilise data to forecast carbon market behaviour and strategically plan methods to reduce emissions.

6.2 Conclusion

South Africa is the largest GHG emitter in Africa and one of the top 20 emitters globally. Recognising the adverse effects of these emissions, environmental experts in South Africa have set a goal of achieving zero emissions by 2050. One of the strategies to achieve this goal is the implementation of a carbon trading mechanism and carbon taxation, introduced in June 2019. However, the system's flaws soon became apparent. In 2022, the fee levied on the GHG-emitting system was R134 per ton of CO2e, yet the returns amounted to only R7 per ton of CO2e. This discrepancy is likely due to manipulation in the reported emission rates.

The scalability of the carbon market necessitates robust safeguards against any form of human or machine-induced manipulation, especially as the government plans to increase the value of CO2e per ton to $30 by 2030 and to $120 per ton beyond 2050. This exponential increase demands 100% integrity and transparency within the system.

In this study, a framework is designed wherein BCT will be utilised to power the carbon trading and taxation system. BCT was chosen due to its ability to transfer authority from a centralised system to a decentralised network of stakeholders. This not only eliminates a single point of failure but also integrates trust and transparency into the system, owing to the security and immutability of data provided by the blockchain ecosystem.

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Author's contribution:
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The Evolution and Future of Cryptocurrency-Based Fundraising Mechanisms

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Abstract

This scholarly work offers an in-depth analysis of the transformative impact of cryptocurrencies on fundraising mechanisms, with a particular focus on the evolution from Initial Coin Offerings (ICOs) to airdrops and beyond. We delve into the importance of tokens, elucidating the advantages of ICOs over traditional fundraising methods such as Initial Public Offerings (IPOs) and crowdfunding. Additionally, we critically assess the effectiveness of airdrops as a bootstrapping mechanism and facilitator of project development. To optimise the benefits for the ecosystem, we propose a set of design criteria for airdrops. Furthermore, we introduce the latest innovative fundraising approaches for future development and indicate meaningful directions for further research. By providing valuable insights and references, our study offers a comprehensive guide for researchers and industry professionals exploring new cryptocurrency funding methods.

Keywords: *Cryptocurrencies, Fundraising Mechanisms, ICOs, Airdrops, Blockchain Technology, DeFi, DePIN, IEOs, IDOs, DAOs, Digital Assets, Cryptocurrency Ecosystem*

JEL Classifications: *D02, D70, G30, Z0*

1. Introduction

Cryptocurrencies, created using cryptographic techniques and stored as data in virtual space, have transformed finance in recent years (Geuer, 2023). These decentralised digital assets operate independently of central banks and provide a novel payment system constructed on blockchain technology (Jiménez et al., 2021). Cryptocurrencies, particularly Bitcoin, have significantly changed how transactions, investments, and wealth storage are managed (Stein, 2020). They offer greater transparency in transactions, lower fees, and faster cross-border transfers, marking a paradigm shift in the financial world (Enajero, 2021). Gaining a deeper understanding of their long-term implications is necessary. One notable impact of cryptocurrencies is their ability to facilitate successful fundraising for projects that bring benefits and revolutions to society (Li et al., 2019).

This article will serve as a comprehensive guide to rethink fundraising strategies by utilising cryptocurrencies in the modern financial landscape. This article covers various aspects of using cryptocurrencies for fundraising, from Initial Coin Offerings (ICOs) to airdrops, as well as recent developments such as BRC-20 and decentralised physical infrastructure networks. It provides a complete depiction of the evolution of fundraising and where to go next. Section 2 explains the core value of tokens. Section 3 introduces ICOs and their development, including opportunities and risks, and a comparison with other traditional fundraising methods. Section 4 presents the most popular way of fundraising nowadays via the airdrop mechanism. Section 5 proposes effective fundraising criteria using cryptocurrencies for future protocols to reference. Section 6 shows the latest way that crypto natives use cryptocurrencies to bootstrap projects, such as BRC-20 and DePIN.

2. The Importance of Tokens

With the advent of the digital age, the adoption of digital financial tools has been widespread (Johnson et al., 2021). However, there are still many people around the world who have difficulty accessing traditional banking services, which limits their growth opportunities (Yao et al., 2021). Digital currencies deployed on consortium or private chains are restricted to specific areas.

Cryptocurrencies deployed on public chains offer an innovative solution to these problems. They facilitate the free flow of wealth without relying on trusted third parties (Li et al., 2020). This decentralisation helps build a more inclusive financial system free from the control of centralised entities. Cryptocurrencies can provide critical financial support to individuals and businesses in areas where traditional financial services are limited (Corbet et al., 2018). The decentralisation of cryptocurrencies is an important step towards a more inclusive and free financial system.
In addition, cryptocurrencies serve as an important coordination mechanism (Enajero et al., 2021). As a decentralised autonomous organisation (DAO) gains more influence, more people will buy the governance tokens that represent the organisation's ownership, thereby pumping the price of the tokens (Light, 2019). This increased value not only provides financial benefits to token holders but also increases the connections between the organisation's stakeholders (Jagtiani et al., 2021). It would attract more contributors and drive the organisation to grow.

3. Initial Coin Offering (ICO) Introduction and Milestone

3.1 ICO Introduction

ICO, also known as a token sale, has emerged as a novel fundraising mechanism, allowing projects to raise capital by issuing digital tokens on the blockchain. It is a swap of newly created tokens with liquid cryptocurrencies that enable blockchain start-ups to execute their experimental community projects. It is an innovative way to swap tokens to access funding and indirectly fiat currencies. Investors are not buying equity but are swapping their cryptocurrencies for tokens to be created by the software (Lee & Low, 2018).

In the evolving landscape of ICOs, tokens serve multiple purposes beyond mere equity representation. Some tokens act as vouchers, granting holders access to specific services or products the underlying project intends to offer, effectively acting as a pre-sale mechanism.

In essence, while ICOs offer a promising avenue for capital raising in the digital age, they come with inherent risks and challenges (Şarkaya et al., 2019). Unfortunately, the allure of rapid capital accumulation in the ICO space has attracted malevolent actors, while investors, often driven by FOMO (Fear of Missing Out), may bypass rigorous due diligence, making themselves vulnerable to meticulously crafted scams (Shehu et al., 2023). Instances of replicated whitepapers, counterfeit project websites, and 'exit scams' where initiators vanish post-fundraising underscore the need for meticulous project evaluation. Navigating the ICO terrain requires understanding its regulatory ambiguities as countries take different approaches (Oliveira et al., 2021). While some jurisdictions, like Switzerland, have adopted a more accommodative stance, others, such as China, enforce stringent prohibitions. This regulatory mosaic, compounded by evolving regulatory perspectives, requires adept navigation by project initiators and investors. In addition, the value proposition of these tokens is contingent upon a singular period of demand, which might constrain fundraising potential compared to traditional equity financing mechanisms (Sousa et al., 2021). A comprehensive understanding of their dynamics, coupled with appropriate regulatory frameworks, is essential to harness their potential while safeguarding investor interests.

The whitepaper, a comprehensive document detailing the project's goals, team, technical specifications, and token distribution strategy, is core to the ICO process. If meticulously researched and transparent, this whitepaper can serve as a bellwether of the project's credibility. During the ICO epoch, a significant capital increase was often driven by speculative fervour rather than intrinsic project value (Li et al., 2021). This resulted in scenarios where nascent projects, armed only with conceptual whitepapers, commanded valuations in the millions, drawing parallels with the dot-com era. Such speculative environments are inevitably punctuated by market corrections, posing risks for investors, especially those entering inflated valuations (Li et al., 2020).

3.2 Key Milestones of ICOs

The ICO concept originated with the emergence of Mastercoin. Its popularity surged after the launch of the Ethereum network in 2015. Table 1 shows the key milestones of ICOs (Zheng et al., 2020).

Table 1. The Key Milestones of ICOs

Year	Milestones	Description	Impact	Total Funds Raised
2009	Bitcoin	First decentralised cryptocurrency	Laid foundation for crypto ecosystem	N/A
2013	Mastercoin's ICO	First ICO conducted	Introduced new fundraising model	$5 million
2014	Ethereum's ICO	Platform for decentralised applications	Enabled smart contracts and new tokens	$18 million
2016	The DAO incident	Major security breach in Ethereum-based DAO	Raised awareness about smart contract security	$150 million
2017	Regulatory intervention	SEC statement on ICO regulations	Increased scrutiny and legitimacy of ICOs	N/A
2017 – 2018	Peak and decline of ICOs	ICOs reached their height before declining	Demonstrated both potential and risks of ICOs	Tens of billions
2019	Rise of IEOs	Initial Exchange Offerings emerged	Improved trust and security in token sales	Varied

Throughout the development of ICOs, many cases, such as Tezos, EOS, and Filecoin, successfully raised substantial funds. However, numerous projects failed for various reasons, providing valuable lessons for investors and regulatory bodies (Lee et al., 2018).

3.3 Comparison with Initial Public Offering (IPO)

In the stock market, an IPO is when a company publicly lists its shares for sale on the stock exchange for the first time, thereby going public. This endeavour aims to raise capital in exchange for ownership in the firm (Lee et al., 2021).

ICOs and IPOs represent distinct paradigms in the capital-raising arena, each with unique advantages and challenges. ICOs, underpinned by blockchain technology, offer a swift and decentralised fundraising mechanism, allowing projects to transition from ideation to capital acquisition in a significantly shorter time frame than the traditionally protracted IPO process. This expedited approach in ICOs, devoid of intricate regulatory entanglements and intermediaries, democratises investment opportunities, breaking geographical barriers and welcoming a diverse spectrum of investors. In contrast, IPOs, with their rigorous audits, regulatory compliances, and collaboration with established financial institutions, offer a more structured but elongated path to fundraising. The dichotomy between ICOs and IPOs encapsulates the trade-off between speed and decentralisation versus regulatory rigor and stability, with the choice contingent on an investor's risk tolerance, objectives, and familiarity with the evolving cryptocurrency domain.

Shareholders in an IPO have rights, such as voting on company matters or receiving dividends. The purpose of an IPO is to raise capital in exchange for ownership in the firm. ICO participants, however, often do not share profits. Their potential gains are usually tied to the token's value appreciation or utility within the project's ecosystem.

IPOs are often restricted to institutional investors or those with significant capital in the early stages. ICOs democratise this process, allowing anyone with an internet connection and some cryptocurrency to participate. Table 2 summarises the comparison between ICO and IPO.

Table 2. Comparison between ICO and IPO

Parameter	ICO	IPO
First launch	Mastercoin in 2013	Dutch East India Company in 1602
Accessibility	Open to anyone globally	Regulated, often restricted
Regulation	Lightly or unregulated (R)	Heavily regulated and disclosure required (A)
Investment Type	Tokens with utility or governance functions, but not shares of companies	Shares in a company

Stage	Early stage, even just an idea	Mature, meets specific requirements regarding profits and revenues
Duration	Weeks to months	Months to years
Due Diligence	Often limited	Extensive
Investor Protection	Limited (D)	Strong legal frameworks (A)
Secondary Market	Immediate, but potentially volatile (V)	Established, more stable markets
Typical Investor Profile	Crypto enthusiasts, risk-tolerant investors	Institutional investors, public
Post-Offering Reporting	Limited or voluntary	Mandatory regular financial reporting

Note: Legend: A: Advantage R: Potential Risk D: Disadvantage V: Variable

3.4 Further Developments: IDO and IEO

Although ICOs have been ground-breaking, they have faced challenges, particularly regarding regulation and investor protection. This has led to the emergence of Initial Exchange Offerings (IEO) and Initial DEX Offerings (IDO), which offer similar fundraising opportunities but with fewer regulatory constraints, increased decentralisation, and improved due diligence.

In 2017, regulatory bodies in several countries began scrutinising ICOs more closely. Notably, the U.S. Securities and Exchange Commission (SEC) suggested that certain ICOs might be considered securities offerings, requiring compliance with relevant regulations. Additionally, countries like China and South Korea outright banned ICO activities. The increase in ICO activities also led to a rise in fraudulent schemes and scams. Many projects vanished after raising significant funds, causing substantial losses for investors. The popularity of ICOs has waned over time. In contrast, IEOs and IDOs gained traction for various reasons and significant events that triggered this shift.

IEOs differ from ICOs in that they are hosted by cryptocurrency exchanges. This gives investors higher trust and security as exchanges conduct preliminary vetting and screening of projects. Furthermore, tokens are typically listed on the exchange immediately after the IEO concludes, ensuring liquidity for investors. Binance exchange introduced Binance Launchpad, which aimed to provide a more structured and secure platform for projects to raise funds. The endorsement from a reputable exchange added more credibility to the projects. The success of Binance Launchpad spurred other major exchanges to introduce their own IEO platforms. This shift marked a transition from the decentralised ICO model to a more centralised, arguably more secure, IEO model. With the backing of a well-established exchange, investors felt more confident participating in IEOs, knowing that the projects had undergone some vetting.

In contrast, IDOs involve token sales on decentralised exchanges (DEXs), offering more decentralisation than IEOs. This allows project teams to raise funds more quickly and flexibly in the IDO model. This method combined the decentralised spirit of ICOs with the structured approach of IEOs. Conducting a token sale via IDOs means projects can bypass centralised exchanges' often rigorous listing criteria. Additionally, the DEXs provide immediate liquidity for the project's tokens. While ICOs revolutionised the fundraising landscape, the security of smart contracts should not be ignored. The market's evolution towards IEOs and IDOs reflects the industry's adaptability and continuous efforts to balance innovation with security. As the cryptocurrency space matures, regulatory bodies worldwide are working to catch up. The shift from ICOs to IEOs and IDOs can be seen as a response to this evolving regulatory landscape, offering investors more protection while fostering innovation.

4. Airdrops Introduction

The concept of airdrops dates to the early days of cryptocurrencies when developers would distribute tokens to holders of a specific coin or to wallets that met certain criteria. The term "airdrop" was coined because it was like dropping something from the sky, with no effort required from the recipient. The first notable airdrop was in 2011 when Bitcoin holders received a free distribution of Litecoin.

Airdrops are a marketing strategy used in the cryptocurrency space where tokens are distributed to many wallet addresses for free or only at a small cost. Various protocols have employed this method to increase the fair distribution of their tokens, build a decentralised community, and sometimes incentivise users to engage with the protocols. One classic example is the saga between UniSwap and SushiSwap. SushiSwap was created as a fork of Uniswap, introducing the SUSHI token to offer additional rewards for liquidity providers. The platform attracted liquidity providers from Uniswap to migrate their funds to SushiSwap, awarding them SUSHI tokens. This strategy proved highly successful, resulting in a significant migration of liquidity from Uniswap to SushiSwap. To maintain its market position, Uniswap launched its governance token, UNI, in response to SushiSwap's strategy. UNI tokens were distributed to liquidity providers and users who had previously transacted on the platform. This event is a significant milestone in the decentralised finance (DeFi) sector and airdrop history, demonstrating how protocols use strategic airdrops to attract and reward users.

The core benefit of airdrops is their cost-effective approach to realising ideas quickly and sustainably. At the beginning of the Web3+ project, users dedicate time and resources to engage in protocol testing without compensation. Protocols, guided by user feedback, improve their products before seeking fundraising. Investors identify promising protocols through thorough due diligence. Once these protocols secure funding, they reward early users by distributing airdrops of tokens. These early users can then use these tokens for active participation in DAO governance or exchange for other cryptocurrencies. Users who receive tokens are more likely to use services, provide feedback, and support protocols. Entrepreneurs and investors dedicated to advancing the internet endorse these blockchain-based solutions, which facilitate the coordination of all stakeholders at a minimal cost. Web3+ frees itself from relying on Web 2.0 giants to initiate changes and instead directly compete with Web 2.0 companies (Zheng & Lee, 2023).

Airdrops are important in generating excitement and publicity, attracting new users to the platform. When airdrops are distributed, the media and community members take it upon themselves to publicise□ promote, and research the protocols,

giving them a great deal of exposure. Developers foster loyalty and stimulate sustained community engagement by incentivising and rewarding early supporters. This approach bolsters the project's visibility, attracting a broader user base and ensuring the decentralised distribution of tokens, mitigating the risk of disproportionate ownership by a select few.

However, airdrops also have drawbacks. Holders with large amounts of airdrop tokens may manipulate the market or dump them to a low price. Users may create multiple wallets to hunt for more airdrops, diluting the intended benefits of the airdrops. Additionally, the resources spent on airdrops could be used for other development or marketing activities. Airdrops can be challenging due to uncertain regulatory environments. If classified as securities, they may be subject to rigorous regulatory requirements. Therefore, projects must know the current regulatory landscape and ensure compliance to avoid legal complications. The amount of allocation can also be a double-edged sword. If the airdrop reward is not sufficiently large, it may cause resentment among community members. On the other hand, excessive distribution might dilute the token's value, adversely affecting its price and dampening investor enthusiasm. This instability is exacerbated if many recipients decide to sell their tokens simultaneously. To counteract this, projects can implement a meticulously planned airdrop, incorporating explicit guidelines and vesting durations, to curb abrupt value dilution. The structure and rollout of an airdrop can significantly shape participant behaviour. Ill-conceived airdrops might foster a short-term mindset, potentially jeopardising the project's overarching goals. Ensuring that airdrop incentives resonate with the project's long-term aspirations is crucial, fostering sustained growth and evolution.

Industrial builders can reference Table 3 for design criteria when creating token economics, while investors can refer to them when deciding whether to hold tokens in the long term.

Table 3. Design Criteria for Airdrops

Criterion	Description	Importance	Implementation Tips
Clear Objectives	Define the goals of the airdrops with appropriate allocations for rewards, incentives, marketing, and community building.	High	Set measurable targets. Align with overall project strategy. Communicate objectives clearly to the community.
Multiple Parameters	Multiple parameters need to be considered, such as the percentage of circulating tokens, the amount of money deposited, the number of interactions, and the timing of uses.	High	Use a weighted scoring system balance between engagement and token value. Regularly review and adjust parameters.
Fair Distribution	Ensure the distribution is fair and transparent, with clear and reasonable eligibility rules when published.	Critical	Implement a tiered system based on user engagement. Use smart contracts for automated distribution. Publish distribution formula beforehand.
Regulatory: Compliance	Understand and comply with the relevant regulations to avoid legal issues.	Critical	Consult with legal experts. Implement KYC/AML procedures, if necessary. Stay updated on changing regulations.
Minimise Sybil Attack	Implement appropriate criteria to minimise the potential harm from users who create many wallets to exploit the airdrop.	High	Use on-chain analysis to detect suspicious patterns. Implement reputation systems. Set minimum thresholds for eligibility.
Post-Airdrop Strategy	Develop a sustainable plan to retain current users and attract new ones through appropriate token incentives. The benefits of these incentives should outweigh the inflation costs to token holders. Further research is needed to design this plan.	High	Design long-term staking programs. Implement governance rights for token holders. Create a roadmap for continued development.
Technical Robustness	Ensure that the technical infrastructure can handle the airdrop without causing any disruptions to the platform. A smooth claiming process can enhance users' confidence in the protocols.	High	Conduct thorough testing stress. Use scalable blockchain solutions. Have a contingency plan for technical issues.
Community Engagement	Foster active participation and feedback from the community.	Medium	Host AMA sessions. Create community polls for decision-making. Reward constructive feedback and contributions.
Tokenomics Integration	Align airdrop with overall economics to ensure long-term token value.	High	Consider vesting periods for airdropped tokens. Align with token emission schedule. Factor in potential market impact.

5. Other Fundraising Mechanisms Using Cryptocurrencies

BRC 20 and the decentralised physical infrastructure network (DePIN) are two innovative fundraising mechanisms.

Bitcoin is commonly viewed as a stored value asset, while Ethereum is viewed as an innovation ecosystem that creates decentralised applications. However, with the proposal of the Ordinals protocol by Casey (2023), a core member of the Bitcoin community, there is growing interest in creating an ecosystem for Bitcoin.

Satoshi is the smallest unit of Bitcoin. It is equal to one hundred millionth of a Bitcoin. Ordinal protocols assign each Satoshi a unique ordinal number based on the order in which it was mined. This ordinal number remains constant throughout any transfer of Satoshi, giving each Satoshi unique irreplaceability. Inscriptions, a core part of the Ordinals protocol, allow information to be inscribed on individual Satoshi. Some people consider the Satoshi with inscriptions as a unique digital artefact. Ordinals give Satoshi a non-fungible character, while inscriptions add unique information to these satoshis, like creating art on a blank sheet of paper. Combining the two characters creates a new NFT standard for the Bitcoin ecosystem.

Inspired by ERC-20 tokens and Ordinal protocol, Twitter user @domodata created a new fungible token standard called BRC-20. It employs ordinal inscriptions of JSON data for the deployment of token contracts, as well as for the processes of minting and transferring tokens. BRC-20 tokens are deployed on a 'first-come, first-served' basis. Once a BRC20 token has been deployed, no more tokens with the same name can be deployed. Although @domodata categorised BRC-20 as a social experiment, this standard has been widely adopted after being promoted by community members and supported by central exchanges and Bitcoin farmers.

Venture capitalists acquire large amounts of tokens at a meagre price during private placements. They use their reputations to support protocols and present compelling narratives to persuade retail investors to invest. However, these retail investors unfortunately become liquidity providers for venture capitalists when they sell off tokens. Retail investors are tired of this unfair mechanism. The emergence of BRC-20 offers an opportunity for fair distribution. There are no private placements for venture capital or angel investors. Everyone has an equal chance to acquire tokens by minting them. During the minting event, investors pay a gas fee to mint tokens. There is no limitation on how many tokens each investor can mint. This mechanism distributes tokens fairly and dispersedly. Token holders are motivated to promote and support protocols spontaneously. The consensus among community members is solid when using the BRC-20 standard, as they have equal chances to join minting. If venture capitalists want BRC-20 tokens, they must participate in minting or buying in the secondary market. It is important to note that many successful BRC-20 tokens have a strong community vibe, and some may even incorporate meme culture. MEME coins play a significant role in the cryptocurrency ecosystem. The current price of BRC-20 tokens is primarily supported by the consensus and meme culture within the cryptocurrency community. Intrinsic value refers to the discounted value of cash generated over the life of a product or business; as such, most BRC-20 tokens have no intrinsic value. However, the psychological value of BRC-20 tokens is determined by the subjective emotions of the holders, like the emotional value of other collectibles or pets. Because the BRC-20 is a fungible token standard, its liquidity is better than NFT. On the other hand, some BRC-20 tokens have specific utilities, such as being used as gas fees or entry tickets for launchpad.

After the success of BRC-20, many other token standards have emerged on the Bitcoin system and on other blockchains. For instance, ARC-20, Rune, BRC-420, and SRC-20. The innovative token standards original from inscriptions are worthy of further research and development. These new token standards provide an inclusive financial ecosystem with improved functions, ensuring that everyone with internet access has an equal chance to participate in fundraising.

Another track that is becoming popular is DePIN. The emergence of a DePIN represents a novel paradigm that leverages blockchain technology to facilitate and administer distributed physical infrastructure systems. DePIN aims to address the challenges associated with deploying and managing physical infrastructure, which large corporations typically dominate due to substantial capital needs and logistical complexities.

IoTex (2021) initially put forth the concept of DePIN as MachineFi, aiming to pioneer the fusion of machine and DeFi to capitalise on data, events, and tasks driven by machines. Messari introduced the term "DePIN" in its 2022 report following a Twitter poll.

At the beginning of the protocol, DePIN uses tokens or potential airdrops to incentivise users to participate in the construction of the ecosystem and attract skilful developers to provide more cost-effective products. As more and more users use the product or service, the protocols' revenue increases, which can be used for market capitalisation management and further marketing, giving returns to the demand and supply side, incentivising more participants, and attracting the market's attention to build a thriving ecosystem. DePIN will have a good positive flywheel effect during the bull market. By implementing the incentive mechanism of DePIN, networks can generate the initial momentum required to rival established Web2 companies and achieve widespread adoption (Sami, 2023). DePIN is an essential link between the virtual Web3+ and the real world, which can promote data security, effectively coordinate idle resources, and improve our lives while letting more people see the practical value of cryptocurrencies. It is the first that cryptocurrencies are applied for developing physical facilities in the real world.

6. Comparative Analysis of Web2 and Web3 Fundraising Mechanisms

To provide a comprehensive understanding of the evolving landscape of fundraising mechanisms in the cryptocurrency era, we conducted a multifaceted analysis comparing traditional Web2 methods (such as Initial Public Offerings and crowdfunding) with emerging Web3 approaches (including Initial Coin Offerings and token sales). Our analysis comprises two main components: a systematic review of existing literature and in-depth case study comparisons.

6.1 Systematic Review of Existing Studies

We dove into 20 top academic papers and industry reports on Web2 and Web3 fundraising methods published between 2015 and 2023. We were pretty strict in our selection, focusing on peer-reviewed academic journals, credible industry reports, and publications from well-known financial institutions. During our research, we extracted both data and descriptive information, mainly concentrating on three aspects: fundraising success rates, average funds raised, and time needed to secure funding. To be honest, these studies varied widely in their methods and focus, and 20 samples isn't a huge number. So instead of trying to crunch precise figures, we focused on identifying broad trends and patterns that kept popping up across different studies. Our systematic review revealed significant variations in fundraising outcomes between Web2 and Web3 methods, as summarised in Table 4.

Table 4. Comparison of Web2 and Web3 Fundraising Metrics

Metric	Web2 (IPOs & Crowdfunding)	Web3 (ICOs & Token Sales)	Trend Web2	Trend Web3
Success Rate Range	50—80% Median: 65% (σ = 15%)	30–70% Median: 50% (σ = 20%)	Stable	Increasing
Avg. Funds Raised Range	$10–50 million Median: $30M (σ = $20M)	$5–30 million Median: $15M (σ = $12M)	Increasing	Volatile
Avg. Time-to-Funding Range	4–9 months Median: 6 months (σ = 2 months)	1–6 months Median: 3 months (σ = 1.5 months)	Stable	Decreasing

The data suggest that Web2 fundraising methods generally exhibit higher success rates and larger average funds raised, albeit with considerable variability. This variability likely reflects the diverse nature of Web2 fundraising, encompassing both traditional IPOs and newer crowdfunding approaches. In contrast, Web3 methods demonstrate a wider range in success rates, potentially indicative of the higher risk and speculative nature often associated with cryptocurrency projects. However, Web3 approaches consistently show shorter time-to-funding periods, highlighting their potential for rapid capital acquisition.

These trends suggest that Web3 fundraising methods may offer greater speed and flexibility in capital formation, potentially at the cost of lower success rates and smaller funding amounts. This trade-off aligns with the nature of many blockchain and cryptocurrency projects, which often prioritise rapid development and deployment over extensive pre-launch preparations.

6.1 Limitations

It is crucial to note that this review is based on a limited number of studies and should be interpreted with caution. The wide ranges observed in our data reflect not only the diversity of fundraising contexts but also the rapidly evolving nature of Web3 technologies. As the cryptocurrency and blockchain sectors continue to mature, these trends may shift. Further research with larger sample sizes and more granular data is necessary to draw more definitive conclusions.

6.2 Case Study Comparison: Facebook IPO vs. Ethereum ICO

To provide a more concrete illustration of the differences between Web2 and Web3 fundraising approaches, we conducted an in-depth comparison of two landmark events: Facebook's Initial Public Offering (IPO) in 2012, representing a traditional Web2 approach, and Ethereum's Initial Coin Offering (ICO) in 2014, exemplifying the Web3 paradigm.
We analysed publicly available data, financial reports, and contemporary news coverage to compile comprehensive profiles of these two fundraising events. Our analysis focused on key metrics including funds raised, time to completion, investor base, post-fundraising performance, and regulatory context. Table 5 presents a summary of our findings.

Table 5. Comparison of Facebook IPO and Ethereum ICO

Metric	Facebook IPO (Web2)	Ethereum ICO (Web3)
Funds Raised	$16 billion	$18 million
Time to Complete	9 months	42 days
Number of Investors	421 institutional	~6,000 individual
Post-Fundraising 1-Year ROI	-30%	+2,300%
Regulatory Hurdles	High	Low (at the time)

This case study comparison reveals stark contrasts between Web2 and Web3 fundraising approaches. While Facebook's IPO raised a substantially larger amount, reflecting its status as a mature company with an established user base, Ethereum's ICO demonstrated remarkable efficiency in terms of time to completion. The Ethereum fundraise was completed in just 42 days, compared to Facebook's 9-month process, highlighting the agility of Web3 fundraising mechanisms.

The investor base also differed significantly. Facebook's IPO was primarily accessible to institutional investors, while Ethereum's ICO engaged a much broader base of individual participants, aligning with the Web3 ethos of democratising investment opportunities.

Perhaps most striking is the difference in post-fundraising performance. While Facebook's stock price declined by 30% in the year following its IPO, Ethereum's token value skyrocketed by 2,300%. However, it's important to note that this extreme appreciation also reflects the highly speculative nature of early cryptocurrency investments.
The regulatory landscape also played a crucial role. Facebook's IPO navigated a complex regulatory environment, while Ethereum's ICO occurred in a period of minimal regulatory oversight for cryptocurrency projects. This regulatory gap has since narrowed, with increasing scrutiny of ICOs and token sales in many jurisdictions.

7. Summary

The evolution of cryptocurrency fundraising, underpinned by blockchain technology, has ushered in an era that challenges traditional financial paradigms. This fundraising democratisation has redefined the essence of value exchange and trust and expanded global access to investment opportunities. However, with this profound shift come challenges, notably regulatory ambiguities and the potential for fraudulent activities. The dynamic nature of the cryptocurrency ecosystem, evidenced by its adaptability and innovations such as ICOs, IEOs, and strategic airdrops, stands as a testament to its resilience and potential.

Facilitating fundraising is one of the core functions of cryptocurrencies. It operates much more efficiently compared with traditional finance and brings more inclusion. The inclusiveness of cryptocurrencies in financing activities cannot be overstated. Cryptocurrencies allow for more funding opportunities and exposure for core businesses and lower the barriers for investors to fund projects that can potentially change the world. As we consider how to get more people to understand and use cryptocurrencies for fundraising, protecting investors and reducing the risk of fraud without stifling innovation are worthwhile directions for policymakers, industry groups, academics, and project owners to consider and work on.

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Can DAOs Innovate Governance beyond Hierarchies?

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Abstract

Decentralised autonomous organisations (DAOs) represent a novel organisational form made possible by blockchain technology. This article summarises a research project that sets out to establish an intellectually coherent, consistent, and academically robust theoretical framework that locates DAOs within a theory of organisation. I examine the unique characteristics of DAOs, focusing on their ability to facilitate coordination and cooperation without traditional hierarchical structures. By leveraging market-like mechanisms and token-based governance, DAOs aim to reduce agency costs and promote inclusive decision-making. The efficacy of these mechanisms, however, in achieving effective governance remains an empirical question. This research provides a theoretical framework to understand DAOs within the context of organisational theory, offering insights for researchers, practitioners, and policymakers on the potential and challenges of this emerging form of organisation.

Keywords: *Decentralised Autonomous Organisation, Organisation Costs, Open Source, Property Rights*

JEL Classifications: *D23, D71, D86, L22, L86*

1. Introduction

In May, I was honoured to be inducted as a Fellow of the British Blockchain Association at a ceremony held in Singapore. This article is a longer form exposition of the presentation I gave in Singapore and summarises a research programme that I have pursued over the past three years that examines the economic function and purpose of decentralised autonomous organisations (DAOs) [1–3]. This research programme has been partly financed by a research grant generously provided by the Ethereum Foundation.

There is a large emerging literature that examines DAOs as novel institutional forms and the governance of those forms. See, for example, [4–10] and [11] for recent literature and the governance of DAOs. I commend this literature to the reader. In this article, I focus on the contribution I am making to our understanding of DAOs.

DAOs are organisational forms that have become possible following the advent of blockchain technology. They appear to be the native digital analogue to real-world organisational forms. This immediately raises the question as to whether they are a new and unique organisational form, or whether they are simply 'organisations on the internet'? This is not a matter of mere semantics. If DAOs are novel organisational forms, then we know much less about them than we think we do. If, however, they are a variation on a theme – now 'just' organisations on the internet – then we might know much about them.

The extent to which DAOs are indeed novel is important – we are beginning to see empirical research into DAOs (for example [12]), but if we do not have a clear theoretical understanding of DAOs, it may be the case that the empirical questions that we ask are not as informative as we might otherwise expect.

In my research, I have been attempting to isolate those features of DAOs that make them novel and the organisational challenges that they must resolve that make them viable.

In summary, to be novel organisational forms, DAOs must facilitate coordination (as markets do) and facilitate cooperation (as organisations do) while suppressing agency costs. If DAOs are able to do so, then they can provide 'public goods' even though they are private organisations. All of this must be possible in the absence of centralised and hierarchical management systems.

Whether or not DAOs as currently formulated and structured can meet those criteria is an open, and empirical, question. If my theoretical contributions are correct, then empirical researchers will have some guidance when evaluating the empirical success of DAOs as an organisational form.

2. What Is a DAO?

Berg, Davidson, and Potts [13] define DAOs as being

> A decentralised autonomous organisation (DAO) is a bundle of smart contracts that incorporate a system of governance – the blockchain equivalent of a company. A DAO is a company in which the decision-making rules are hard-coded into self-executing algorithms.

DAOs, however, appear to be much more than simply being 'a company' on the internet. Davidson, De Filippi, and Potts [14], for example, define DAOs as follows:

> A [DAO] is a self-governing organisation with the coordination properties of a market, the governance properties of a commons and the constitutional, legal and monetary properties of a nation state. It is an organisation, but it is not hierarchical. It has the coordination properties of a market through the token systems that coordinate distributed action, but it is not a market because the predominant activity is production, not exchange.

In this view, DAOs represent a novel and pioneering framework in organisational design, blending characteristics of markets, commons, and nation states. Surprisingly, what is missing are characteristics of organisational forms such as firms.

At its core, a DAO is an organisational entity that operates autonomously, free from traditional hierarchical structures. This autonomy is facilitated by blockchain technology, which enables a DAO to function based on pre-set rules encoded as smart contracts. These smart contracts are executed automatically, ensuring adherence to the rules without the need for centralised oversight. The self-governing aspect of DAOs heralds a shift from top-down control to a more horizontal structure of management, where decision-making is distributed among its members.

DAOs embody market-like characteristics through their use of token systems. These tokens, often taking the form of cryptocurrencies or utility tokens, serve as a means to incentivise and coordinate the actions of distributed individuals. Much like a market, these token systems facilitate the allocation of resources and labour through mechanisms akin to supply and demand dynamics. Unlike traditional markets where the primary activity is exchange, however, DAOs utilise these market mechanisms primarily to coordinate production and collective action.

DAOs also share similarities with commons in their governance structure (see [15] for more discussion on this point). In commons, resources are managed collectively by a community, with decisions made through consensus or democratic processes. Similarly, DAOs often rely on collective decision-making processes, where token holders or contributors have a say in key decisions. This participatory governance model ensures that decisions reflect the collective will of the community, aligning with the ethos of decentralisation.

The resemblance of DAOs to nation states lies in their self-contained 'legal and constitutional' frameworks and the ability to issue their own tokens, akin to a national currency. DAOs can establish their own rules and norms, much like a constitution, that govern the interactions within the organisation. The issuance of tokens can be compared to a nation state's monetary policy, as these tokens can often serve as the medium of exchange within the DAO ecosystem, influencing economic activities and value distribution.

Contained within that definition, however, are a number of implicit assumptions that need to be examined. The definition assumes that DAOs can effectively govern themselves without traditional hierarchical structures. In reality, the effectiveness of self-governance in DAOs can vary significantly. The reliance on technology for governance assumes a level of infallibility in smart contracts, which may not always hold true given the potential for bugs or unforeseen scenarios. Moreover, the assumption overlooks the human element in governance – the potential for conflicts, divergent interests, and collective action problems, which can be challenging to manage purely through automated systems (if at all).

The assumption that DAO decision-making reflects the 'collective will' of the DAO membership may overlook the challenges inherent in democratic governance systems. Furthermore, token-based governance could lead to plutocratic tendencies, where those with more tokens (and hence more voting power) can dominate decision-making, potentially leading to decisions that favour a minority of token holders. Tokens are themselves often highly volatile and can be subject to speculation and manipulation, which can distort the intended coordination and incentivisation mechanisms they are intended to facilitate. These issues are further discussed below.

In Davidson et al.'s view, DAOs are hybrid institutions as envisaged by Oliver Williamson [16, 17]. The question then becomes, 'What sort of hybrid are they?' In [2], I investigate that question by applying Williamson's [16] framework to the question at hand. Table 1 is adapted from Williamson [16] and reproduced from [2] and adds a column where the governance attributes of DAOs are included. In Williamson's [17] theory, markets and hierarchy are mirror images of each other, and hybrids constitute an organisational compromise. Note that 'hybrids' as envisaged by Williamson tend to not be 'autonomous'.

Table 1: Attributes of Governance Structures

Attributes	Governance Structure			
	Market	Hierarchy	Hybrid	DAO
Instruments				
Incentive Intensity	++	0	+	++
Administrative Control	0	++	+	0
Performance				
Autonomous Adaptation	++	0	+	++
Cooperative Adaptation	0	++	+	++?
Adaptive Integrity	0	++		++?
Contract Law	++	0	+	+

Key: ++ Strong; + Semi-strong; 0 Weak.
Source: Adapted from [2] and [17].

Looking at the first panel, DAOs employ market incentive structures and do not have 'administrative controls'. By definition, there is no hierarchy within DAOs. Community control is manifest via market mechanisms, that is, voting by token holders (this being equivalent to shareholders voting directly to control a firm).

Williamson [17] argues that adaptation to change is an important organisational attribute. He labels adaptation that is driven primarily by market forces as 'Autonomous Adaptation', while adaptation driven by 'conscious, deliberate, purposeful cooperation' is defined as 'Cooperative Adaptation'. If DAOs are to be described as being an organisational form (and not simply a dark pool), then there must be a mechanism to facilitate 'conscious, deliberate, purposeful cooperation'. As a matter of theory, DAO governance (token voting and smart contracts) must result in 'conscious, deliberate, purposeful cooperation' in the absence of administrative control but in the presence of (market) incentive intensity. Whether or not DAOs do achieve that goal is an empirical question. There is much more theory that underpins that insight, however, and that is discussed below.

Davidson et al. [14] also argue that DAOs have features of nation states – they provide 'public goods'. Williamson [16] argues that the provision of public goods requires 'adaptive integrity' by which he means 'probity'. In private sector organisations, Williamson suggests that probity is secured by contract law. In the case of the nation state, however, probity cannot be secured solely by contract law. This is an empirical claim, and Williamson appears to introduce an impossibility theorem at this point in his argument. Nonetheless, the point remains that a 'probity hazard' (defined as being the 'loyalty and rectitude' whereby the transaction is discharged) exists in all organisational forms, including DAOs. Within DAOs, probity would be secured by open-source norms, smart contracts, and 'community values'. The antecedents of community values within DAOs generally are under-researched, and this does represent an opportunity for cultural economists, ethnographers, and sociologists to explore important and interesting questions in this space.

Finally, Williamson [17] discusses the role contract law plays in governance structures. Contract law plays a very important role in the functioning of markets, but less so within hierarchy. Within DAOs, however, smart contracts play an important role, albeit they are not 'contracts' as envisaged by the legal system per se.

3. DAO Governance

Following Shleifer and Vishny's [18] exposition of corporate governance, Davidson [2] defines DAO governance as follows:

> DAO governance involves the mechanisms whereby token-holders ensure they receive a return on their community involvement, either in the form of additional tokens, or utility (somehow defined), or influence. How do token-holders ensure that blockchain miners and validators, or smart contracts, perform as expected and as intended? How do they protect against the misappropriation of the treasury or the misallocation of funds into underperforming initiatives?

In plain language, how are 'agency problems' [19] resolved?

The challenge facing DAOs is this: DAOs are a hybrid of several organisational forms (markets, organisations, commons, and nation states), yet they deploy political governance as their governance mechanism. It is the case that political governance does promote consensus and inclusion. Yet it does so at the cost of decisive decision-making. By contrast, corporate governance mechanisms impose discipline on hierarchies but do not necessarily promote consensus and inclusion. Corporate governance usually involves aligning the interests of insiders (management) with outsiders (providers of capital – usually shareholders). By analogy, governance problems arise when contracts do not execute as expected. Generally, there are three reasons why a contract may not execute as expected (beyond the immediately obvious explanation of there being a bug in the contract). Opportunism (self-interest seeking with guile) is the first reason, maladaptation occurs when the contract's terms and conditions do not adequately reflect the original agreement as business and economic conditions change, and finally, hold-up can occur when contracts are being renegotiated.

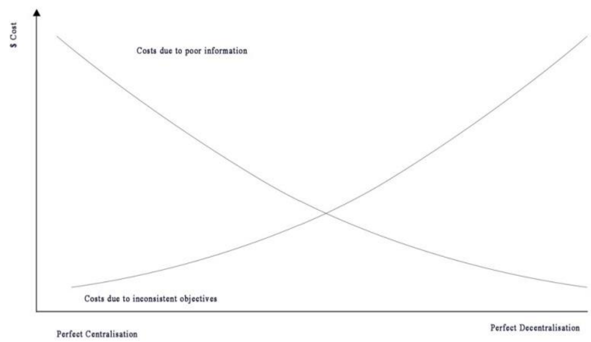
Jensen [20] has argued that four corporate governance control forces exist to align the interests of insiders (managers) and outsiders (capital providers). These are capital markets, legal, political, and regulatory systems, product and factor markets, and internal control systems. Within DAOs, the analogous mechanisms include capital markets and internal control systems. The token allocation and valuation process operates similarly to capital markets. To be clear, however, there is no hostile takeover market for DAOs. Nonetheless, outsiders are able to exert some control over DAOs through the prices they are prepared to pay for tokens. That leaves the notion of 'internal control systems' to govern DAOs.

The challenge that DAOs face in their governance then is answering the question as to how decisions are made, why they are made, and how they are enforced. It is all very well suggesting that smart contracts enforce 'good governance', but who writes those smart contracts? Who commissions the writing of those smart contracts? At present, DAOs make extensive use of political governance to engage in decision-making. In particular, there appears to be an assumption that 'direct democracy' is a viable mechanism to govern organisations.

The problems of direct democracy are well-known in the literature [21]. Voters may be rationally ignorant, excessively ideological, or disinterested. The voter paradox means that there are few incentives for voters to seek out or acquire information that could result in better decision-making. Davidson and Potts [3] argue that corporate governance mechanisms are a far superior tool to deploy in the governance of DAOs than is political governance. Their argument is that political governance creates legitimacy for coercion, whereas corporate governance is about solving agency problems via voluntary cooperation.

Jensen and Meckling [22] make the argument that economies have the problem of dispersed information (or knowledge) and the problem of decentralised decision-making rights. Jensen and Meckling then set out the optimal level of decentralisation within the organisation as the trade-off between 'costs due to poor information' which decline as the organisation becomes more decentralised and 'costs due to inconsistent objectives' (or agency costs – 'the sum of the costs of designing, implementing, and maintaining appropriate incentive and control systems and the residual loss resulting from the difficulty of solving these problems completely') [22], which rise as the level of decentralisation increases. See Figure 1.

Figure 1: The Optimal Level of Decentralisation. Jensen and Meckling 1992 [22]



Within DAOs, the argument would be something as follows: Those individuals with the best knowledge to undertake specific tasks within a DAO can bid for the work. The wisdom of crowds (in this case the token holders) allocates tasks. In theory, this results in two effects: Costs due to poor information should fall very rapidly, resulting in faster decentralisation than otherwise would be the case. The second argument is that agency costs within DAOs are suppressed because token holders are making the decisions and not delegating to management.

There is an important distinction between how DAOs define decentralisation and how Jensen and Meckling define decentralisation. Jensen and Meckling discuss the colocation of decision-making power and knowledge. Within DAOs, the notion of decentralisation implies a lack of hierarchy and direct democratic decision-making by the community. There is no notion of collocating decision-making with local knowledge.

4. Conclusion

This article summarises some of the recent works I have undertaken on DAOs and their governance. It begins by accepting Davidson et al.'s [14] definition of DAOs as being complex hybrid organisations. The very first challenge that arises, however, is that DAOs rely on a very simple governance mechanism – direct democracy. As a system of governance, direct democracy does promote consensus and inclusion. It can also result in majoritarianism and plutocracy. Direct democracy, however, is not well disposed to decisive or effective decision-making.

Other insight that has become apparent from this research is that in order for DAOs to survive as a unique organisational form, they have to suppress agency costs as defined by Jensen and Meckling. In order to do so, they must reduce costs associated with poor information and reduce the costs associated with inconsistent objectives. These latter costs are probably reduced by the strong community values that DAOs generate. It is not clear how DAOs resolve poor information problems (or what Hayek would define as being a knowledge problem). Hierarchies solve this problem through colocation (see also [23]). How DAOs solve this problem – without resorting to hierarchical solutions is a matter of on-going research.

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SUMMIT PROCEEDINGS

Proceedings of 4th Annual Member Summit of Blockchain Associations Forum (BAF) 18 September 2024

Blockchain as a Force for Good: Sensible Policymaking to build Trusted Economies of Scale was the topic of Blockchain Associations Forum's Annual Member Summit 2024. Speakers from around the world including policymakers, industry leaders, regulatory specialists, and the heads of the national blockchain associations participated in the summit.

Professor Dr Naseem Naqvi MBE
President of The British Blockchain Association and BAF Summit Chair

Hello everyone, it is a great honour to chair the BAF summit again this year. The theme of this year's summit is Blockchain as a Force for Good: Devising Sensible Policies to Build Trusted Economies of Scale. Blockchain Associations Forum is a global forum of 51 member countries, hosted by the UK, established in 2021 with the aim of bringing these associations together to learn from each other, discuss challenges, and serve as a good platform for collaboration. We meet regularly, not just at the annual summit, but also through our BBA forums and webinars. We hosted a forum earlier this year on National Blockchain Roadmaps, where representatives from countries that have published their roadmaps discussed the challenges surrounding national adoption of blockchain.

There has been a monumental shift in the global economy, driven by decentralization and tokenization. I would like to thank all of the UK policymakers who have been at the forefront of building the blockchain infrastructure in the UK over the past years. Last year, we heard from Natalie Elphicke, former MP and chair of the Parliamentary Group on Blockchain. This morning, we also heard from members of BAF and UK policymakers. Let's now reflect on where the UK stands in terms of blockchain—what have we achieved so far?

We have done some things really well, although there is still work in progress. What have we accomplished? First, we have a dedicated national level blockchain association, the British Blockchain Association, and not every country has a national blockchain association. If your country does, you should be proud of it because you are doing a great job of bringing together industry and policymakers. Our association was established in 2017, making us one of the oldest blockchain associations in the world. The UK is also home to the first and only Centre for Evidence-Based Blockchain in the world. We have world-class universities, scientific conferences, the world's first peer-reviewed blockchain research journal—The JBBA—and a dedicated parliamentary group on blockchain where we meet with industry stakeholders to discuss challenges and solutions.

We have a very good regulator in the Financial Conduct Authority (FCA), which manages sandboxes, crypto-asset sandboxes, and stakeholder consultations that are evidence-based and operate transparently. Additionally, the UK is one of the only nine countries globally with a National Blockchain Roadmap. Our tech sector is vibrant, home to many leading fintech firms. The UK is the second-largest hub after the U.S. for foreign exchange trade, handling $3.6 trillion of foreign exchange trades per day, more than Singapore, Tokyo, Hong Kong, and New York combined. Our tech industry is worth over £1 trillion, and we have 43 unicorns—more than any other European country. We also have an active HM Treasury Department. The Law Commission of England has taken an evidence-based approach to recommending crypto-related policies and regulations. The Financial Services and Markets Bill, which became law, added the definition of crypto assets to financial services regulation. The UK is the world's third-largest digital asset economy and the largest in Europe by raw transaction volume, with an estimated $250 billion received in 2022 alone.

Now, let's address the UK government's ambitions to become the next global hub for crypto assets, science, and tech, aspiring to be the next Silicon Valley. This has been a one-step-forward, two-step-back situation, largely due to frequent changes in government and other factors. However, we are now the third-largest crypto economy by transaction volume, with 10% of the UK population—around 6-7 million people—holding some type of cryptocurrency or digital asset. But there are challenges, such as the fact that only about 40 odd firms have successfully registered with the FCA compared to Switzerland's 1,100, UAE's 500, and Singapore's 18.

Access to banking is a major issue. Many SMEs, including digital asset businesses, have faced account shutdowns. Although the government's tone is positive and its vision bold, this isn't always mirrored in the approach of UK regulators. The King's Speech, which outlined the government's plan for the next five years, did not specifically mention blockchain or crypto, though it touched on important topics like digital identity and smart data, which relate to blockchain. It's a cautiously optimistic approach overall.

In the coming 12 months, what steps must the UK take to fully benefit from blockchain and crypto assets? Access to banking for blockchain and crypto firms is crucial. We must support skills and jobs, as demonstrated by the UK's rise to second place globally in the number of blockchain-related jobs, according to the Coincub report. Last year, we ranked 12th.

This space is moving extremely fast. Every day brings new developments, and we need to be dynamic and agile, proactively engaging with stakeholders at the forefront of innovation. The policies and regulations we devise must be business-friendly, consumer-cantered, and evidence-based.

As I often say, the best time to prepare for the Web3 paradigm shift was yesterday; the second-best time is now. We must give the industry clarity, support, and guidance. The BBA is actively working with stakeholders, and our recent policy roundtable in Parliament attracted over 100 industry representatives. Learning from international best practices is key, and this forum is an excellent opportunity for that.

To conclude, it is my hope that the new government will move swiftly and, in an evidence,-based manner to create laws and policies that position the UK as a leader in this space, truly becoming a global hub for blockchain technology.

Lord McNicol of West Kilbride
Member of the UK Parliament, the House of Lords

Thank you very much for the invitation. It's great to be here again and to be invited to this summit in the metaverse. I also want to thank you for your help in getting me prepared for this event. I'm glad to have the chance to talk to you all about how we, as a community, can support these emerging technologies and how we can help make the UK a leader in blockchain, fintech, and other emerging technologies as we move forward. I will also discuss how we can work with the government to make this happen.

Before joining the House of Lords, I was General Secretary of the Labour Party from 2011 to 2018. The General Secretary role is equivalent to a Chief Executive Officer (CEO). I was in charge of finances, staffing, campaigning, fundraising, and political management. Policy matters, however, were the domain of the leader and the shadow cabinet.

Now, Sir Keir Starmer, Rachel Reeves, and the team are running the government and have an opportunity to rebuild and reshape our country. You, within the metaverse, in this forum and summit, also have an opportunity to help shape that vision. This is especially important because of the lack of knowledge around digital assets, blockchain, fintech, AI, and CBDCs. These emerging technologies have the potential to shape the future of Britain, but they are not yet understood in the way they need to be. Hopefully, my speech today will encourage some of you, particularly those in the UK, to reach out to your politicians and help educate them. There is fear of the unknown, fear of things that cannot be controlled, and fear of new technologies. You can see this reflected in the media's language around AI and large language models.

Now, let me take a step back, and we can work through it. The financial sector, where blockchain partially resides, is a sector I know best. It's huge, contributing about 12% of our economic output, over £100 billion to the treasury each year, and supporting over a million jobs across the country. Labour's job, and its priority in government, as set out by Keir, is to achieve the highest sustained growth in the G7. To achieve that, we need a financial services sector that works and grows because when it grows, the country grows with it. The Labour government must provide a stable, consistent environment that allows the industry to do what it does best.

Blockchain and fintech are already incredibly important sectors, and they're only going to grow. In my conversations, I've learned that Labour is not only impressed by fintech's capacity to revolutionize finance but also by its potential to promote social change and improve the everyday lives of people across the UK. Fintech is leading the way in green finance, health technology, and financial inclusion. In green finance, for example, fintech is creating lending markets for SMEs to access funding they need to reach their net-zero targets. This is critical because SMEs contribute a third of the UK's carbon emissions and often face significant challenges in adopting greener practices. Companies like Funding Options in the green finance market are helping address this. Another example is EarthChain, which uses blockchain to show consumers their real-time carbon footprint based on their spending data. This technology has the potential to reform supply chain reporting and trace ecological footprints back to the source, making a significant impact on environmental sustainability.

I've also been involved in fintech and new technologies myself, not just as a politician but as a non-executive and advisor. One company I work with is an AML/KYC business called Astra Enterprise, and the other is an ethical lending business called Salad Money. Salad Money uses AI and machine learning, built on open banking, to make lending decisions in the unsecured near-prime and subprime markets. This ethical approach helps those with thin credit files or County Court Judgments (CCJs) rebuild their credit scores, preventing them from falling into the hands of loan sharks or high-cost credit providers.

Labour is committed to ensuring the UK does not fall behind in fast-moving, borderless industries. The 2021 Kalifa Review showed that the UK has the potential to be a world leader in fintech. It's now the job of the new Labour government to make sure the UK capitalizes on that potential.

As for AI, it's a highly complex area that requires a formal strategy, legislation, and regulatory frameworks. AI must be used to innovate the way we work, live, and deliver public services. Data and AI will play a crucial role in saving our NHS, and it's up to us to shape that future. We need to expand the successes of open banking to include open finance, covering areas like mortgages, pensions, insurance, and investments, helping households and supporting their savings.

Another key area is the development of a digital pound (CBDC). The Bank of England is already exploring this, but it will need parliamentary oversight. The UK cannot be left behind as other countries advance in this area, but there's still uncertainty about who will deliver it and how it will be implemented.

Lastly, regulation is important. It protects businesses, consumers, and the industry, especially when data is involved. However, regulation must be proportionate, so it doesn't stifle innovation in the fintech and blockchain sectors. A Blockchain All-Party Parliamentary Group (APPG) is being developed in the new Parliament, and I encourage you to contact your MPs about the opportunities these technologies present.

Joshua Ashley Klayman
Head of Blockchain and Digital Assets, Linklaters
Advisory Board Member, The BBA

Thank you for having me. I think the best way to think about the approach in the US, just from a macro level with respect to blockchain and digital assets, is somewhat similar to how the US has begun looking at tech in general, and other forms of tech, including AI and other cutting-edge technologies. This is primarily through a national security lens. If you do that, it begins to explain some of the somewhat puzzling steps that we've seen taken at times. So, why do I say this? If you think of things through a national security lens, then you see tech as potentially both a race to the moon and an arms race, and for certain technologies, a talent war.

Now, within the digital assets space, unfortunately, many in the US administration, as well as many regulators and some legislators, do not yet see digital assets as a talent war in the US. I think that will come, as we have increasingly seen institutional adoption and continued growth within the industry to become a multi-trillion-dollar industry. But I think what is currently focused on a lot is the arms race. And why do I say that? Well, if you look at a lot of what is being done and much of the federal and state legislation through that lens, you can see that much of it is focused on things like anti-money laundering, the prevention of terrorist financing, and similar concerns. You might ask, "Why was this decision made?" and then realize, "Ah, they're concerned about whether value could go into the hands of hostile actors or if this technology could be used for such purposes."

Now, as we've seen from data from Chainalysis and other analytics providers, that narrative doesn't really hold up in terms of the actual number or volume of transactions. However, some large incidents, like those involving Tornado Cash, capture the attention of governments, including the US, especially when hostile state actors are involved. This causes US regulators and legislators to use tools from their arsenal that may have been used for other purposes. I mention Tornado Cash because, as you may know, there was significant litigation about the sanctions applied to Tornado Cash, with many arguing, "This is not a person; Tornado Cash is not property; these are smart contracts." The Treasury, however, was successful in its bid to sanction Tornado Cash. Shortly afterward, FinCEN, the Financial Crimes Enforcement Network, used a seldom-used power under the USA PATRIOT Act, from shortly after September 11th, to designate all virtual currency mixers as being of heightened money-laundering concern—an entire type of smart contract, an entire type of program.

I think we will see more of this. On the other hand, many are unaware of some Commerce Department proposed rules that would apply KYC/AML obligations to infrastructure-as-a-service providers. Why does this matter? Well, many arguments in the US concerning things like KYC/AML focus on whether there is money transmission or BSA (Bank Secrecy Act) obligations at either the federal or state level. If infrastructure-as-a-service is required to comply with KYC/AML, many projects that currently claim they are "just infrastructure" and not engaged in money transmission will need to adapt. I think this is something to watch, as many projects are not sufficiently focused on KYC/AML, partly because regulators like the SEC and CFTC dominate the news with their enforcement actions.

As we often tell clients, if you don't comply with securities laws, absent fraud, you're probably not going to jail in many instances. However, failure to comply with KYC/AML requirements could very well result in jail time. This is something that, from a US perspective, we need to reframe so that projects focus on it. This comes up in various spaces, including DeFi and other business types.

Moving to the US regulatory structure: as you know, we have overlapping regulators. We don't have a single regulator focused on digital assets. Instead, it seems nearly all regulators potentially have jurisdiction over digital assets at both the federal level and across the 50 states and DC. For example, you may have to register with FinCEN, but if you are operating in New York, you also need to worry about the BitLicense. State laws aren't necessarily consistent, either. And then, there's the ongoing debate about how to classify digital asset transactions—is this token a commodity, or is it a security? People often frame it as an "either-or," but the reality is, it can be both. Without taking a regulator's view, the CFTC considers nearly every digital asset a commodity, but it also believes some of those commodities can be subject to US securities laws. It's not either-or; it's a different test. Even NFTs, which some say can't be commodities because they are one-of-a-kind, could be commodities according to the CFTC's view, as even art is considered a commodity.

Many of these jurisdictional questions are being fought out in the courts right now. There are large cases against trading platforms and other market participants, mostly led by the SEC staff, though not entirely. You've likely seen differing court decisions already. But these are at the district court level, meaning district court judges don't have to follow the reasoning of other district court judges, even within the same district. So, we are slowly determining what the law is. At the same time, we have an upcoming election. The candidates have different positions on digital assets. We're yet to know what Kamala Harris's position will be, especially compared to President Biden's. Of course, President Biden has given us Gary Gensler as the SEC chair and vetoed the proposed repeal of the accounting guidance SAB 121. There could be differences if Harris wins, but we don't know yet. On the other hand, former President Trump has vowed to make the US the crypto capital of the planet, as he said when speaking in Nashville at the Bitcoin Conference.

This election will be one to watch, not just for many other issues, but also for digital assets. Although I've painted a rather bleak picture, there has been federal legislation moving forward. Some believe, including sitting senators, that we may still see market structure regulation at the federal level for digital assets during a lame-duck session—after Congress ends but before new members are seated. This could include things like the FIT21 Act or developments based on it. I hope this has provided a good overview of the Blockchain policy and regulatory overview.

Dino Cataldo DELLACCIO
Chief Information Officer (United Nations Joint Staff Pension Fund)

Thank you, Prof. Naqvi and the British Blockchain Association, for inviting me to address this distinguished community. My name is Dino Cataldo DELLACCIO, and I am the Chief Information Officer of the United Nations Joint Staff Pension Fund (UNJSPF), based in New York, where I've served for 25 years in various IT leadership roles (Cybersecurity Officer and Chief IT Auditor). I also co-lead the UN Digital Transformation Community of Practice, and the Working Group on Blockchain Assurance and Standardization within the United Nations – Internet Governance Forum.

I'm pleased to share that in 2021, UNJSPF deployed a blockchain-based digital identity solution for "Proof-of-Existence", incorporating biometrics and geo-localization. We recently enhanced it with Artificial Intelligence to detect/prevent deepfakes and added a kiosk mode to address "digital divide" concerns. Furthermore, the UNJSPF solution evolved into a broader Digital Identity initiative for all UN staff.

Our solution has received notable recognition, including the Award of the UN Secretary-General on Innovation and Sustainability; and - Award of the Government Blockchain Association for Social Impact. The solution was also featured as a Gartner case study.
My focus is developing assurance criteria for blockchain and related technologies, which I summarize as "Emerging Technologies = Emerging Standards." As a former Chief IT Auditor, I've been concerned with providing assurance to our governing body on the trustworthiness and security of blockchain solutions. To address this, I established a working group within the UN Internet Governance Forum, to develop consensus around assessment criteria and best practices for blockchain-based solutions.

There's strong alignment between our goals and the British Blockchain Association's mission to promote evidence-based adoption of blockchain and DLT across sectors. I appreciate your efforts in this area.

In closing, blockchain technology offers immense potential, but we must ensure its responsible and secure implementation. By working together to establish standards and best practices, we can unlock the full benefits of blockchain while maintaining trust and accountability. Thank you for your attention, and I look forward to our continued collaboration in advancing blockchain adoption.

Mr Peter Kerstens
Advisor, European Commission

16 years after the publication of Satoshi Nakamoto's White Paper, less than 6 years after the first major Bitcoin bull run, and 5 years after Libra's audacious plans to create a global stablecoin and a series of ups and downs since, the European Union is well-advanced in setting up the world's first comprehensive regulatory framework governing (financial-like) blockchain activities, by a major jurisdiction.

We have the Markets in Crypto Assets Regulation (Micar) but also our Transfer of Funds Regulation on transparency on senders and receivers of funds that has been extended to crypto transfers, our DLT-pilot regime Regulation for DLT-based financial market infrastructures, we have extended our Anti-Money Laundering rules to cover crypto transactions and have also clarified the applicability of taxation rules to crypto trades.

While you may think that this is a lot of regulation for a budding industry – which it is – it is also a major vote of confidence of the EU authorities in the future and promise of blockchain technology. Rather than dismissing blockchains and crypto assets as a fad, the EU authorities believe that blockchain technology holds major transformational and competitive potential for the EU economy and that is why we chose to onshore crypto activity on our market, rather than push it offshore or deny its relevance.

We do in a way regret that still so much crypto and blockchain activity is finance related and often amounts to little more than trading crypto assets for speculative purposes. The regulation tries to shed sunlight on this and ensure that consumers and investors can engage with confidence on crypto markets if they so wish. But it would be so much more interesting and powerful if builders were to focus less on crypto asset trading and more on industrial and real world and main street applications of blockchains. Failing that we will never see the real potential of blockchain technology and my invitation and call on you is to direct energy and effort onto unlocking that potential. Finance – be it traditional or blockchain based – serves little purpose for itself. Finance, like blockchain and other technologies must be at the service of wider economic and societal objectives. And I hope that these can be pursued without regulatory intervention.

Mr Tasos Oureilidis
Xenios Blockchain Group and Hellenic Blockchain Association, Greece

Greece has steadily moved forward towards accepting blockchain and its benefits, both in the public & private sector. XBG assisted HCMC as trusted advisor for blockchain to effectively comprehend and enforce the DLT regime regulatory framework in Greece. Hellenic Blockchain Association & Xenios Blockchain Group will soon launch a blockchain programme on a MSc with one of the biggest Greek universities as well as coordinated the issuance of the first tokenized Greek bond under the eWpG legal framework.

Furthermore, we see an increasing interest from the defence & shipping sector in applying blockchain and integrating its benefits within their operations. Blockchain's dual utility, both as ESG enhancer & cryptographic catalyst, offers a win-win proposal to every party.

Xenios Blockchain Group remains the leading blockchain powerhouse in South Eastern Europe, and we do hope to see more companies being established with the sole purpose of preaching and delivering this futuristic technology to the public, today!

Mr Antonio Guimaraes
Central Bank of Brazil

Brazil Speech Summary: Hello and thank you for the opportunity to speak with you today about a topic that is increasingly relevant, not just globally but also in my country, Brazil—namely, the regulation of the crypto assets market. My name is Antonio Guimarães. I am a consultant in the Financial System Regulation Department at the Central Bank of Brazil, where I coordinate the regulatory framework for crypto assets based on Brazil's Law No. 14,478, enacted in 2022.

Before we dive into today's discussion, I would like to extend my gratitude to the British Blockchain Association for organizing this event and for inviting me to share insights on this important subject.

Well, first things first—a relevant question before we start is: Why regulate the crypto asset market? The global movement towards regulating the crypto asset market, including in Brazil, is driven by the rapid growth and adoption of these assets. According to recent data, Brazil ranks among the top countries in crypto asset adoption, with millions of users engaging in trading and investment activities. This popularity brings benefits such as increased financial innovation; however, it also introduces significant risks, particularly those related to financial stability, consumer protection, and the potential misuse of these assets for malicious activities, such as money laundering and fraud.

International incidents, such as the collapse of major crypto exchanges like FTX, have highlighted vulnerabilities within the sector. These events demonstrate that while the underlying blockchain technology remains robust, issues often arise from poor governance, lack of transparency, and inadequate internal controls. As a result, there is a pressing need for a regulatory framework that addresses these risks while allowing innovation to thrive.

When we talk about the regulation of crypto assets, we are not only referring to cryptocurrencies like Bitcoin or Ethereum but also to the broader concept of asset tokenization. Tokenization involves using technology to represent real-world assets digitally; this could be anything from financial securities to real estate. The intersection between crypto assets and asset tokenization presents both opportunities and risks. On one hand, tokenization can enhance liquidity, improve transaction efficiency, and provide more transparency. On the other hand, it introduces risks such as liquidity mismatches, where the liquidity of the underlying asset may not match that of its tokenized version. There is also the risk of market manipulation, cybersecurity threats, and operational vulnerabilities stemming from reliance on third-party service providers. The similarities in the technological foundations of crypto assets and tokenized assets imply that risks in one domain could easily spill over into the other. Hence, a coherent regulatory approach is necessary to ensure that these innovations do not compromise financial stability.

What about the Central Bank of Brazil's approach? At the Central Bank of Brazil, our approach to regulating the crypto assets market is grounded in caution and collaboration. The enactment of Law No. 14,478 in December 2022 laid the foundation for this regulatory framework. We have already initiated a public consultation process, posing 308 questions to gather feedback from market participants, industry experts, and the public. This engagement is critical to ensuring that the regulatory framework we develop is robust, comprehensive, and reflective of the needs and concerns of all stakeholders. We plan to conduct a second public consultation in October 2024, focusing on draft regulations. This iterative and consultative process will help us refine our regulatory approach, ensuring that it is both effective and practical.

Our regulatory strategy emphasizes technological neutrality, meaning we aim to regulate the uses and activities associated with the technology rather than the technology itself. By doing so, we can adapt to future innovations without stifling technological advancement. Our primary focus will be on ensuring transparency, accountability, and risk management, particularly concerning custodial services, anti-money laundering protocols, and the solvency of service providers.

The regulation of the crypto assets market is essential for several reasons. Firstly, it helps protect investors by setting standards for market conduct and ensuring that entities operating in this space have adequate risk management and transparency practices. Secondly, it safeguards the integrity of our financial system. By regulating crypto assets, we can prevent their misuse for illegal activities and ensure they do not pose a threat to financial stability. Thirdly, a well-regulated crypto assets market enhances trust and confidence, encouraging more institutional participation and fostering innovation in a secure environment.

In conclusion, while the potential benefits of blockchain, crypto assets, and tokenization are immense, they must be accompanied by appropriate regulatory oversight to manage the associated risks. At the Central Bank of Brazil, we are committed to building a regulatory framework that not only addresses these challenges but also supports sustainable growth and innovation in the financial sector. By doing so, we can ensure that Brazil remains at the forefront of financial evolution, providing a secure and inclusive financial system for all.

Thank you for your attention, and I look forward to further discussions on this important topic.

Juan Jimenez Zaballos
ALASTRIA Blockchain Ecosystem, Spain

Spain Speech Summary: Thank you for having me and for hosting us at the Alastria Blockchain ecosystem, as you mentioned in this amazing environment. I'm trying to figure out how to navigate things here in this metaverse, but yeah, hopefully, you can see me. My avatar is wearing a cap. I'm not that much into caps, which is why I do these things in avatar form. I'm more involved in the corporate world, but I provided a bit of an explanation of what's happening in the Spanish ecosystem and how we at Alastria view things. I'm sure our European colleagues, particularly someone from Greece, one of the 27 member states of the EU, are also enjoying this exciting moment for digital assets. Fortunately, this phenomenon has regulatory backing. Why? Due to two important pieces of regulation available in the European Union since 2023 and now 2024.

I'm specifically referring to the DLT pilot regime, which launched in 2023. This pilot is not definitive but allows European companies to apply for certain exemptions regarding licensing for tokenizing financial instruments. It's crucial for the banking and financial services industries, as it introduces a new class of instruments similar to traditional ones but utilizing DLT for issuance and commercialization. This is where primary and secondary markets coexist, offering more liquidity and enhancing the transferability of assets. Since March 2023, many Alastria members have submitted their ideas to sandboxes such as those of the European Central Bank and the Bank of Spain, moving from sandbox to pilot regime, with some already operating under it. While the volume is still low, this is under review, and there is now an incentive for issuers and dealers to participate in this new ecosystem. The good news is that we have regulatory clarity and certainty in this part of the financial services market.

The second important regulation is MiCA. MiCA has been in place since June 24 for stablecoins, and by December 30 of this year, it will cover new licenses for virtual asset service providers (VASPs), who can then become crypto-asset service providers (CASPs). This will enable them to serve B2C clients in distributing crypto assets, including stablecoins and other assets. Unfortunately, the evolution of the regulation is still ongoing, especially concerning real-world assets. We've seen many ideas related to real estate and tokenization of real-world assets, but they are not yet fully covered in Spanish regulation, as Spain lacks the registrar role that exists in jurisdictions like France and Germany. Once this registrar role is implemented, we expect more ideas to flourish in real estate tokenization. Real estate is a significant part of Spain's economy, and we're all hoping for clearer regulation to support the growth of business concepts and use cases in this space.

Additionally, it's important to advocate for the use of public networks, especially in the regulated sectors like financial services and telecommunications. We need to ensure that regulators, such as BIS and the European Central Bank, do not penalize the use of public networks, as this would stifle innovation. If public networks are supported, we can leverage their full potential, promoting competitiveness, which, as you know, is crucial. Mario Draghi's report emphasizes the need for competitiveness in Europe. Without innovation and scalability, it will be difficult to compete with other jurisdictions.

Lastly, in Spain and at Alastria specifically, we have seen more collaboration between the public sector and the government. There's a funding plan in

Europe called the Next Generation EU Fund, and the good news is that Alastria has received a significant grant from the Spanish government, which is part of the Next Generation EU Fund. This grant will help us build a public permissioned network for the entire ecosystem to deploy use cases. This is exciting, especially for regulated industries that require privacy and compliance. The public permissioned network, a collaboration between the public and private sectors, is expected to be fully operational in about a year. It will have real service-level agreements and the capability to sign contracts with users. This is a huge step forward, and Alastria will be a key driver in implementing it. We're happy to share this progress with you all and to be at your service. When you think of a use case that can benefit the economy, think of Alastria, as this will be a federated European network connected to similar initiatives in other European countries. It's an exciting time for DLT, and the future looks promising. Thank you so much!

The British Blockchain Association

Advocating Evidence Based Blockchain

Policy Advocacy Domains
&
Working Groups

2024 - 2025

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BBA Policy Advocacy Domains (2024 - 2025)

(In line with the Recommendations of the UK NBR 2030 and APPG Work-streams)

Blockchain: Skills, Talent, Jobs and Workforce Planning

Decentralised Finance (DeFi) and the Crypto-assets

The Token Economy: Tokenizing Real-World Assets (RWA)

Blockchain for Enterprise, Business, Trade and Supply Chains

Decentralised Autonomous Organisations & Web3 Governance Models

Blockchain Standards, Frameworks & National DLT Roadmaps

Blockchain and Allied disciplines: AI, Quantum Computing, IoT

Education, Research, Development, Think-Tanks & Knowledge Networks

Diversity, Inclusion, Sustainability and Social Good

Smart Contracts, NFTs, IP, Copyrights and Law

Blockchain for Government & UK Public Services

Metaverse and Blockchain-based Extended Reality Applications

Evaluation and Audit of Blockchain Ecosystems

Blockchain: Skills, Talent, Jobs and Workforce Planning

Web3 Industry Growth and Workforce Planning

Careers in Blockchain and Web3

Coders, Programmers and Developers of Blockchain

New employment Opportunities in Blockchain Industry

Blockchain Sandboxes, Pilots and Incubators

International Cooperation and Coopetition in Web3

Blockchain Skills in-Demand and Web3 Job Market

Start-ups, Funding and VCs

Recruitment and Retention of Web3 Talent

Making UK an attractive destination for Web3 jobs

Decentralised Finance (DeFi) and the Cryptoeconomy

Supporting Crypto and Digital Asset Businesses in the UK

FCA registration and approval of Crypto Firms

Supporting Banking and Financial Services for Crypto Firms

Regulation of DeFi applications and platforms

Governance of DeFi applications and platforms

Auditing Tokenomics

Crypto Staking

Travel Rules for Crypto Firms

Risks, Threats and Opportunities in DeFi for UK Economy

Crypto payments: Businesses, Consumers and Regulators

The Token Economy: Tokenising Real-World Assets (RWA)

Tokenising Financial Instruments and Applications

CBDCs and Tokenisation of Currencies

Stable Coins

Policies and Regulations around RWA Tokenisation

Tokenising Real Estate

Tokenising Commodities

Tokenising Arts, Antiques and Music

Tokenising Carbon Credits and Environmental Assets

Tokenisation and the role of Oracles

Blockchain for Enterprise, Business, Trade and Supply Chains

Blockchain for Business Processes

Enterprise Blockchains: Public V Private

Blockchain Education and Training for C-Suite executives

Blockchain for Global Trade

Blockchain for Supply Chains

Consortium Capabilities for Enterprise Blockchain

Blockchain for Logistics and Transportation

Blockchain for Trade Finance

Blockchain-based Project Management

DAOs (Decentralised Autonomous Organisations) and Web3 Governance Models

DAO's Decentralised Digital Workforce

DAO Labour Economics

Distributed Governance of Web3 Ecosystems

DAO Treasuries

DAO Tokenomics

DAO Regulation

DAO Policymaking

DAOs as Legal Entities and Corporations in the UK

Blockchain Standards, Frameworks & National Roadmaps

Implementation of UK National Blockchain Roadmap 2030

Establishing the UK as a Centre of Excellence in Blockchain

Trans-national Web3 Partnerships

Consensus building among stakeholders and BAF

Blockchain in Global context: UN SDGs

International Blockchain Standards:

Benchmarks, Frameworks and Guidelines

Convergence of Blockchain and Allied disciplines: AI, Quantum Computing, IoT, AR, VR, et al

Blockchain based AI Applications

AI-based Blockchain Applications

Post Quantum Blockchains

IoT, Smart Cities and Blockchain

Blockchain and Genomics

Singularity and Emerging Technologies

Ethical Challenges in Emerging Technologies

Education, Research, Development, Think-Tanks and Knowledge Networks

Universities and Blockchain Education

Universities and Blockchain Research

University Incubators and Spin-offs

Industry – Academia – Government – Society of Quadruple Helix

Postgraduate Curriculum for Blockchain in the UK

R&D Funding for Blockchain and Crypto research

Teaching the Teachers: Pastoral support for Web3 Educators

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Diversity, Inclusion, Sustainability and Social Good

Diversity, Equity and Inclusion in Web3 Ecosystems

Environmental Impact of Web3 applications

Blockchain, Social Good and Life Sciences applications

The Promise of Web3 for end user and consumers

Blockchain for SMEs

Public awareness of Blockchain and Cryptoassets

Blockchain for Sustainability and UN SDGs

Blockchain and Crypto payments for Humanitarian Aid

Smart Contracts, NFTs, IP, Copyrights and Law

Smart Contracts and "Smarter" Contracts

Intellectual Property Rights and NFTs

Copyright Laws of Blockchain-based Creative Industries

Tokenomics: Litigation and Legislation

Blockchain Analytics, Cyber intelligence and Web3 Platform Surveillance

Blockchain Analytics and Evaluation of Web3 Crime

Privacy and Zero Knowledge Proofs (ZKPs)

Blockchain Arbitration

Blockchain for Government & UK Public Services

Blockchain-enabled Public Services

Nurturing Quadruple Helix Blockchain Ecosystems

Building Blockchain Centres of Excellence (CoE)

Establishing Public-Private Partnerships in Web3

Blockchain for e-Voting

Blockchain based Decentralised Digital ID (DID)

Blockchain based Public and Citizen records

Blockchain to tackle Procurement Fraud

Blockchain Inter-operability among government departments

Metaverse and Blockchain-based Extended Reality Applications

Metaverse for Public Good

Cybersecurity in the Metaverse

Ethical and Legal Challenges of the Metaverse

Digital Twins and e-Government in the Metaverse

Native Metaverse Organisations

Digital Avatars, NFTs and Tokenomics of Metaverse economies

Metaverse for Education

Metaverse for Business

Metaverse for Entertainment and Arts

Evaluation and Audit of Blockchain Ecosystems

Auditing Societal Impact of Web3 applications

Building Sustainable and Energy efficient Blockchain applications

Governing Web3: Transparency, Accountability and Quality Assurance

Evidence Based Blockchain: Evaluation of Blockchain Programmes

Collecting Qualitative evidence for national budgeting processes

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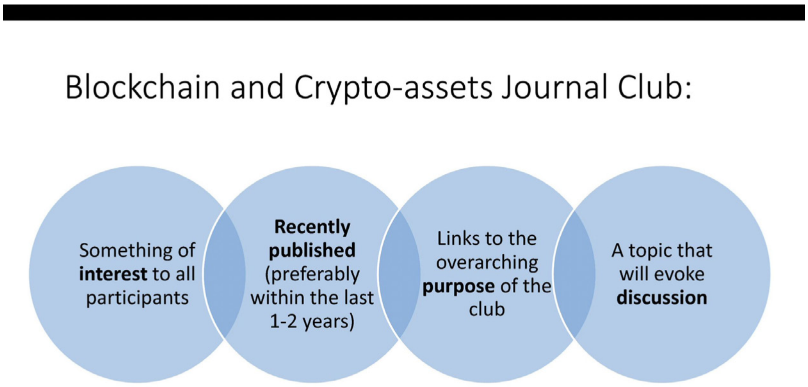

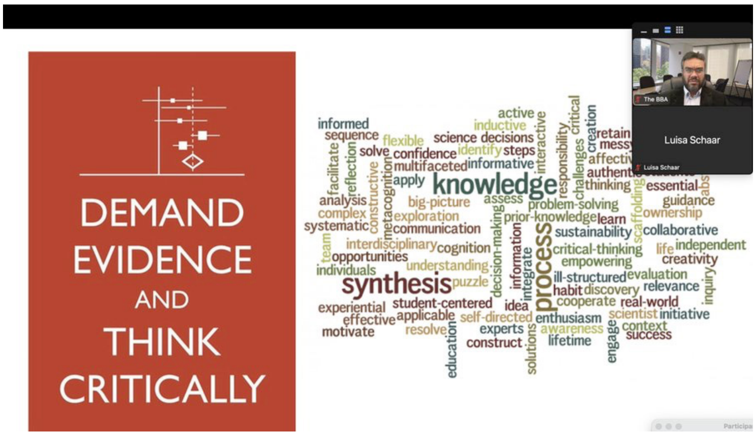

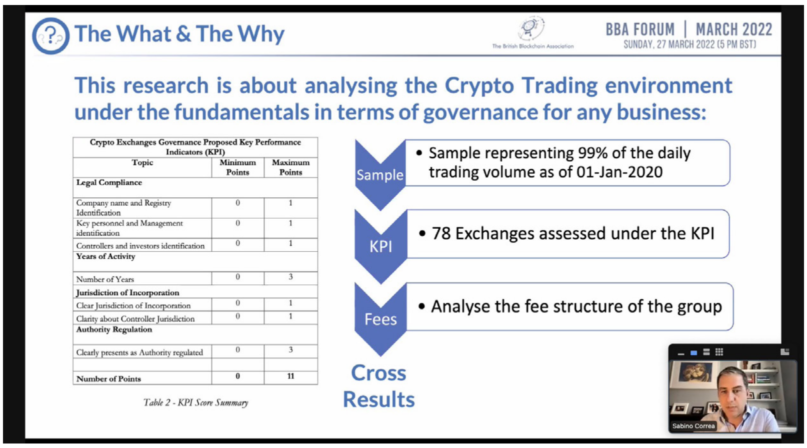

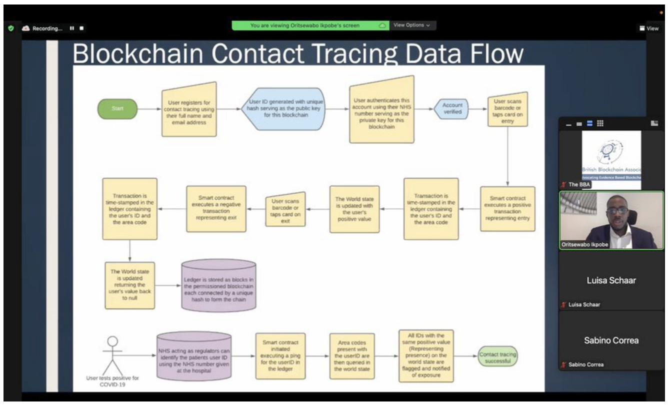

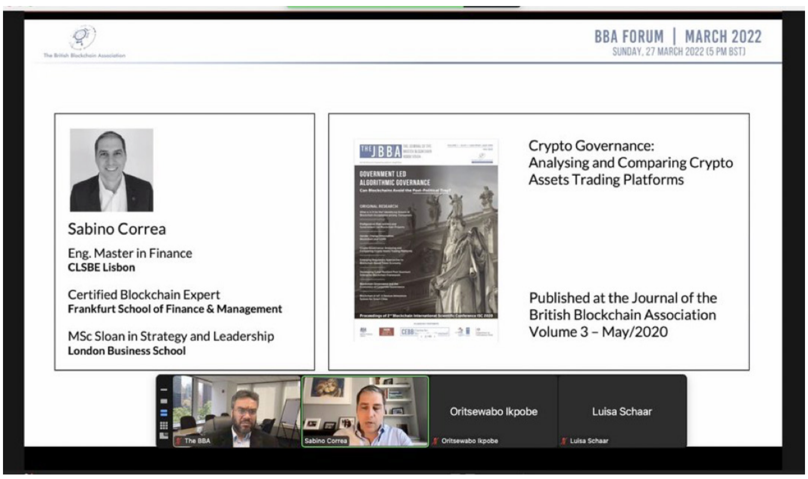

BBA-SF

STUDENT FORUM

UNIVERSITY REPRESENTATIVE

CEBB | Centre for Evidence-Based Blockchain

THE JBBA THE JOURNAL OF THE BRITISH BLOCKCHAIN ASSOCIATION

britishblockchainassociation.org

THE BBA STUDENT FORUM

A BBA student chapter helps reinforce classroom and experiential learning. In addition to the learning that occurs during chapter meetings, the submission of research articles to the JBBA journal helps develop industry-specific skills, along with skills in project management, technical writing and interpersonal communications.

Chapter activities culminate at the annual scholars in Blockchain conference, where students interact with students from other chapters, BBA members and advisors and network with industry leaders, scientists, and researchers.

The BBA recognises that students are the future leaders of the industry, and treats them as such. Chapters instil future professionals with an understanding of the role that collaboration, research, development and networking plays in blockchain developments and industry progress.

REASONS TO START THE BBA STUDENT CHAPTER

Encourage student collaboration

Foster dialogue about trends, issues, movements, opportunities impacting the blockchain industry

Connect to industry professionals and career opportunities

Obtain leadership experience driving BBA student chapter activities

Form student and professional relationships across the BBA including those with students from other chapters

Compete in hacking events

Publish papers in the JBBA

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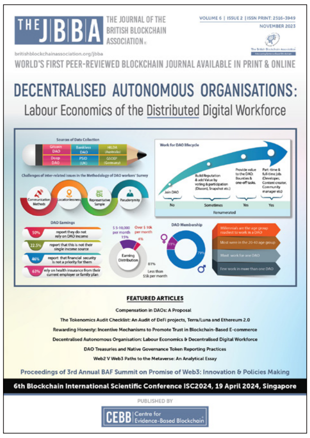

Volume 6 - Issue 2
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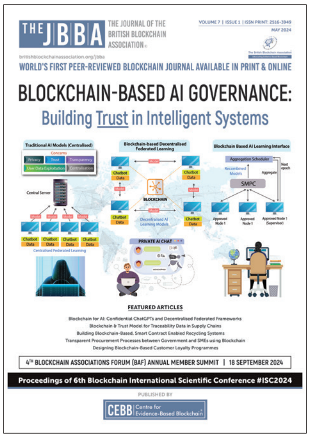

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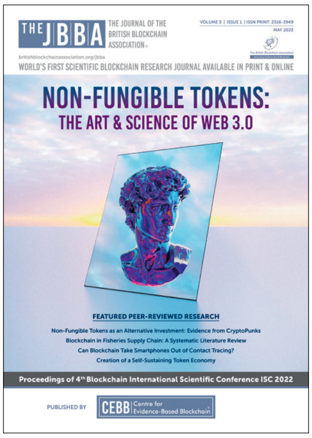

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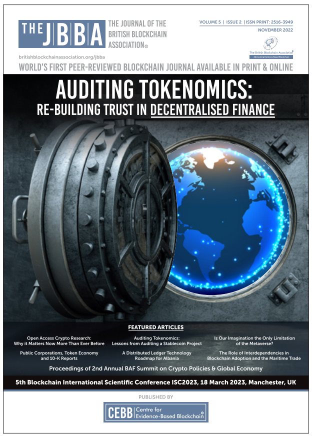

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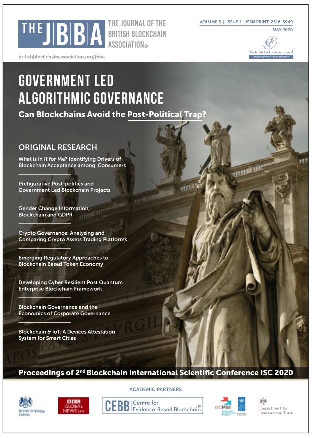

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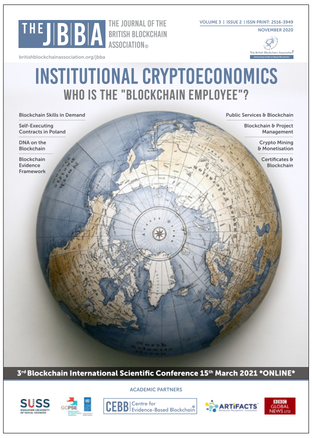

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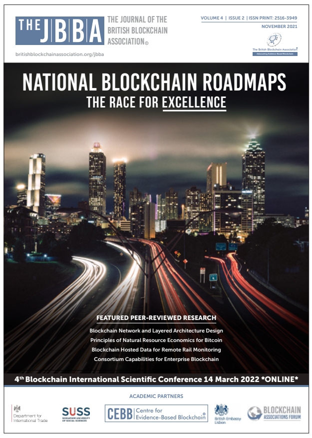

Volume 4 - Issue 2
November 2021

Volume 1 - Issue 1
July 2018

Volume 1 - Issue 2
December 2018

Volume 2 - Issue 1
May 2019

Volume 2 - Issue 2
October 2019

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