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Review Article

Regulatory landscape of blockchain assets: Analyzing the drivers of NFT and cryptocurrency regulation

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ABSTRACT

The study analyzes the global regulatory landscape for blockchain assets, particularly cryptocurrencies and non-fungible tokens, focusing on the motivations behind policymaker actions, the diversity of regulatory approaches, the challenges posed by decentralized technologies and provide future regulatory pathways. The study uses a conceptual and mixed-method approach, combining qualitative and quantitative content analysis of 59 peer-reviewed articles selected through the PRISMA framework. Findings reveal that regulation is primarily driven by concerns over consumer protection, financial stability, anti-money laundering, taxation, and environmental sustainability. Regulatory responses vary widely, ranging from the harmonized MiCA framework in the EU to the fragmented enforcement model in the U.S., along with diverse strategies across Asia. Stablecoins, DeFi, and CBDCs emerge as major regulatory frontiers. The study recommends adopting regulatory sandboxes, promoting international coordination, enforcing environmental standards, and building regulatory capacity in emerging economies to balance innovation with risk mitigation. It also highlights the importance of industry self-regulation and technology-assisted compliance in decentralized finance. The limitation of this study is that it relies solely on secondary data sources, which may limit the accuracy of real-time policy impact assessments. Future research should focus on empirical validation and dynamic policy modeling to enhance global governance of digital assets.

1. Introduction

Over the last decade, blockchain technology has emerged as one of the most revolutionary innovations in the digital age, revolutionizing a variety of industries, including supply chain management, financial services, healthcare, and entertainment. Blockchain (BC) based assets, particularly cryptocurrencies and NFTs are at the forefront of this upheaval [27]. Bitcoin (BCT) and Ethereum (Eth), in particular, are among the top cryptocurrencies that have made it possible for individuals to send and receive money across borders with relative ease, without the need of financial institutions. In turn, ownership in the digital world was disfigured by NFTs, turning them into distinct digital products akin to artwork, songs or virtual products [48]. Yet the surging popularity of these new asset classes is not without its critics. Promoters of BC assets are excited by the prospect of these instruments democratizing finance and empowering investors, while critics are concerns about their deep ties to criminality [4]. The inherent volatility of digital currencies, scams and frauds on the rise in the NFT market, and environmental challenges with BC mining are viable reasons for discussions about regulations. In addition, the decentralized and borderless characteristics of these technologies present distinct issues for conventional regulatory paradigms that are generally rooted in a nation-state milieu directed towards centralized actors [39].

An increase in the issuance of BC assets prompts policymakers and regulators around the globe to address these challenges while still encouraging innovation. Hands of regulators interest in regulating has

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been sparked by the need to protect consumers, uphold financial stability, mitigate threats like money laundering and tax evasion, and ensure fair market practices [54]. It is acknowledged, however, that excessively onerous laws may have the unintended consequence of impeding innovation and pushing BC companies to other, more lenient jurisdictions, a phenomenon known as regulatory arbitrage [1]. Many governments and regulatory bodies around the world have taken different approaches to how cryptocurrencies and NFTs should be regulated, in light of these concerns. Some countries, like China, have taken a very extreme stance in prohibiting the practice of mining and selling cryptocurrency because it is thought to have negative effects on the environment or financial profits [60]. On the other hand, Switzerland, for instance, has a law on the use and trade of cryptocurrency with a proviso. And some, such as the US and the EU, are attempting to create new but more complex regulatory frameworks that balance innovation with rules for the sake of protecting consumers. In this regard, the U.S. Securities and Exchange Commission (SEC) is investigating whether some digital assets are considered securities, while Europe is searching for assets with this kind of growth through its Markets on Cryptocurrency Assets (MiCA) legislation [3].

However, attempting to regulate BC assets has proved difficult. One of the main issues with BC networks is their decentralized structure, which prevents them from functioning from a central authority or control point. Because transactions can occur without a legal authority that can enforce traditional laws, this presents difficulties for the implementation of domestic law. Additionally, as new technologies arise, the BC sector tends to change swiftly and authorities typically lag behind, which distract both consumers and companies [6]. Another major obstacle is that, by nature, cryptocurrencies and NFTs lack borders. Even if national governments are capable of regulating BC assets in their own jurisdictions, they fail to control where individuals and businesses operate, as BC assets are global by nature. Additionally, it may expose companies to regulatory arbitrage, in which they choose areas with less stringent regulation, undermining a degree-taking discipline strategy [10].

The rapid growth of BC assets, particularly cryptocurrencies and NFTs, presents both unprecedented opportunities and complex regulatory challenges. In developing regions, these technologies hold the promise of advancing financial inclusion by offering individuals access to decentralized financial systems, effectively functioning as digital banks [13]. Additionally, BC has empowered artists and content creators to monetize their work in innovative ways, overcoming long-standing barriers such as copyright constraints [13]. Despite these advancements, the unregulated or under-regulated nature of BC assets has raised concerns about consumer protection, illicit financial activity, environmental impact, and systemic financial risk. While some regulatory bodies have adopted proactive approaches, others remain cautious, opting for a “wait and see” strategy. Meanwhile, the industry is increasingly leaning toward self-regulation, with many platforms voluntarily adopting AML and KYC measures to align with traditional legal standards [12].

Hence, given this dynamic and fragmented landscape, there is a critical need to investigate the motivations behind regulatory efforts, evaluate current frameworks, and propose balanced strategies that safeguard public interests without stifling innovation. This study seeks to address these gaps and contribute to the development of more coherent, adaptive, and forward-looking regulatory policies. The primary objective of this study is to understand the regulatory approaches of different countries and discuss some challenges in regulating decentralized technologies and potential pathways for the future regulation of BC assets. Therefore, this study will (1) provide an overview of BC assets and identify the key drivers behind regulatory efforts, including consumer protection, financial stability, AML or KYC compliance, taxation, and environmental concerns; (2) examine the diversity of regulatory frameworks across major jurisdictions such as the European Union, United States, China, Singapore, and others, and assess their effectiveness and implications; (3) conduct a quantitative analysis of the regulatory impact on BC assets; (4) evaluate the core challenges associated with regulating BC assets; (5) explore potential pathways for the future regulation of BC assets; and (6) propose balanced policy recommendations that align regulatory safeguards with the need to support innovation and adaptability in the evolving digital asset ecosystem.

This study will employ a conceptual and mixed-method approach of qualitative and quantitative guided by the PRISMA framework to contribute to the growing body of knowledge on BC governance. It will offer a comprehensive and multidimensional understanding of how and why BC assets are regulated across global jurisdictions. The research will clarify the complex interplay between innovation and regulation by identifying key policy drivers such as consumer protection, financial stability, AML or KYC enforcement, taxation, and environmental sustainability. Additionally, the study will provide insights through quantitative analysis of regulatory impacts, enabling an evidence-based evaluation of policy outcomes. By examining regulatory diversity and associated challenges, the research will advance the discourse on cross-border regulatory coherence and expose gaps in existing frameworks. Furthermore, the study will propose forward-looking and balanced policy recommendations that align regulatory safeguards with innovation needs, thereby offering practical guidance for policymakers, regulators, researchers, and industry stakeholders navigating the evolving digital asset landscape.

The remainder of this article is organized as follows. The second section presents the methodology of the study. The third section discusses the definition and evolution of BC assets. The fourth section outlines the rationale for regulatory oversight. The fifth section analyzes global regulatory approaches to BC assets and their evaluation. The sixth section identifies the challenges in regulating BC assets. The seventh section explores the future of regulatory frameworks for BC assets. The eighth section addresses implementation, applicability, policy formulation, and validation analysis. Finally, the ninth section provides the conclusion and policy recommendations.

2. Methodology

The study adopted a conceptual and mixed-method approach using quantitative and qualitative content analysis of peer-reviewed articles, international reports, and legal frameworks to describe the regulatory landscape for BC based assets. A variety of research papers, publications, and journals that have addressed regulatory landscape and challenges of BC based assets have been assessed for secondary study. The sources will be utilized to support the ideas and analysis that will shed light on the specifics. Though there will be a gap in original data, this strategy makes use of earlier sources, which may be taken into account for future study.

2.1. PRISMA framework

The proposed review investigates the regulatory landscape of BC-based assets using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, ensuring a structured and transparent methodology for the selection process of relevant publications. The primary objective of this review is to evaluate the regulatory approaches, compliance standards, and jurisdictional challenges associated with BC assets across different regions. The PRISMA model was employed for the systematic selection of relevant literature, as illustrated in Fig. 1. A total of 304 articles were initially retrieved through searches in major academic databases including Scopus, Web of Science, Google Scholar, and other sources using specific search terms such as BC assets, NFTs, cryptocurrency, BC regulation, regulatory approach of BC assets, and digital asset compliance.

The Fig. 1 illustrates that 304 articles were identified for preliminary consideration, covering publications from 2015 to 2024. During the screening stage, 109 articles were excluded 21 due to errata and 88 for being outside the scope of the study, resulting in 195 articles for further

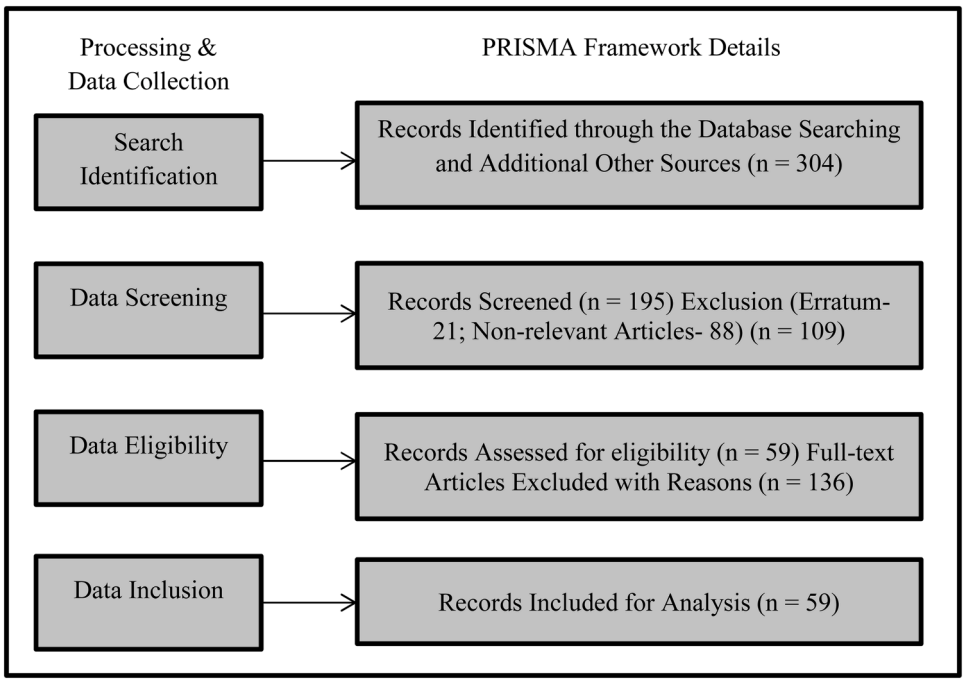

Fig. 1. PRISMA framework for collecting information.

evaluation. A full-text eligibility assessment was then conducted, during which 136 articles were excluded for not meeting the relevance criteria. This process led to the final selection of 59 eligible studies. These studies were chosen from peer-reviewed journals and were selected based on criteria such as emphasis on BC assets including cryptocurrencies and NFTs, clarity in model deployment, feasibility analysis of regulatory challenges, and accuracy and transparency in reporting. The final 59 publications formed the foundation of a detailed analysis that focused on legal frameworks, regulatory standards, and implementation associated with BC asset management, as discussed in the subsequent sections.

3. BC assets: definition and evolution

3.1. Definition of BC technology

The BC is a distributed, decentralized ledger system that enables multiple parties to maintain a common record of information without the need for a central authority. The term "BC" refers to the method of organizing data into cryptographically linked blocks, or chains. The foundation is a series of liquid blocks, each containing a list of transactions; after immutability (after chaining), proof-of-work, security, and transparency are offered [47]. Decentralization is the chief legacy of BC. While legacy databases are maintained and controlled by a centralized authority, BC networks operate on a distributed system where transactions are verified and logged by several computers called nodes. This decentralized architecture removes the need for intermediaries such as banks or clearinghouses driving the transition to trustless systems which allows for engagement between parties without any form of prior trust [62]. BCs provide the underlying technology for a number of digital assets, such as cryptocurrencies and NFTs. While these assets have been growing in prominence and various countries have made changes to such markets, the past few years have seen some major shifts in how they are operated across the world landscapes [23].

3.2. Cryptocurrencies: definition and types

Cryptocurrencies are digital or virtual currencies secured using cryptography. BCT is arguably the most notorious, but other cryptocurrencies including Eth, Ripple (XRP), and Litecoin have all surpassed the seven-figure milestone. Most cryptocurrencies are based on decentralized networks utilizing a technology called the BC, where transactions are confirmed by a network of nodes through mining or staking (Fig. 2, Table 1).

3.3. Non-fungible tokens (NFTs): definition and applications

NFTs represent a distinct category of BC assets. While cryptocurrencies are fungible, meaning that each unit can be swapped out for another of the same size and kind, NFTs are less compatible since each

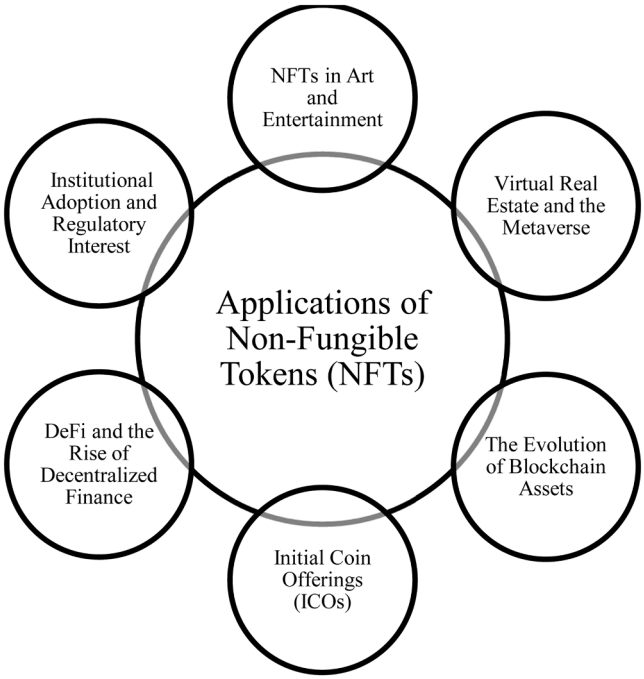

Fig. 2. Applications of non-fungible tokens (NFTs).

Table 1
Types of cryptocurrencies.

Cryptocurrencies	Concepts
Bitcoin	Cryptocurrency website Description BCT from 2008, was the first decentralized cryptocurrency, because of this it is also known as origin cryptocurrency. It was created as a peer to peer digital cash system that would allow online payments to be sent directly from one party to another without going through a financial institution. Mining with its Proof-of-Work (PoW) consensus mechanism in which miners solve complex cryptographic puzzles to validate transactions and add new blocks to the chain is a fundamental component of BCT [53]. Because of this limited supply, capped at 21 million coins (never to be passed) and its decentralized nature, BCT has become known as the "digital gold", or a store of value. B BCT is the standard for digital gold. Institutional Acceptance and Business Treasury BCT eventually gained recognition from firms and institutional investors on the world financial scene [20].
Ethereum	Eth is a BC-based platform that allows people to create and run decentralized applications (dApps). Unlike BCT, which is mainly for sending and receiving money, Eth is like a whole world where you can build programs that run exactly as coded, without any chance of fraud or interference [8]. By facilitating peer-to-peer lending, borrowing, and trading without the need for middlemen, Eth has accelerated the development of decentralized finance (DeFi). Ether (ETH), a native token, manages the Ether power needed for transactions on the Eth network [43].
Ripple (XRP)	It is a cryptocurrency that established to permit international payments that are both more economical and faster. Simply it is designed to make cross-border payments faster and cheaper [9].
Litecoin (LTC)	It is a cryptocurrency that attempts to increase the efficiency and speed of transactions. It is a smaller and more lightweight alternative to BCT. A faster, lighter spin on BCT that targets transaction speed and efficiency [32].
Stablecoins	A type of cryptocurrency that hedges on the like of Tether (USDT) or USD Coin (USDC), which seeks to be pegged either by or in contrast to the value of a sovereign lawsuit currency cosmetics the U.S. dollar, and provides approximately much more shadow help during together with volatility from the issue as a replacement for good currencies [63].

one has a distinct digital signature. Since each NFTs is (typically) unique, each token has intrinsic value linked to its attributes, making it ideal for representing a unique online or tangible product [4].

- **NFTs in art and entertainment:** NFTs have benefited the art industry in particular since they provide artists another method to add value to their work and sell it directly to collectors after becoming a little aspect of our digital lives. Collectibles of NFTs Beeple's 'First 5000 Days' sale brought in $69 million. Nine million dollars The most costly NFT ever sold is Beeple's creation. According to Mazur and Polyzos [40,41], NFT art pieces have recently gained more publicity than ever before, garnering more external attention than ever before. In addition to digital art, NFTs are being picked up by other forms of entertainment. For instance, musicians can tokenize records or songs that feature exclusive rights such as limited-edition releases to fans. NFTs have also surfaced in the gaming space, letting gamers buy and sell things like skins, weapons or virtual land on BC-powered marketplaces [59].
- **Virtual real estate and the metaverse:** Virtual real estate in the metaverse is one of the most exciting developments happening within NFTs, virtual worlds where users can purchase sell and trade digital land. The platforms are complete immersive worlds with NFT land ownership, and users can build on this land, as well as interact with other live avatars. As the metaverse blurs the lines between digital and physical, it presents increasing opportunities to monetize content, establish brand engagement and foster complex communities, increasingly positioning it as a next frontier of NFT applications [29].
- **The evolution of BC assets:** BC already looks very different from when BCT was first released. This will be in stark contrast to the early days of the tech-driven currency, as what was once an exclusive eye on cryptocurrencies now nurtures a multifaceted market of NFTs, DeFi and DAOs. Contributing to the transformation is the development in BC technology and implementation by consumers as well as businesses, along with widespread institutional involvement [59].
- **Initial coin offerings (ICOs):** Initial Coin Offerings (ICOs) were used by many BC startups to secure funding back in the beginning of crypto. ICOs enabled projects to issue funds in return for their own tokens, often BCT or Eth of sorts. However, without regulatory oversight, the industry has been hit by an epidemic of scams around new initial coin offerings (ICOs) leading to U.S. Securities and Exchange Commission (SEC) stepping in saying some ICOs are nothing more than unregistered securities [41].
- **DeFi and the rise of decentralized finance:** (DeFi) is the next big step in the discharge of BC assets. Again this is a paraphrase, it means that DeFi platform on the left offers functions such as lending, borrowing, trading and insurance in ways similar to traditional financial services (and using the same assets) but without intermediaries like banks or brokers. Powered by smart contracts on BC networks such as Eth, these services enable more transparent, accessible and efficient means to handle and track financial transactions [21]. DeFi had seen an explosion in popularity during the past few years, measured by Total Value Locked (TVL) in DeFi protocols, amounting to billions of dollars. By offering the ability to disrupt traditional financial systems, a mix of retail and institutional investors are starting to take interest in DeFi, while regulators have been flying over with skepticism around security implications as well as how it might impact overall economic stability [14].
- **Institutional adoption and regulatory interest:** The growing interest of the institutional investor community has symbolized a new chapter in the maturation of BC assets. Tesla, Square and Micro Strategy have added BCT to their own balance sheet, and the largest banks like JPMorgan or Goldman Sachs began offering cryptocurrency products & services. In turn, this has given a sense of credibility to the BC-based assets but also fueled the expectation for regulatory standards. Governments and regulatory bodies around the world are now embarking on the development of oversight mechanisms that mitigate BC asset risks yet unlock innovation. In other words, requiring that KYC and AML regulations are imposed on cryptocurrency exchange activities as well as providing guidelines governing the trade of NFTs and tokenized assets. Today, BC assets which include cryptocurrencies, NFTs and other types of digital tokens have grown from niche curiosities to major fixtures in the global financial and digital economy. Using NFTs to monetize digital art and other property interests could be a business model for the recent wave of decentralized power, giving creator control over both distribution and profits. The ultimate trajectory of these assets over the longer term will be influenced by technological innovation, institutional demand, and regulatory frameworks designed to protect security, transparency and innovation in this emergent but rapidly maturing asset class [46].

4. Rationale for regulatory oversight

The most growing two BC assets are cryptocurrencies and NFTs, which have attracted the attention of authorities and policymakers worldwide. Although there is a lot of potential for creativity with all of this new technology, there are also a lot of hazards and difficulties that have led to calls for regulation. These are some of the many justifiable goals that provide support for regulating these asset classes, ranging from financial stability and consumer protection to stopping tax fraud and maintaining market integrity [44]. In this section, the main justifications for authorities' desire to control BC assets are examined.

4.1. Consumer protection

Consumer protection is the clearest rationale for some regulatory interference in the BC space. More people who might not have had much financial knowledge or stock market awareness have entered the world of investing as a result of cryptocurrencies and NFTs. American customers could be reluctant to take on this kind of activity due to the very volatile and speculative character of these items. People might lose a lot of money on investments in cryptocurrencies like BCT and Eth because of their notoriously volatile value. Similarly, NFTs, which were heralded as a paradigm change in digital ownership, have shown to be equally speculative as investors lost trust in them and the value of digital collectibles plummeted [30]. To make matters worse, the lack of legal insurance on exchanges in many nations makes it easier for people to commit fraud and theft. However, there are several hacking instances and scams occurring in marketing sites and exchanges that act as middlemen between buyers and sellers (cryptocurrencies being the primary example here). Other well-known hacks that deprive investors of their coins, which are valued millions of dollars, include the Coincheck and Mt. Gox attacks. Even worse, attempts to exploit gullible investors have spread to fraudulent ICOs and NFT ventures, where dishonest actors are able to acquire funds but fall short of providing the promised goods or services [11].

By establishing guidelines for how exchanges and markets should function, mandating disclosures of those risks, and offering channels for consumer recourse, that regulatory supervision may be made to lessen these risks. Investors are aware of what they are getting into when the listing process is more tightly regulated, for instance, by mandating that the assets be transparent before being listed. Regulation of NFTs may concentrate on digital asset identification and avoiding consumers possessing counterfeit or deceptively marketed items [24].

4.2. Financial stability

The risk of BC and cryptoassets to financial stability is another important factor driving regulators attention. Cryptocurrencies, on the other hand, have come a long way from being obscure items to financial assets that have billions in market value. The more people utilize cryptocurrencies, the bigger their effect on national and eventually global financial systems. Authorities see widespread adoption of cryptocurrencies as containing risks for broader financial stability due to their systemic nature [2]. For example, the entrance of cryptocurrencies into the traditional financial system by means of institutional investment or wider payment acceptance could increase reliance on these volatile assets and therefore expose investors to a higher degree of risk. In the worst-case scenario, a large sell-off in the cryptocurrency market could bring down the wider financial markets if large banks are either heavily invested in or trading cryptocurrencies. Indeed, ahead of tightening policy, markets are already beginning to pay for years of inadequate oversight across all kinds of financial instruments. The global financial crisis brought home the dangers not only of systemic risks in asset bubbles from the failure to regulate them properly but also the fact that emerging assets like cryptocurrencies can and will certainly be caused by a massive unregulated bubble as seen in 2008 [24].

Stablecoins, a subcategory of cryptocurrencies designed to have price stability characteristics, have similarly raised regulatory concerns over the impact they may have on financial stability. Although the objective of stablecoins is to manage volatility, concerns have been expressed about whether or not these tokens collateralize in real assets and if confidence in their underlying assets were to be lost, could there be a run on stablecoins. Tether, which is among the largest of so-called stablecoins and pegged against the U.S. dollar, has long had questions swirling about whether it has adequately maintained and transparently disclosed its reserves to investors, causing some market observers to fret that a wider collapse in cryptocurrencies could ensue if Tether were proven incapable of redeeming them on demand [44]. This would be similar to a regulatory oversight in order to prevent anything happening within cryptocurrency that could threaten financial systems at large. Such measures could involve introducing capital and liquidity safeguards for exchanges, as well as stablecoin issuers; regulating the relationship between traditional financial institutions with crypto markets or monitoring systemic risk from digital assets [44].

4.3. Anti-money laundering (AML) and know your customer (KYC)

The unregulated, decentralized, and pseudonymous nature of BC transactions have been a perfect tool for the anonymous type of black markets that can range from illicit drug trafficking, racketeering to financial crimes. Fraud can use cryptocurrencies which are difficult to detect in order to transfer funds from one country to another, avoiding the traditional banking and financial systems governed by AML and KYC regulatory requirements. BC technology also brings an aspect of anonymity, so it is not surprising that this could easily be used for illegal activity when the true source and endpoint destination are unknown [34]. More countries are agitating for greater regulatory control to enforce AML and KYC in crypto. Regulators require information about who is using cryptocurrencies requiring exchanges and wallet providers to know their customers in the same way as banks know theirs should, in theory, make it harder for virtual coins to be used for ill-gotten gains. KYC processes generally involve collecting personal information about customers (i.e., name, address, proof of identity) to verify that they do not use the service for illicit practices [55].

Other regulatory bodies worldwide like the FATF have also urged countries to follow a "Travel Rule," which requires data on crypto transaction parties to be exchanged between institutions. It is similar to some requirements that have been traditionally required by financial institutions when transferring money. The implementation of these AML and KYC measures are considered as a necessary part in preventing the abuse of BC assets for fraudulent activities to guarantee their compatibility with standard financial systems [19].

4.4. Tax evasion and transparency

Cryptocurrencies are challenging for tax authorities due to their decentralized nature and the fact that they can be transacted anonymously, peer-to-peer without any intermediaries. The pseudonymous nature of cryptocurrencies permits individuals to possibly avoid taxes by hiding their wealth and income from tax administrations. This has made governments more desperate to put the same tax reporting and enforcement on cryptocurrency transactions as they try in traditional financial assets [56]. As far as legal supervision is concerned, the focus should be on ensuring transparency in the way cryptocurrency transactions work and requiring people to report their holdings of profits. Countries like the USA have even started taking steps towards this by making it mandatory for crypto exchanges to report transactions carried on their platform to their revenue collectors. According to the Internal Revenue Service (IRS), cryptocurrencies are considered property for tax reasons and must be reported as capital gains [26].

Greater regulatory scrutiny also has the added benefit of making cryptocurrency users, exchanges, and custodians legally obliged to report their activities, which would help tax authorities bridge the gap on cryptocurrency-tax evasion. Governments can ensure that cryptocurrencies are not used to evade tax payments by developing better tax regulations and improving transparency [45].

4.5. Environmental concerns

The last justification for regulation is probably the impact that BC assets like BCT have on the environment. The proof-of-work (PoW) consensus mechanism, which powers BCT and most other cryptocurrencies, requires miners to solve complex mathematical problems in order to validate transactions and protect the network. In turn, this consumes a significant amount of power and has raised concerns about the quantity of carbon emissions from cryptocurrency mining facilities [57]. Regulators have also been stepping up their investigations to find an environmental solution that would lessen the impact of mining operations. Because cryptocurrency mining uses so much power, some countries, like China, have gone so far as to completely outlaw it. Other nations are also thinking about imposing environmental regulations on miners. Conversely, there are also initiatives to incentivize more energy-friendly models like proof-of-stake (PoS) that require much less energy consumption in operation [45].

This might be accomplished directly by penalizing miners who use non-renewable energy sources, indirectly by promoting the use of greener technology through the regulatory framework, or indirectly by giving energy-efficient consensus methods priority attention. By doing this, governments may address the environmental problems associated with cryptocurrency mining while continuing to support the growth of the BC industry [56]. Some BC assets will most likely be subject to strict regulation if the financial services industry in every major country in the world concurs that cryptocurrencies need to be regulated. Even though MAS and industry players have been able to collaborate effectively on sandbox projects, the reality is that going beyond this still calls for some ground rules because everyone agrees that a balanced approach is necessary to promote innovation while taking into account the risks that such technology may present. As participants in the BC ecosystem ourselves, having a framework to identify the underlying drivers of regulatory efforts will help us navigate this national, regional, and international environment more skillfully and, as a result, create responsible and efficient regulations [58].

5. Global regulatory approaches to BC assets and evaluation

Given the global reach of BC assets, such as cryptocurrencies and NFTs, it is no surprise that governments and regulatory bodies have been under growing pressure to adopt a forward-looking approach which strikes the right balance between consumer protection, financial stability and transparency on one side; and innovation that can fuel economic growth on another. But the decentralized and global nature of these technologies makes it difficult for regulators to act [31]. This part focuses on BC asset regulation all over the world, introduce some ways of block and describe regulatory actions in different countries or regions.

5.1. The United States

Since various federal agencies have disagreed and in some cases agreed on the status of cryptocurrencies and even NFTs, the U.S. has instituted disparate regulations of BC assets. The U.S. Securities and Exchange Commission (SEC) is likely the largest, as it has played a role in determining whether or not a number of cryptocurrencies are securities. The SEC's most notable move in this case was the lawsuit it filed against Ripple Labs, claiming that the business marketed XRP securities and that XRP ought to be regulated as such. This case has reignited the debate over how digital assets should be classified and further highlighted the legislative ambiguity surrounding them [38]. The Commodity Futures Trading Commission (CFTC) and even the Internal Revenue Service (IRS) are reportedly under the oversight of the SEC, which is not the only government body that has established laws for cryptocurrencies. Another intriguing problem is that the CFTC identified at least one cryptocurrency derivative in its determination of its jurisdiction over virtual currencies, with BCT being regarded as a "commodity." On the other hand, for tax reasons, the IRS separates BCT from other types of money and will regard your sale as a capital gain or loss [7].

The New York Department of Financial Services (NYDFS) introduced the BitLicense in 2015, which mandates that companies that deal with virtual currencies obtain a license and stay in compliance with strict know-your-customer KYC and AML laws. Some people view the BitLicense as a good thing because it clarified regulations, but it has also been excessively complicated and difficult for the majority of businesses who are trying to operate in New York [18]. In recent years, collaborative support for the establishment of a national framework to regulate BC assets has grown, and Congress has continued to introduce legislation to elucidate some aspects of this regulation, such as the Responsible Financial Innovation Act and the Digital Asset Market Structure and Investor Protection Act [5].

5.2. The European Union

(EU) is seeming quite a bit more structured and unified when it comes to the regulation of BC assets with the recently proposed Markets in Crypto-Assets (MiCA) Regulation. It is a framework law, one of several steps that MiCA seeks to enact to guarantee the entirety of digital assets including cryptocurrencies, stablecoins and NTFs are acknowledged legally as assets more generally throughout its 27 member states. Expected to be implemented in the next years, the proposed legislation seeks to give issuers and service providers legal certainty while also guaranteeing a high degree of investor and consumer protection. MiCA introduces a nomenclature to distinguish the various categories of digital assets. MiCA creates three different categories of cryptocurrencies such as asset-referenced tokens, e-money tokens, and other cryptoassets. Regulatory requirements are different for each category and issuers and service providers have to comply with transparency, disclosure and governance standards. In the case of stablecoins, for example, they are regulated much more heavily because of the potential impact that they can have on monetary policy and financial stability [28,33].

In addition to compelling issuers to reveal the capabilities of the consensus processes that drive the network, MiCA also seeks to be ecologically conscious. This would operate as a gauge for the environmental effect of BC assets. This clause is a result of the EU's broader sustainability initiative and concerns about the energy-intensive nature of BC technology, particularly proof-of-work based cryptocurrencies like BCT [28,33]. In addition to MiCA, the EU's General Data Protection Regulation (GDPR) has made an effort to govern BC at the nexus of data privacy. BC networks' decentralized structure makes it challenging to comply with GDPR, particularly when it comes to data subjects' rights like the "right to be forgotten" and personal information kept on immutable ledgers. Regulatory attention is to be expected even if, as of right now, the EU does not have explicit rules to handle such challenges, even if privacy and the integration of BC technology with existing privacy laws are ignored [33].

5.3. Asia

Asia is a region of wide-ranging regulatory responses to BC assets, due in part to the diverse economic, political, and cultural contexts of individual country-regulatory primatene issues. China, the government of which took a tough stance on cryptocurrencies last year, banning all cryptocurrency transactions and mining. The Government of China is

Table 2
Evaluation of regulatory policy across different jurisdictions.

Jurisdiction or Region	Regulatory Approach Characteristics	Key Strengths	Key Weaknesses	Potential Impacts
United States	Fragmented, Ambiguous, Enforcement-centric	Proactive engagement of multiple agencies, focus on investor protection (SEC), clarity for derivatives (CFTC), early state-level efforts (BitLicense), bipartisan efforts for national framework.	Lack of cohesive federal approach, ambiguity hindering innovation, potential for stifling growth through enforcement, BitLicense seen as overly burdensome, challenges with global nature.	Slower innovation due to uncertainty, compliance burdens for businesses, potential for regulatory arbitrage, eventual move towards a more unified national framework.
European Union	Harmonized, Comprehensive (MiCA)	Unified legal framework across member states, legal certainty for issuers, tailored requirements based on asset categories, proactive stablecoin regulation, and consideration of environmental sustainability.	Potential challenges in implementation and enforcement across diverse member states, impact on innovation still unfolding, need for further harmonization with existing regulations (e.g., GDPR).	Increased legal certainty and consumer protection, potential for a leading global regulatory standard, possible compliance burdens for businesses, and influence on global regulatory trends.
Asia (Singapore)	Enabling, Clear, Balanced	Sensible and clear regulations conducive to innovation, balanced AML or KYC requirements allowing business growth, positioned as a BC hub.	Potential for over-regulation stifling some aspects of innovation, ongoing need to adapt to evolving technologies.	Fosters BC innovation and business growth, attracts investment, establishes Singapore as a key player in the digital asset space, balances risk management with economic development.
Asia (China)	Restrictive, Prohibitive (Cryptocurrencies), Promotive (BC Tech)	Strong state control over financial assets, focus on developing state-sponsored BC infrastructure (BSN) and CBDCs.	Blanket ban on cryptocurrency transactions and mining potentially stifles innovation, fragmented approach with promotion of underlying technology but suppression of assets.	Suppression of cryptocurrency markets within China, focus on state-controlled digital finance, potential global leadership in CBDC technology, impact on overall BC innovation within its borders is complex.
Asia (Japan/S. Korea)	Structured, Focused on Security	Early recognition of digital assets (Japan), supervision of exchanges (Japan), strong AML/KYC requirements due to past security issues (South Korea).	Potential for stringent regulations to hinder some innovation, ongoing need to adapt to new threats and technologies.	Mature and relatively secure digital asset markets, strong emphasis on consumer and investor protection, potential for slower innovation compared to less regulated environments.
Other Jurisdictions (El Salvador)	Adoption-focused (Bitcoin Legal Tender)	Potential for increased financial inclusion, attracting foreign investment.	Criticism from international financial institutions regarding financial stability and money laundering risks.	Uncertain long-term economic and financial stability impacts, potential for increased adoption of Bitcoin in specific contexts, influence on other nations considering similar moves.
Other Jurisdictions (Switzerland)	Enabling, Supportive	Supportive regulatory climate, clear guidance on token classification, integration of BC assets within existing financial regulations.	Potential for complexity in applying traditional financial regulations to novel BC assets, ongoing need to adapt to rapid technological advancements.	Fosters innovation and attracts BC businesses, provides regulatory clarity within a well-established financial system, potential model for other jurisdictions.
Other Jurisdictions (India)	Uncertain, Evolving	Exploration of a digital rupee, ongoing discussions about regulating private cryptocurrencies.	Flip-flopping between outright bans and regulation creates market uncertainty, lack of definitive legislation.	Market volatility and uncertainty, delayed adoption and innovation, potential for a more defined regulatory framework in the future depending on legislative outcomes.

Source: Author's self-assessment.

concerned about financial stability, capital flight and energy consumption with such a volatile currency that consumes 13 TWh per year of electricity, the blink rate at which Hong Kong has been gobbling up coal-fired power plants. Meanwhile China has been aggressively pushing the development of BC technology with it BC Service Network (BSN) and is also leading the innovation in Central Bank Digital Currencies (CBDCs), apart from the more advanced project on digital yuan. The regulatory backdrop in China is a sign that it wants to manage digital financial assets while enthusing about other kinds of state-sponsored choices [64].

In contrast, Singapore has long positioned itself as a global center for BC innovation by instituting sensible and clear regulations conducive to the expansion of the ecosystem. In 2020, the Monetary Authority of Singapore (MAS) brought out the Payment Services Act, a licensing regime for digital payment token services, which also cover cryptocurrency exchanges. The law forces companies to follow AML and KYC regulations, but its demands are balanced such that start-ups rooted in the BC can still thrive in Singapore [37,61]. Japan and South Korea, for example, have built some of the most sophisticated regulatory structures around BC assets in the world. Enforcing regulation, Japan was among the first nation to regulate digital assets, back in 2017 when they acknowledged BCT as legal tender. In addition, the Japanese Financial Services Agency (FSA) supervises cryptocurrency exchange regulation and confines transactions to registered exchanges [37]. Meanwhile, South Korea has seen a number of significant hacks and fraud cases that led to the adoption of very rigorous AML and KYC requirements for cryptocurrency exchanges [37,51].

5.4. Other jurisdictions

Meanwhile, authorities in other parts of the world have adopted a wide array of regulatory stances on BC assets; some have provided open arms to crypto and NFTs while others take a heavy-handed approach in policing or even banning them. In 2021, El Salvador grabbed headlines for being the first country ever to make BCT legal tender. President of the nation drove the initiative, which officials say aims to increase financial inclusion and attract investment from abroad. Nevertheless, the overall concept of BCT as a legal payment option got criticism from International Monetary Fund (IMF), and other large financial organizations are starting to worried about the repercussions it might have on the world's finance stability and money laundering [25,52].

India has been much more conservative in her attitude towards

cryptos, flip-flopping between offers of an outright ban and the potential regulation of existing names. The Indian government in 2021 was exploring the idea of a bill to ban all private cryptocurrencies and provide for an official digital rupeegni shake, shake up. Nonetheless, definitive legislation has not come to fruition and the market is still in flux [25]. In Switzerland, one of the country's best-known for its supportive regulatory climate for BC has created a system that can fit cash assets under prevailing financial regulations. The Swiss Financial Market Supervisory Authority (FINMA) issues guidance on how BC tokens are classified in Switzerland, leading the way internationally for future BC innovation [34,35].

5.5. International coordination and self-regulation

One of the greatest challenges in trying to regulate BC assets is that they are borderless by nature, which necessitates international cooperation. And while individual countries are coming up with their own rules, there is a growing consensus that international cooperation is necessary to avoid regulatory arbitrage and ensure where crypto-assets exist on BCs they exist under regulation [42]. International bodies like the Financial Action Task Force (FATF) have led efforts to establish a set of global norms on BC asset regulation, particularly in the AML and KYC space. Fondly referred to as the Travel Rule, the measure means that crypto exchanges and other virtual asset service providers are expected to transmit details of parties in transactions above a certain threshold so as to control money laundering and terrorist financing operations

Besides government enforcement, the BC space has also begun to use self-regulatory policies. Inroads are being made by addressing identity management, with numerous cryptocurrency exchanges going the extra mile to conduct KYC and AML processes, even when they are not legally mandated for them to do so in their jurisdiction, an effort to clean up the industry and prevent fraud and other transgressions from occurring. Group such as 'CryptoUK' and the 'Blockchain Associationare,' are an example of industry groups working towards friendly yet fair regulation efforts [40,52]. As one might image, the global regulatory landscape in relation to BC assets is variable and still developing with different countries and sometimes states within a country taking quite differing tact based on their specific legal, economic, and political environments. Some countries saw BC as an innovative tool and integrated with openness, some others took a long journey by being conservative or even prohibitive towards BC assets. The world is edging closer to being able to untap the potential of these decentralized, borderless assets by harnessing BC technologies but international collaboration and balanced regulatory frameworks remain vital in solving some of the challenges they pose [52].

5.6. Evaluation of regulatory policy

To provide a clear and concise comparison of the diverse regulatory approaches to BC assets across different jurisdictions, the following table summarizes the key characteristics, strengths, weaknesses, and potential impacts of the policies discussed in this study. This comparative analysis aims to highlight the contrasting strategies adopted by various nations and regions as they grapple with the opportunities and challenges presented by cryptocurrencies, NFTs, and other digital assets. By examining these different regulatory frameworks side-by-side, we can gain a deeper understanding of the potential trade-offs between fostering innovation, ensuring consumer protection, and maintaining financial stability in the evolving landscape of BC technology, as described in Table 2.

5.7. Quantitative evaluation of regulatory effect of BC assets

To provide a comparative and quantitative overview of the regulatory effects on BC assets across key jurisdictions, the following tables and graphs presents specific metrics indicating the key information related BC assets regulation.

Table 3
AML or KYC compliance scores by nations.

Nations	AML/KYC Compliance Rate (% VASPs)	Basel AML Index Score	FATF Recommendation 15 Status
Singapore	91 %	5.29	Compliant
Switzerland	88 %	4.98	Largely Compliant
USA	61 %	5.34	Partially Compliant
India	54 %	6.44	Non-Compliant
Nigeria	42 %	7.01	Non-Compliant

Source: Basel Institute on Governance [65].

Table 3 and Fig. 3 offers a revealing snapshot of the global AML or KYC compliance landscape, highlighting significant disparities between jurisdictions. Singapore emerges as the clear leader, boasting a 91 % compliance rate paired with a low Basel AML Index Score of 5.29, reflecting its robust regulatory framework and effective enforcement mechanisms. Switzerland, while slightly behind at 88 % compliance and a 4.98 score, also showcases strong regulatory performance, benefitting from its long-standing financial reputation. In sharp contrast, the USA, despite its advanced financial infrastructure, displays a surprisingly lower compliance rate of 61 % with a slightly higher risk score of 5.34, suggesting potential gaps in enforcement or variations in regulatory interpretation across states. More concerning are India and Nigeria, with compliance rates of only 54 % and 42 % respectively, and notably higher Basel Index scores (6.44 for India and 7.01 for Nigeria), signaling persistent vulnerabilities, regulatory weaknesses, and a higher exposure to financial crime risks. These differences underline how both regulatory maturity and consistent application play critical roles in shaping the effectiveness of AML/KYC regimes worldwide.

Table 4 captures the evolving landscape of regulatory development and its tangible impact across several key jurisdictions. In the EU, the introduction of the Markets in Crypto-Assets Regulation (MiCA) in December 2024 has markedly tightened the crypto sector's footprint, with crypto-focused funds accounting for <1 % of the EU fund universe and an overwhelming 95 % of EU banks maintaining no exposure to crypto assets, signaling a cautious and risk-averse regulatory environment. Meanwhile, the United Kingdom (UK), through the issuance of DP24/4 covering Admissions, Disclosures, and the Market Abuse Regime in late 2024, is navigating a more balanced approach, as evidenced by 12 % of UK adults holding crypto and 33 % expressing confidence that the Financial Conduct Authority (FCA) would intervene in case of disputes, reflecting moderate but growing public engagement. In the USA, upcoming deregulatory shifts anticipated under Trump's 2025 administration suggest a probable loosening of constraints, likely aimed at boosting financial industry contributions and innovation, though potentially at the cost of regulatory rigor. Singapore, however, stands out for its aggressive expansion: the number of Major Payment Institution (MPI) licenses for crypto exchanges more than doubled from 6 in 2023 to 13 in 2024, complemented by a thriving ecosystem of 1600 BC patents, 2433 related jobs, and 81 active exchanges, underscoring its ambition to become a global BC and crypto hub through progressive regulation.

Table 5 and Fig. 4 provides a comparative view of crypto fraud losses and the corresponding regulatory strategies adopted by various nations, highlighting stark contrasts in both financial impact and regulatory philosophy. The USA records the highest estimated fraud losses at a staggering $5600 million, reflecting the scale of its crypto market and a predominantly enforcement-driven regulatory approach that tends to act after fraudulent activities have occurred. India, despite its large population and growing crypto user base, reports much lower fraud losses at $44 million, but its regulatory stance remains largely reactive, indicating delayed or inconsistent responses to emerging threats. In contrast, Singapore presents a model of proactive governance, with estimated fraud losses of $180 million and a strong regulatory focus on prevention and public education, demonstrating an emphasis on risk mitigation before incidents materialize. Meanwhile, the United

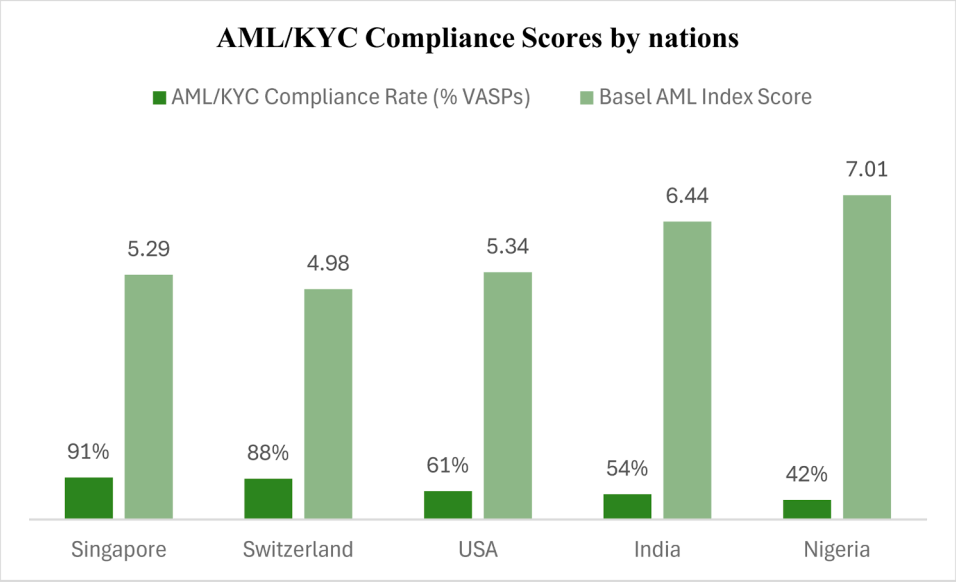

Fig. 3. AML or KYC compliant scores and rates. **Source:** Basel Institute on Governance [65].

Table 4
Impact of regulatory.

Nations	Regulatory Development	Quantitative Impact
EU (EU)	Implementation of Markets in Crypto-Assets Regulation (MiCA) in December 2024.	Crypto-focused funds <1 % of EU fund universe; 95 % of EU banks have no crypto exposure.
United Kingdom (UK)	Issued DP24/4 on Admissions & Disclosures and Market Abuse Regime (late 2024).	12 % of UK adults own crypto; 33 % believe FCA would help if problems arise.
United States (US)	Anticipated deregulatory changes under Trump (2025).	Increased financial industry contributions expecting favorable regulation.
Singapore	Doubled MPI licenses for crypto exchanges in 2024.	13 licenses in 2024 vs 6 in 2023; 1600 BC patents, 2433 jobs, 81 exchanges.

Source: Coin360, [16,17]; KPMG, [36]; Reuters, [49]; Reuters, [50].

Table 5
Crypto fraud losses.

Nations	Estimated Fraud Losses (USD)	Regulatory Focus
USA	$5.6 billion	Enforcement, post-factum
India	$44 million	Reactive
Singapore	$180 million	Preventive, education-led
UK	$490 million	AML/KYC reinforcement

Source: Federal Bureau of Investigation, [22]; Business Standard, [15].

Fig. 4. Crypto fraud losses. Source: Federal Bureau of Investigation, [22]; Business Standard, [15].

Table 6
Legal and regulatory concerns for investors.

Concern	Percentage of Affected Investors
Asset Classification Uncertainty	30 %
Fraudulent Scheme Proliferation	12 % increase
Taxation Compliance Challenges	45 %
Investment Disclosure Requirements	$50,000 threshold
Consumer Protection in Stablecoins	35 % of countries
Intellectual Property Challenges (NFTs)	17 %
Cross-Border Legal Complications	40 %

Source: Coin360 [17].

Kingdom, with fraud losses estimated at $490 million, channels its regulatory energy into strengthening AML or KYC frameworks, aiming to fortify institutional safeguards and prevent financial crimes at the systemic level. Collectively, these variations underscore how differing regulatory strategies significantly influence the scale and nature of crypto-related vulnerabilities across countries.

Table 6 highlights the range of legal and regulatory concerns currently confronting investors in the crypto space, painting a complex picture of the evolving risk environment. Asset classification uncertainty remains a major challenge, affecting 30 % of investors who struggle to navigate inconsistent definitions across jurisdictions, complicating compliance and investment decisions. Fraudulent scheme proliferation has surged by 12 %, signaling an increasing threat to investor security and trust. Taxation compliance poses another significant hurdle, impacting 45 % of investors due to opaque or rapidly shifting tax reporting obligations. Investment disclosure requirements have also tightened, with a $50,000 threshold triggering mandatory reporting, increasing administrative burdens. Consumer protection, particularly in the stablecoin sector, is gaining attention, with 35 % of countries instituting specific safeguards to shield users from volatility and misuse. Intellectual property issues surrounding NFTs affect 17 % of investors, reflecting the emerging legal gray areas around digital ownership and copyright. Finally, cross-border legal complications trouble 40 % of investors, underlining the jurisdictional challenges and regulatory fragmentation that complicate international crypto activity. Together, these concerns illustrate the growing need for clearer, harmonized regulatory

Table 7
Central Bank Digital Currency.

Nations	CBDC Project Status	Adoption/Usage Statistics
China	Digital yuan expanded	40 million users; $15B transactions
European Union	Digital euro pilot in phase two	Planned by 2026
India	CBDC in second testing phase	10 million users
Jamaica	JAM-DEX 30 % adoption	30 % adoption
Nigeria	eNaira reached over 1M users	1M+ users; 10 % cash reduction projected

Source: CoinLaw [16].

frameworks to support investor confidence and market stability.

Table 7 presents a detailed overview of (CBDC) initiatives and their respective adoption and usage metrics, illustrating varied progress across regions. China leads the global CBDC race with its digital yuan, boasting 40 million users and facilitating transactions worth $15 billion, signaling both government commitment and growing public acceptance. The EU's digital euro project is progressing steadily, currently in its second pilot phase with a full rollout targeted by 2026, reflecting a cautious but structured approach to integration within its complex multi-national financial system. India's CBDC development is also advancing, now in its second testing phase and already attracting 10 million users, underscoring the country's rapid digital adoption and financial inclusion efforts. Jamaica's JAM-DEX demonstrates notable success with 30 % adoption, indicating strong national engagement in a smaller economy context. Meanwhile, Nigeria's eNaira has surpassed 1 million users and is projected to contribute to a 10 % reduction in cash usage, pointing to meaningful, if gradual, shifts in consumer behavior. Collectively, these initiatives showcase the diverse strategies and paces at which different economies are embracing the digitalization of money.

6. Challenges in regulating BC assets

Since BC assets have soared in popularity and value as seen with cryptocurrencies and NFTs, they have posed enormous challenges to regulators the world over. These assets are reshaping industries by power decentralized transactions, digital ownership, and peer-to-peer exchanges just as they create challenges that became hard to fit in with traditional regulatory frameworks [42]. This part examines the major challenges confronted by policymakers, regulators and overseers in pursuing to supervise BC assets (Fig. 5).

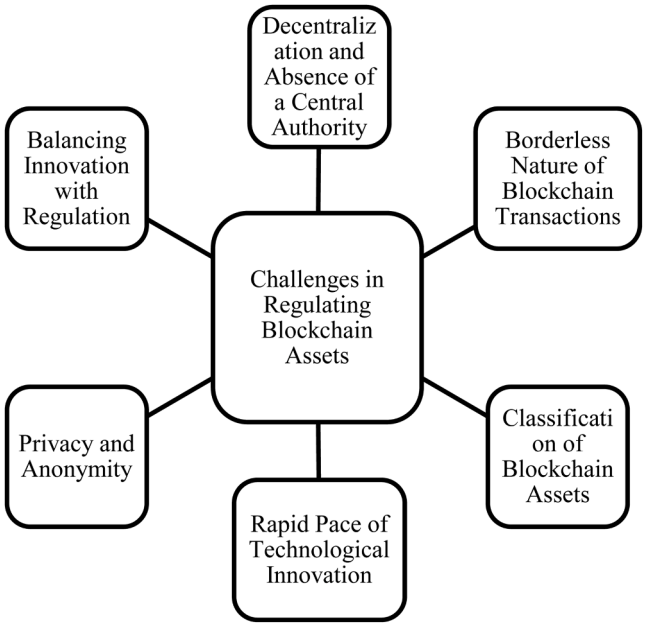

Fig. 5. Challenges in regulating BC assets.

6.1. Decentralization and absence of a central authority

Although one of the main features of BC assets is decentralization, the operation of these networks differs from that of traditional finance. Because BC technology is decentralized and trustless, it does not need a central authority to monitor transactions, such as a bank or financial regulator. To maintain the ledger, transactions are validated by this dispersed network of participants, or nodes. Because of this, enforcement tasks are difficult [40]. For instance, banks and other financial entities that function as middlemen between participants in financial transactions may be subject to regulations from authorities in legacy (or conventional) financial systems. Yet with BCT being a decentralized network, there exists no central authority or middleman. Regulations that are standard in controlling illicit activities do not apply to DeFi primarily because there is no central control point [52]. Additionally, DeFi platforms can both trade and lend or borrow cryptocurrencies in an intermediate form network. Autonomous operating mechanisms are used in these types of platforms using smart contracts (self-executing code). However, smart contracts are especially hard to regulate because they operate on their own and do not depend on human intervention, which makes it even harder to monitor the participants in transactions [58].

6.2. Borderless nature of BC transactions

One of the main problems when it comes to decentralized BC-based assets is that these are borderless. These can interexchange cryptocurrencies and NFTs across sovereign boundaries without any intermediary or third-party institutions. Their global presence also makes it difficult for any one specific nation to enforce their laws and regulations, or if they do try, the transactions can simply move beyond their territories [45]. A cryptocurrency exchange is one good example where a company based in one country can serve users in multiple other countries without being subject to the regulatory frameworks of those foreign jurisdictions. This cross-border activity frequently results in regulatory arbitrage, whereby companies and individuals relocate their efforts to jurisdictions with lower regulation. This undermines the utility of regulations, as entities can effectively evade oversight by moving to more weakly regulated areas [42]. Cross-border transactions also complicate tax enforcement. Cryptocurrencies are commonly transferred cross-border and the self-explanatory nature of cryptocurrencies makes it difficult for government tax authorities to associate incomes from the source. This creates a possibility of tax evasion where people can simply move large amounts of money from one country to another without informing the tax authorities about this [40].

6.3. Classification of BC assets

One highly controversial area is the categorization of BC assets. Cryptocurrencies and NFTs have several uses and hence they may not fit in any of the existing legal categories. For instance, some cryptocurrencies such as BCT are viewed as a type of currency with additional functionalities; others like Eth were created as platforms for being able to run Dapps otherwise known as decentralized applications [52]. In some jurisdictions, regulatory bodies do not agree on classifying these as securities, commodities or currencies either. For example, in the US, some cryptocurrencies have been classified as securities by the Securities and Exchange Commission (SEC), imposing a certain framework of security regulations on them; at the same time BCT and Eth are deemed commodities by the Commodity Futures Trading Commission (CFTC) meaning that these fall under another set of rules. The lack of a standard classification causes regulatory uncertainty, making businesses and consumers alike unsure of their legal obligations [42]. Such as NFTs,

that has very different classification challenges. Although we most often hear about NFTs in the context of proving and owning digital art, collectibles or virtual property, an NFT can just as well be a claim on a ticket, a license or the proof of ownership over some physical object. This has made regulation far more complex, with different categories of NFTs potentially classifying as different types of securities requiring its own approach to define and regulate [40].

6.4. Rapid pace of technological innovation

BC technology is changing faster than regulators can regulate. Cryptocurrencies, smart contracts, Defi, NFTs and the resulting derivaties continue to evolve and drive new risks alongside regulatory concerns. Because the BC field is so dynamic, pre-existing laws and regulations are often inadequate to deal with new developments [58]. For instance, the advent of DeFi platforms has brought about securities, fraud and market manipulation issues. While these platforms allow the users to do trade on it without any intermediaries, but code vulnerabilities, flash loans attacks and a rug pull i.e., developers exit scamming are also found simultaneously. Regulators are still finding their footing on these risks and building frameworks to protect consumers against such risk but the prompt progress made by DeFi space makes it further complicated for regulators on how they should be responding to the developments [52]. Also, the technical sophistication of BC assets may create an information asymmetry between regulators and professional services industry. The nature of smart contracts, BC consensus mechanisms such as proof-of-work & proof-of-stake and interaction between different types of BC networks is fairly complex to understand and getting too technical. If not enough knowledge exists about these technologies, it will be very difficult for regulators to implement useful supervisory approaches that address precisely the risks that BC assets bring with them [42].

6.5. Privacy and anonymity

The privacy and anonymity of BC transactions also make it more difficult to enforce regulation. BCT and Eth are on pseudonymous networks, which means users are represented by their public addresses instead of real-world identities. So, while these networks are open with every transaction recorded on a public ledger, the pseudonymous nature of transactions leads to difficulties in regulators being able to tie addresses back to individuals [40]. Furthermore, by hiding transaction information, privacy cryptocurrencies like Monero (XMR) and Zcash (ZEC) offer even higher degrees of anonymity while making it difficult for authorities to track the money. Users who value financial privacy may find these privacy features appealing, but there are worries that they might be abused for illicit reasons (money laundering, funding terrorism, tax evasion) [52]. The threat of informed consent violations prompted regulators to turn their attention toward finding a solution for the privacy issues in the DeFi space. Certain governments are insisting for more transparency and some form of regulation in terms of BC transactions, suggesting KYC or AML orders where users would have to identify themselves before taking part in cryptocurrency exchanges or DeFi platforms. But the tension in balancing ensuring compliance with not overreaching into users' rights to privacy is where regulators must tread dangerously [42].

6.6. Balancing innovation with regulation

The real challenge in regulating BC assets is to balance between supporting innovation and maintaining appropriate level of control. Although this technology will transform both industries and people, overly strict regulations could strangle innovation at the root of the BC ecosystem. While governments and regulatory agencies have an obligation to protect consumers, maintain stability in financial markets & prevent illegal activities. At the same time, they must also see the promise of BC to boost economic growth, enhance financial inclusion and unlock new business models. Balancing these interests is a complex exercise that should consider both potential benefits and possible risks of BC assets [40]. In this way, many regulators are following a "regulatory sandbox" approach allowing BC companies to experiment with new technologies under regulatory supervision without having to deal with all the regulatory burdens. This helps regulators learn about new tech without stifling businesses that need to build and experiment with technology in order to innovate [52].

Decentralized and borderless, BC assets present unique difficulties in classification; their rapid pace of technological innovation means that laws cannot be made obsolete overnight, while strong privacy concerns make it harder to track the flow of legal money laundering through these cryptocurrencies. All of the above make for a multifaceted and dynamic space to regulate, leaving precious little time and room for policymakers indeed to implement generative, future-looking policies that can ultimately bestow us with the benefits from this BC technology while minimizing its risks [58].

7. The future of regulatory frameworks for BC assets

Regulations must be established as quickly as possible because of the expanding market for digital assets (such as cryptocurrencies and NFTs) and the maturity of BC technology. Globally, policymakers are attempting to determine what kinds of mechanisms should be in place in order to balance promoting and regulating these decentralized, non-geographic technologies. Numerous national, regional, and global initiatives are probably going to identify, create, and maybe implement common regulatory standards for BC assets in the upcoming years, in addition to industry self-regulation. Various considerations, including tax reporting, financial stability, AML and KYC compliance, consumer protection, and environmental concerns, influence these systems [52] (Fig. 6).

7.1. Consumer protection and financial stability

One of the main reasons for the regulation supervision is to secure consumers from the natural risks related to BC assets. For example, cryptocurrencies are extremely unstable. Values of things like BCT and Eth can vary wildly in hours, leaving the retail investors with a lot of money at great risk. The NFTs boom also directly coincided with a new era of scam-related scams, whereby unsuspecting buyers were hoodwinked into purchasing fake digital art. As these markets expand, regulators are likely to increasingly focus on protecting consumers by issuing more guidelines and potentially increasing their enforcement activities [40]. In the future, regulatory jigsaw puzzles are likely to include mechanisms for guarding against fraud risks, and ensuring that a consumer will benefit an accurate view of what they are buying. For instance, depending on the case, it may increase requirements for transparency of BC transactions (e.g., by requiring disclosure of risks), ensure companies issuing tokens provide standardized or verifiable information and so on [58].

Another primary focus is addressing financial stability. If there is more widespread usage of cryptocurrencies, it could pose risks to the wider financial system including a great deal of cross-contagion effects as movements in huge crypto markets might end up having highly spillover impacts on conventional markets. Stablecoins are a variety of cryptocurrency that are tied to the value of reliable assets beside them

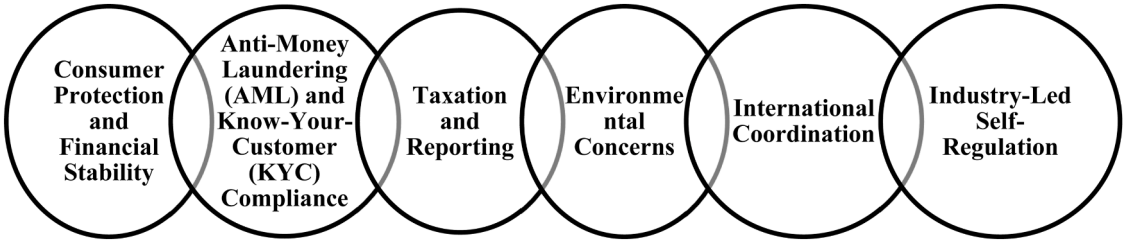

Fig. 6. Regulatory frameworks for BC assets.

and could thus interfere with national fiat currency systems (like US dollar-tied stablecoins). Governments and central banks, now more than ever, will seek stronger controls for stablecoins with requirements on reserves and audits of real-world collateral backing [18]. The concerns described before may move central banks to think about introducing digital currencies, CBDCs. One way is providing a sovereign digital replacement for cryptocurrency, giving consumers and businesses a better yet still safe asset. This trend is expected to continue as countries such as China and Sweden trial their own CBDC programs, shaping the regulatory landscape of tomorrow [45].

7.2. Anti-money laundering (AML) and know-your-customer (KYC) compliance

The crypto sphere has been a target for criminals looking to remain anonymous and avoid the scrutiny of state-enforced AML legislation, resulting in some sites and users using cryptocurrencies as a means to facilitate transactions related to money laundering, terrorism financing or tax evasion. Consequently, regulators have been (more or less) eager to guarantee that BC assets are held to the same AML and KYC standards as traditional financial institutions. AML and KYC compliance soon to be core elements in BC asset regulatory frameworks in future years [52]. Even in the traditional financial world, it can be observed that a similar trend of countries moving to AML and KYC regulations for digital currency exchanges that would involve adhering to identity verification mechanisms as well reporting suspected activities to respective authorities around the globe. Looking ahead, it can be anticipated that more international standardization on these types of regulations to maintain the balance and prevent regulatory arbitrage by bad actors in between countries with different standards. Organizations like the Financial Action Task Force (FATF) are already in the process of developing global standards for AML and KYC of digital assets, and future frameworks may be based on these measures [58].

The decentralized nature of many BC platforms is a big hurdle for compliance with AML and KYC regulations. For example, many regulators are accustomed to the requirements of centralized exchanges but have not yet experienced the capabilities (or lack thereof) provided by decentralized exchanges (DEXs), which operate outside the purview of a central authority. In turn, regulators may adopt a more reluctant hybrid model where decentralized platforms would be compelled to comply with some degree of due diligence; for instance, they could implement identity verification at certain phases in transactions. This could result in the emergence of new technologies that allow decentralized compliance, without breaking the cardinal tenets of BC such as privacy and autonomy [18].

7.3. Taxation and reporting

The taxation of BC assets is still murky and not a foregone conclusion. For instance, cryptocurrencies can be treated as property much like gold or real estate rather than as a currency, which means each transaction no matter how trivial such as buying goods or exchanging one crytocurrency for another can create taxable events. The growth of digital asset markets has led tax authorities around the world to begin to provide clarity on certain issues related to reporting obligations of individuals and businesses dealing in BC transactions [58]. Perhaps future governance models will include more rigorous reporting standards for exchanges and even other BC platorms to provide users with information on how to accurately report their transactions to the IRS. This can include automated reporting systems that monitor cryptocurrency transactions in real time and provide capital gains/losses calculations. The governments of some countries have already introduced rules under which data apparently from crypto exchanges is collected to detect cases of tax evasion. As these systems advance, international cooperation between tax authorities may be required in order to properly monitor cross-border transactions [52].

7.4. Environmental concerns

Regulations pertaining to the environmental impact of BC technology will also evolve. Even now, despite all the evidence to the contrary, the energy appetite of BCT and its kin, which rely on competing proof-of-work consensus to operate both the broadcast full nodes that process transactions and mining to mint new coins is commonly cited as evidence of their unsustainability. Given that policymakers worldwide are increasingly focusing on the environment, such regulatory pressure is more likely to originate from governance's desire to see BC networks use less energy [18]. In the near future, this may even serve as a mandate to support energy-efficient consensus models, such proof-of-stake rather than proof-of-work. For BC businesses, especially those that mine cryptocurrency, governments can even start imposing carbon fees or limitations on power use. Additionally, BC enterprises may be required to publish their environmental effect, similar to how traditional organizations are required to disclose their sustainability initiatives [45].

7.5. International coordination

Since BC assets are structurally borderless, international coordination will be necessary to make the regulations effective. This may be true for individual countries, but as BC technology allows assets and transactions to exist globally and decentralized across nations, state borders can hardly contain regulated financial activities. This clearly necessitates that the regulations must be designed optimally and uniformly to prevent bad actors from slipping through cracks [18]. Due to their proven track record in fostering international cooperation, it is probable that entities such as the IMF, World Bank and FSB will be important in creating a global framework of regulation for BC technology. Standardizing the way in which regulators approach digital assets from country to country will ensure that there is a consistent framework for monitoring these new forms of investments, diminishing regulatory arbitrage and enhancing consumer protection worldwide [58].

Frameworks known as regulatory sandboxes, which allow BC

businesses to test new business models and technology while being closely monitored by regulators, could also become more popular. With no regulatory responsibilities, these sandboxes provide businesses a high-quality setting in which to develop innovative BC applications. Policymakers may gain a better practical grasp of the technology through sandboxes, which promote collaboration between market actors and regulators. However, regulations must always follow innovation [45].

7.6. Industry-led self-regulation

Aside from government-led actions, industry likely will be more proactive in self-regulation. By rolling their own compliance features like KYC and AML protocols, top crypto exchanges not limited to but including non-fungible token marketplaces, and BC platforms are fortifying confidence amongst users and heading off potential regulatory backlash. And it will likely continue, as BC companies race to define new baselines and best practices that meet a shifting regulatory landscape [45]. Self-regulation may even go so far as to include the environmental, social and governance (ESG) realm, wherein BC entities opt in best sustaining behaviour and report on their footprint. BC businesses can drive beneficial regulatory evolution by showing a genuine dedication to responsible business practice [18].

The future of BC assets in terms of regulatory frameworks will be interesting to watch as the same matures over time, and it will depend on a delicate balance between national, regional and international progress with individual concerns like consumer protection, financial stability, AML or KYC compliance, tax implications, environmental concerns or simply innovation. By understanding the shared challenges in regulating decentralized and borderless technologies, we can expect global cooperation from a variety of stakeholders including international organizations and the private sector to have an essential part in how BC assets are safely incorporated into the wider financial system in a secure, accountable, and innovative way [58].

8. Implementation, applicability, policy formulation, and validation analysis

The establishment of a robust and adaptable regulatory framework for BC assets necessitates careful consideration across several interconnected domains. These include the practical implementation of the framework, its applicability across diverse global contexts, the meticulous formulation of specific policies and rules, and a thorough validation analysis to ensure its effectiveness and relevance. Each of these areas is crucial for fostering a secure and innovative environment for BC technology.

8.1. Implementation of the future regulatory framework for BC assets

The successful implementation of a future regulatory framework for BC assets demands a well-defined, multi-phase approach that not only aligns with evolving global standards but also demonstrates sensitivity to the unique regulatory needs present at national, regional, and local levels. Given the inherent complexities of decentralized technologies, encompassing cryptocurrencies and NFTs, the overarching implementation strategy must skillfully balance the promotion of technological innovation with the imperative of ensuring robust consumer protection, maintaining financial stability, and rigorously combating money laundering (AML) activities.

1. Multi-Level Regulatory Approach

The regulatory framework's implementation will necessitate a coordinated effort across multiple levels of governance: local, national, and international. Adopting a harmonized approach is paramount to ensuring consistent regulation of BC assets while simultaneously accommodating the distinct legal and economic environments of various jurisdictions. Key implementation steps at each level include:

- **National Level:** Individual countries will be tasked with the critical responsibility of developing entirely new legislation or strategically adapting existing legal frameworks to effectively incorporate BC technology, particularly concerning cryptocurrencies, NFTs, and DeFi platforms. For instance, national tax authorities must provide clear and comprehensive guidelines on the taxation of BC assets, while financial regulators will need to rigorously enforce compliance with established AML and KYC protocols within the BC ecosystem. These national regulations will likely encompass detailed guidelines governing the issuance and utilization of digital currencies, stablecoins, and the operational standards for cryptocurrency exchanges. A particularly critical aspect of this national-level implementation will be the imperative to ensure that the enacted regulations are not unduly restrictive, thereby fostering an environment conducive to innovation while proactively preventing the potential for misuse and illicit activities [45].
- **Regional Level:** Collaborative efforts at the regional level, particularly within established economic and political blocs such as the EU or the ASEAN bloc, will prove essential in achieving regulatory alignment and effectively mitigating the risks associated with regulatory arbitrage. Policies formulated at the regional level should strategically focus on establishing shared standards for the transparent reporting of transactions, ensuring robust consumer protections across member states, and addressing the significant environmental considerations associated with BC technologies [52].
- **International Level:** Recognizing the inherently global nature of BC assets, robust international cooperation will be indispensable for the successful implementation of a comprehensive regulatory framework. Key international organizations, including the International Monetary Fund (IMF), the Financial Stability Board (FSB), and the World Bank, will play pivotal roles in the crucial tasks of crafting and facilitating the adoption of universal standards designed to effectively prevent regulatory gaps and inconsistencies. Furthermore, such high-level international cooperation will be absolutely critical in the effective implementation of AML and KYC regulations on a global scale, thereby ensuring that malicious actors cannot exploit the decentralized characteristics of BC technologies for illicit purposes [18].

2. Regulatory Sandboxes for Experimentation

To facilitate a seamless and well-informed introduction of the regulatory framework, the establishment of regulatory sandboxes is a highly valuable strategy. These controlled sandbox environments will provide a safe space for BC startups and more established organizations to rigorously test their innovative models and solutions under the direct oversight of regulators, but without the immediate and full burden of comprehensive regulatory compliance. By actively fostering a cooperative and communicative space between BC firms and regulatory bodies, these sandboxes offer invaluable insights into the practical operational challenges associated with effectively enforcing regulations within the dynamic BC ecosystem [45].

Furthermore, the strategic use of regulatory sandboxes actively promotes experimentation with novel regulatory techniques and technologies. This could include the testing of real-time transaction monitoring systems specifically designed for AML or KYC compliance or the development and refinement of standardized reporting platforms for tax compliance related to BC assets. Such proactive initiatives will be

absolutely key in ensuring that BC innovations can continue to flourish and evolve without undermining critical regulatory objectives, such as the maintenance of financial stability and the robust protection of consumers.

8.2. Applicability of the regulatory framework to different countries

Acknowledging the inherently global nature of BC assets, the proposed regulatory framework must possess a high degree of adaptability to accommodate the diverse legal systems, varying economic contexts, and differing levels of technological infrastructure present across different countries. The cornerstone of its broad applicability lies in its inherent ability to effectively incorporate specific local needs and priorities while steadfastly adhering to internationally recognized standards and best practices.

1. Emerging Economies

Middle-income and emerging economies including significant players like India, Bangladesh, Brazil, South Africa, Indonesia, and Kenya may benefit most from adopting a carefully planned phased implementation strategy. This approach would logically begin with the establishment of foundational regulatory elements, such as: Formal legal recognition and clear classification of various crypto-assets, the establishment of dedicated regulatory sandboxes to facilitate the testing and understanding of diverse digital asset applications and the introduction of basic and proportionate licensing structures for digital asset service providers operating within their jurisdictions.

This well-considered tiered approach empowers policymakers in these economies to effectively manage potential risks associated with BC adoption while simultaneously actively supporting the growth and development of local innovation ecosystems. For instance India's RBI and SEBI have proactively initiated sandbox environments and are actively exploring a unified and comprehensive approach to the regulation of crypto-assets. Bangladesh is strategically exploring the potential of BC technology for enhancing efficiency and security in areas such as trade finance and the digitization of public records. Brazil's CVM and central bank have already issued important guidance on the treatment of tokenized assets and have established crucial regulatory clarity surrounding payment-based tokens. Kenya's capital markets authority has actively encouraged open dialogue with relevant stakeholders while diligently assessing both the potential risks and the significant opportunities presented by .

This measured and pragmatic progression allows these emerging economies to build essential domestic capacity in BC regulation while concurrently preparing the groundwork for the subsequent adoption of more advanced and comprehensive components of the framework, such as sophisticated taxation policies, clear custodial regulations for digital assets, and effective cross-border reporting protocols.

2. Developed Countries

For nations with well-established and mature financial systems, the primary focus of the regulatory framework would necessarily need to be on effectively mitigating the potential risks associated with the increasing integration of cryptocurrencies and stablecoins into the broader economic landscape. This includes proactively addressing systemic risks that may arise from stablecoins pegged to fiat currencies and ensuring robust consumer protection against the inherent volatility often observed in cryptocurrency markets. Furthermore, these developed nations would require the implementation of advanced regulatory measures, including comprehensive compliance frameworks for tax reporting related to digital assets and stringent AML practices that align with international standards.

The EU's MiCA regulation already provides a robust and forward-looking foundation for crucial aspects such as asset classification, the obligations of digital asset issuers, and the regulation of stablecoins. Switzerlan's FINMA has established a clear and well-defined token taxonomy and has cultivated a supportive and innovation-friendly ecosystem for BC development. Singapore's MAS rigorously enforces a comprehensive licensing regime for digital asset service providers, implements robust KYC or AML protocols, and maintains one of the world's most active and influential regulatory sandboxes. These leading developed countries can effectively serve as benchmark jurisdictions, helping to shape evolving global norms and technical standards in BC regulation while actively facilitating policy diffusion through their participation in key international bodies such as the Financial Action Task Force (FATF), the International Organization of Securities Commissions (IOSCO), and the Bank for International Settlements (BIS).

3. Low-Capacity Jurisdictions

In least developed countries (LDCs) or jurisdictions with limited regulatory capacity and resources, BC technology can still be strategically harnessed to drive significant public sector transformation in key areas such as land registries, the implementation of secure digital IDs, enhancing supply chain traceability, and facilitating more efficient and transparent remittances. These jurisdictions can effectively adopt a more flexible and less burdensome "light-touch" regulatory approach, placing a strong emphasis on active collaboration with regional organizations and international development partners. Key strategies for these jurisdictions include: Utilizing template-based regulations that are thoughtfully adapted from established international standards like those provided by FATF and MiCA, actively participating in regional regulatory alliances or multilateral regulatory sandboxes to gain experience and share best practices, and relying on technical assistance and capacity-building support from prominent global institutions such as the World Bank, the IMF, or the International Telecommunication Union (ITU).

For instance Nigeria, despite implementing a ban on cryptocurrency trading, has strategically deployed a central bank digital currency (eNaira) with the primary goal of promoting greater financial inclusion among its population. Rwanda and Ghana have actively partnered with international bodies to pilot innovative BC-based projects within their respective public sectors. This collaborative and adaptable model ensures that even countries with limited resources and evolving regulatory institutions can foster safe and beneficial innovation in the BC space without overwhelming their existing regulatory capacity.

4. Centrally-Planned Economies

China represents a distinct and unique regulatory archetype, characterized by a strong emphasis on central planning and a "security-first" approach to technological adoption. While the country has implemented a comprehensive ban on cryptocurrency trading and mining activities, it actively promotes the application of BC technology within state-sanctioned applications and has taken a leading global role in the rollout of central bank digital currencies. The People's Bank of China has successfully developed and piloted the digital yuan (e-CNY), which is now increasingly integrated into mainstream payment systems within the country. The state-backed BC Service Network (BSN) supports the development of cross-border digital infrastructure, albeit within a tightly controlled framework dictated by the state. While DeFi and public crypto assets remain strictly prohibited, BC technology is being actively utilized in various sectors, including judicial systems, tax services, and logistics management.

8.3. Formulation of policies and rules

The meticulous formulation of specific policies and rules will constitute the fundamental backbone of the overarching regulatory framework, providing clear guidance for BC asset operations across

diverse sectors of the economy. These policies must be developed through a process of broad and inclusive consultation with a wide range of relevant stakeholders, including regulatory bodies, technology experts, financial institutions, and importantly, the consumers who will be directly impacted by these regulations.

1. **Clear Guidelines for Token Issuance and Trading**
   It is imperative to establish clear and unambiguous regulations governing the issuance and subsequent trading of BC-based tokens, with a particular focus on cryptocurrencies and NFTs. These regulations will need to mandate a high degree of transparency in all token offerings, ensuring that potential investors are provided with comprehensive and easily understandable information regarding the inherent risks involved. Token issuers may be required to disclose critical details such as the specific purpose of the token, its potential for value fluctuations, and a clear articulation of the risks associated with its acquisition and use.
2. **Environmental Standards for BC Mining**
   The significant environmental footprint associated with certain BC technologies, particularly those relying on energy-intensive mining operations, has emerged as a major concern for policymakers and the public. Regulatory policies should proactively establish clear thresholds and standards for the energy consumption of BC networks, actively encouraging the widespread adoption of more energy-efficient consensus mechanisms, such as proof-of-stake, as alternatives to the more energy-intensive proof-of-work. Governments may also consider the implementation of carbon taxes or the imposition of caps on electricity consumption for mining operations as effective mechanisms to incentivize the adoption of more eco-friendly mining practices within the BC industry [45].
3. **AML or KYC Regulations for Decentralized Platforms**
   Given that BC technologies often operate within inherently decentralized environments, the regulatory framework must develop and implement innovative mechanisms to effectively ensure compliance with established AML and KYC standards without unduly compromising the fundamental decentralized principles that underpin BC technology. Well-designed policies could potentially require decentralized exchanges (DEXs) and other decentralized platforms to implement identity verification procedures during critical phases of transactions, while still respecting users' privacy and autonomy to the greatest extent possible [18].

8.4. *Validation analysis of the framework*

To rigorously ensure the overall effectiveness and long-term viability of the proposed regulatory framework, a comprehensive validation analysis will be an absolutely necessary and ongoing undertaking. This critical analysis will systematically assess the framework's ability to successfully achieve its stated objectives, which include the significant reduction of fraudulent activities, the enhancement of financial stability within the digital asset ecosystem, and the robust promotion of consumer protection.

1. **Impact Assessment**
   The initial and crucial step in the validation process involves a thorough evaluation of the potential impact of the regulatory framework on various key stakeholders. This includes a detailed analysis of the effects on consumers, BC companies operating within the regulated space, traditional financial institutions that may interact with BC assets, and the regulatory bodies themselves responsible for enforcement. This impact assessment can be effectively conducted through the use of carefully designed case studies, sophisticated simulations of market behavior under the new regulations, and well-executed pilot projects that test the practical application of the framework in diverse jurisdictions. For example, countries that have already taken proactive steps to implement BC regulations, such as Estonia or Switzerland, could serve as valuable real-world test cases for validating the broader applicability and effectiveness of the proposed framework.
2. **International Validation**
   Recognizing the global nature of BC technology, the validation process must also incorporate significant international cooperation to rigorously test the framework's applicability and effectiveness across different national contexts. Regulatory bodies from various countries can engage in collaborative efforts to evaluate how well the framework integrates with their existing local regulatory structures and to identify opportunities for further harmonization with evolving international standards. This collaborative approach would involve the active sharing of relevant data, valuable experiences gained during implementation, and identified best practices to iteratively refine and improve the framework over time [58].
3. **Continuous Monitoring and Adaptation**
   The regulatory framework must be inherently flexible and possess the capacity to adapt proactively to the rapidly evolving nature of BC technology and its diverse applications. As new and innovative use cases and applications of BC emerge, regulators must maintain the agility to modify existing rules or introduce entirely new policies to effectively address any emerging risks or capitalize on newfound opportunities. Ongoing monitoring and rigorous evaluation, combined with periodic comprehensive reviews of the framework, will be essential to ensure that it remains relevant, effective, and fit-for-purpose in the face of continuous technological advancements within the BC space.
4. **Feedback Mechanisms**
   It is absolutely essential to establish robust and accessible feedback loops that allow all relevant stakeholders to voice their concerns, share their practical experiences with the framework, and suggest potential improvements based on their insights. These crucial feedback mechanisms can be effectively incorporated through various channels, including regular public consultations, dedicated industry forums that bring together regulators and industry participants, and ongoing, open dialogue between regulatory authorities and industry leaders. The insights gained through these feedback mechanisms will be invaluable in ensuring the long-term effectiveness and legitimacy of the regulatory framework.

The journey towards a well-defined regulatory landscape for BC assets is a multifaceted and ongoing endeavor. The success of this endeavor hinges on a thoughtful and adaptive approach to implementation, a keen understanding of diverse global contexts, the meticulous crafting of clear and effective policies, and a commitment to rigorous validation and continuous improvement. By addressing these interconnected elements comprehensively, we can foster an environment that encourages responsible innovation, protects consumers, and ensures the long-term stability and integrity of the financial ecosystem in the age of decentralized technologies.

9. Conclusion and policy recommendations

This study explores the global regulatory landscape of BC assets, particularly cryptocurrencies and NFTs, with the objective of understanding policymakers' motivations and the challenges they face in crafting balanced governance. Employing a conceptual and mixed-method approach, it integrates qualitative and quantitative content analysis of 59 peer-reviewed sources selected using the PRISMA framework. The findings reveal that regulatory efforts are primarily driven by concerns over consumer protection, financial stability, AML or KYC compliance, tax transparency, and environmental sustainability.

Jurisdictional responses vary significantly, ranging from the EU's harmonized MiCA framework to the fragmented and enforcement-centric approach in the US, as well as diverse strategies across Asia. The study highlights key challenges, including the decentralized and borderless nature of BC assets, difficulties in legal classification, the rapid pace of technological change, and the tension between innovation and oversight. The contribution of this study is its comparative analysis of global regulatory approaches to BC assets, highlighting how jurisdictions like the EU, the US, and various Asian nations are addressing cryptocurrencies and NFTs. The research provides practical insights into the trade-offs between fostering innovation and ensuring consumer and market protection. It emphasizes the importance of international cooperation to prevent regulatory gaps and suggests tools such as regulatory sandboxes and industry self-regulation to enable safe experimentation. The study also proposes phased, adaptable models for developing countries, making the findings relevant across different legal and economic contexts. By integrating legal, technical, and policy perspectives, it offers a balanced foundation for designing effective and forward-looking BC regulations. However, this study is limited by its dependence on secondary sources, the lack of real-time data on policy outcomes, and the fast-paced evolution of BC technologies that can surpass current regulatory efforts. To address these gaps, future research should prioritize empirical studies and adaptive policy modeling to support more responsive and effective global governance of digital assets.

9.1. Policy recommendations

To effectively govern the rapidly evolving BC asset ecosystem while fostering innovation, financial integrity, and global trust, policymakers must adopt a holistic and adaptive regulatory framework. This framework should be grounded in a multi-layered strategy that balances innovation with oversight, enabling technology to thrive without compromising systemic safety, investor protection, or environmental sustainability. Firstly, regulatory approaches must emphasize harmonization and interoperability across borders, as the decentralized and transnational nature of BC assets, such as cryptocurrencies and NFTs, renders unilateral regulation insufficient. Global coordination through platforms such as the Financial Action Task Force (FATF), IMF, and Financial Stability Board (FSB) is critical to developing baseline global standards, especially for AML, KYC, and stablecoin reserve requirements.

Secondly, national governments should implement tiered regulatory models based on their technological maturity, market size, and legal traditions. Emerging economies may benefit from phased adoption strategies, starting with legal recognition of BC assets, introducing licensing for service providers, and launching regulatory sandboxes to foster innovation while monitoring risk. In contrast, developed economies must focus on strengthening compliance mechanisms, introducing stablecoin audits, integrating DeFi protocols into existing oversight systems, and mitigating systemic risks associated with mainstream adoption. Third, regulatory sandboxes should be institutionalized globally to enable real-time experimentation and collaboration between innovators and regulators. These environments would allow startups and developers to test products under controlled conditions, generating insights that inform flexible, forward-looking policy. Fourth, environmental sustainability must become a non-negotiable regulatory pillar. With increasing global concern about the energy consumption of Proof-of-Work-based BC, regulators should incentivize the shift toward greener consensus mechanisms like Proof-of-Stake (PoS), mandate carbon footprint disclosures, and explore energy-use taxation or credits for BC operators.

Fifth, tax compliance and reporting mechanisms need to be standardized internationally to prevent tax evasion and close regulatory loopholes. Policymakers should enforce mandatory transaction reporting thresholds, automatic gains or loss tracking, and cross-border cooperation for digital asset tax enforcement. Sixth, asset classification clarity is essential. Policymakers must eliminate ambiguity in categorizing tokens as securities, commodities, or utility assets to prevent overlapping jurisdictions and provide legal certainty to businesses and investors. This includes establishing uniform definitions for NFTs, stablecoins, and DAO governance tokens. Seventh, regulators must embrace technological solutions for decentralized compliance, particularly in DeFi ecosystems. This may involve the deployment of zero-knowledge proofs for identity verification, AI-powered transaction monitoring systems, and integration of smart contract audit standards. Eighth, consumer protection must be central to all policy efforts, especially as retail participation in BC markets increases. Transparent disclosures, financial literacy programs, insurance schemes for exchanges and custodians, and redressal mechanisms for scams and fraud are essential for maintaining trust.

Ninth, data privacy and digital rights must be protected, even while enhancing transparency. Regulations should strike a balance by enforcing KYC requirements in centralized venues while promoting privacy-preserving tools in decentralized settings. Tenth, self-regulation should be encouraged through the formation of accredited industry bodies that establish ethical codes, dispute resolution systems, and voluntary compliance standards. This approach not only fosters accountability but also eases regulatory burdens by promoting industry alignment. Finally, to validate and evolve these regulatory efforts, policymakers must invest in continuous evaluation and capacity-building. This involves real-time data collection, longitudinal impact studies, and regular stakeholder engagement to ensure that regulations remain relevant, effective, and inclusive. Tailored training programs for regulators in low-capacity regions, cross-border pilot projects, and inclusive dialogue with developers and users should be institutionalized. In sum, only through a balanced mix of flexibility, coordination, innovation enablement, and stringent oversight can the global community craft a resilient, fair, and future-ready regulatory regime for BC assets that protects stakeholders, strengthens financial systems, and harnesses the full potential of decentralized technologies.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used Grammarly in order to correct grammatical mistake. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

CRediT authorship contribution statement

Junaid Rahman: Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Conceptualization, Data curation, Formal analysis. **Hafizur Rahman:** Writing – review & editing, Writing – original draft, Visualization, Validation. **Naimul Islam:** Writing – review & editing, Writing – original draft. **Tipon Tanchangya:** Writing – review & editing. **Mohammad Ridwan:** Writing – original draft. **Mostafa Ali:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Also, authors declare that they have no conflict of interest.

Appendix

Table 8

Table 8
List of abbreviations.

BC	Blockchain
NFTs	Non-Fungible Tokens
BCT	Bitcoin
Eth	Ethereum
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
DeFi	Decentralized Finance
KYC	Know Your Customer
AML	Anti-Money Laundering
CBDC	Central Bank Digital Currency
MiCA	Markets in Crypto-Assets Regulation
EU	European Union
USA	United State of America

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