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Article

The regulatory puzzle of decentralized cryptocurrencies: Opportunities for innovation and hurdles to overcome

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Abstract: Decentralized cryptocurrencies, such as bitcoin, use peer-to-peer software protocol, disintermediating the traditional intermediaries that used to be banks and other financial intermediaries, effectuating cross-border transfer. In fact, by removing the requirement for a middleman, the technology has the potential to disrupt current financial transactions that rely on a trusted authority or intermediary operator. Traditional financial regulation, primarily based on the command-and-control approach, is ill-suited to regulating decentralized cryptocurrencies. The present paper aims to investigate the policy option most suitable for regulating decentralized cryptocurrencies. The study employs content analysis method to effectuate the purpose of the study. The paper argues that the combination of both direct and indirect regulatory approaches would be a feasible option for regulating decentralized cryptocurrencies. The absence of centralized authority and the borderless nature of decentralized cryptocurrencies would make them antithetical to centralized direct regulation. Therefore, the findings of the study suggest that regulators should focus on regulating intermediaries bridging the connection between the online world (crypto ecosystem) and the physical world (the point of converting crypto into fiat money). These intermediaries can work as passive actors or surrogate regulators who are indirectly responsible for implementing policy options on behalf of the central authority.

Keywords: cryptocurrency; decentralization; banking; regulation; bitcoin; blockchain; money; virtual currency

1. Introduction

Since the launch of Bitcoin, cryptocurrency has emerged as one of the innovative financial technologies (FinTech), holding the lofty promise of removing intermediaries like banks and solving the double spending problem. Cryptocurrencies, such as FinTech, devise to reduce transaction costs, facilitate risk management, complete incomplete markets by resolving intermediary costs emanating from information asymmetry, and evade taxes and regulations or engage in regulatory arbitrage (Wu and Duan, 2019). Not long before, cryptocurrency was expected to bring a paradigm shift to the monetary system. Still, no concrete proof exists of how much it will transform the current financial system. However, despite being volatile in nature, Bitcoin has achieved relative success in establishing itself as a store of value (Nabilou, 2019).

Cryptocurrencies use peer-to-peer software protocol disintermediating the traditional middleman that used to be banks and other financial intermediaries, effectuating cross-border transfer. The most dominant cryptocurrency that laid the foundation for all the existing cryptocurrencies is Bitcoin. Blockchain, a distributed

ledger technology (DLT), is the underlying technology for creating, distributing, trading, and storing Bitcoin. The white paper on Bitcoin postulates a solely "peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution" (Nakamoto, 2008). DLT presents an opportunity to create new legal frameworks, resulting in new substantive legal issues and changes in legal culture and structure (Reyes, 2017).

One of the prime advantages of blockchain or decentralized finance is that it invents "trustless technology" (Scott, 2015) or "trustless machine" (The Economist, 2015) in the cryptocurrency ecosystem that eliminates the requirement for trusted intermediates so long as the underlying technology can be trusted (Brito and Castillo, 2013). But such a lofty promise of complete decentralization is challenging to explain in an industry rife with opaque neologisms (Favole, 2021). Despite significant cryptographic advancements, the inability to ensure compatibility between centralization, anonymity, and double-spending protection ultimately called into question the feasibility of this new type of currency. Further, there is no consistent or unified definitional category of cryptocurrency, another pivotal issue in regulating cryptocurrencies in addition to their presence in the international and multijurisdictional arena (Allen et al., 2020).

As decentralized cryptocurrencies rely on open-source protocols, introducing and implementing a traditional direct, centralized regulatory framework means targeting computer code or protocol implemented to transact cryptocurrencies. Instead, regulators should shift their focus to intermediaries effectuating crypto transactions in the real world. Unlike intermediaries in the traditional financial system, a new set of middlemen come to the surface to facilitate cryptocurrency transactions which are offering "convenience, market access. transaction scale and liquidity" to the cryptocurrency market in the same fashion "as in commercial banking and securities trading" (Auer et al., 2022).

Consequently, the question arises what regulatory scheme, centralized or decentralized, would be the best possible option to regulate cryptocurrencies? The answer to this question is not easy to articulate. Literature suggests that various regulatory approaches, from outright interdiction (Hsu, 2017; Xie, 2019) to self-regulation or no regulation (Karel et al., 2021; Pavlidis, 2021; Zetzsche et al., 2021), are introduced or implemented by different jurisdictions. These divergent regulatory approaches would not yield satisfactory results in regulating cryptocurrency. Developing a more cohesive and comprehensive legal framework and regulatory perspectives for cryptocurrencies continues to lag. The divergent regulatory approach is partly due to the difficulty of reconciling divergent opinions among regulators, the regulated, and associated legal authorities across multiple jurisdictions regarding the nature and functionality of the cryptocurrency. This study offers essential guidance for regulators and policymakers in crafting a tailored regulatory framework for decentralized cryptocurrencies. It addresses a significant gap in current literature by presenting a conceptual framework to assist policymakers and regulators in developing cryptocurrency regulations, thereby contributing substantially to the discourse on cryptocurrency governance.

The present paper argues complete decentralization is an illusion, whereas regulating decentralized cryptocurrencies through traditional centralized regulation

would encounter several practical hurdles due to a lack of trusted third-party. The paper argues that neither a completely centralized nor a fully decentralized regulatory approach is practical for cryptocurrency regulation. This stance is supported by two key reasons: firstly, the necessity for regulators to monitor operations within decentralized organizations, and secondly, the need to establish an authoritative body responsible for enforcing laws and providing remedies in cases where decentralized cryptocurrency operators violate these laws. This highlights the complexity and unique requirements of regulating the cryptocurrency sector. Therefore, this paper aims to show that both centralized direct and decentralized indirect regulatory approaches are needed to regulate decentralized cryptocurrencies. The traditional direct regulatory approach will incentivize the central banks and other central financial authorities with the supervision power to oversee the financial institutions involved in transacting with decentralized cryptocurrencies.

In contrast, decentralized indirect regulation will help to bring the intermediaries, such as banks, payment institutions, cryptocurrencies exchange institutions, wallets providers, and cryptocurrency ATMs, involved with the cryptocurrency ecosystem under the regulation by making them surrogate regulators or passive actors of regulatory action who will effectuate centralized policy objectives. The unique characteristics of decentralized cryptocurrency placed itself in an advantageous position over traditional payment systems. Therefore, the policymaker should consider a combination of approaches and actors to help regulators empower relevant parties with the appropriate authority to implement the policy goals.

The paper proceeds as follows. The first section illustrates related studies relating to cryptocurrency to narrow the research gap. The third section outlines the methodology of the study. The paper advances with the regulatory schemes adopted by major jurisdictions or recommended by various scholars and international organizations to develop the most coherent regulatory strategies for cryptocurrencies in section four. In sections five and six, the paper further illustrates the challenges of regulating decentralized cryptocurrency through direct or traditional command-control regulation and how such direct regulatory intervention could stifle this novel technology. Section seven of the paper sheds light on the potential regulatory avenue for regulating decentralized cryptocurrency. Finally, the paper presents some concluding remarks.

2. Literature review

Cryptocurrencies have prompted regulatory changes due to their significant social, financial, technological, and legal implications. The emergence of FinTech products has unlocked numerous opportunities for consumers, investors, and businesses. However, along with these opportunities, regulators and policymakers are faced with new challenges, such as money laundering (Hossain, 2023; Nabilou and André, 2019; Sultan et al., 2023; Vandezande, 2017), financial stability (Ayadi et al., 2023; Huang and Mayer, 2022; Nabilou and André, 2019; Prasad, 2018), consumer and investor protection (Didenko and Buckley, 2022; Eichengreen and Viswanath-Natraj, 2022; Hassan et al., 2022; Spaeth and Peráček, 2022), and financial technology (FinTech) play crucial roles in driving the need for cryptocurrency regulation.

Several authors in their scholarly writing discussed benefits and concerns from different angles, for instance, how to regulate the underlying technology (Priem, 2020; Wexler et al., 2018; Wright and De Filippi, 2015; Zetzsche et al., 2017), its myriad uses (Brito et al., 2014; De Filippi, 2014; Tu and Meredith, 2015), and disruptive nature of this technology (De Filippi, 2014; Fairfield, 2014, 2015). Some authors focus on illegal activities effectuating through cryptocurrencies, cybercrimes (Chawki, 2022; Dhali et al., 2023; Foley et al., 2019; Kethineni and Cao, 2020), anti-money laundering, and combating financial crimes (Beessoo and Foondun, 2019; Braeden, 2018; Haffke et al., 2020; Hossain, 2023; Vandezande, 2017). Other authors discussed the regulation of central bank digital currency (Bech and Garratt, 2017; Bossu et al., 2020; Daniel Broby and Baker, 2018; Didenko and Buckley, 2022; Isaac and Ostroff, 2020; Mookerjee, 2021; Nabilou and André, 2019; Ward and Rochemont, 2019), initial coin offering (Caliskan, 2022; Cumming et al., 2019; Feinstein and Werbach, 2021; Huang, 2022; Millard, 2018; Senarath, 2022), taxation (Ali, Naseem, et al., 2022; Al-Shikarchy and Gheorghiu, 2017; Caliskan, 2022; Matsushita, 2023; Nivedha, 2022; Sutherland, 2019; Wronka, 2023), and decentralized finance (Johnson, 2021; Jones, 2021; Ozili, 2022; Wronka, 2023; Zetzsche et al., 2020).

Furthermore, few authors specifically focus on the regulatory aspect of cryptocurrencies as Dennis Chui suggested following the traditional regulation of broker-dealers as a guide to regulate cryptocurrency platforms (Chu, 2018). The author explained how cryptocurrency platforms function as broker-dealers for cryptocurrencies by acting as custodians for customer assets and executing trades for their customers. Therefore, the author argued that as cryptocurrency platforms work like traditional broker-dealers in security investment, these platforms could be regulated like broker-deals regardless of whether cryptocurrencies are considered securities. Johnson (2021) recommended introducing formal registration obligations for the exchange platforms providing a marketplace for secondary market trading. Sonksen advocated that the most effective approach to regulating cryptocurrencies involves implementing a proactive regulatory framework that prioritizes enhancing access to cryptocurrency investments while concurrently safeguarding investors through measures like certifying exchanges (Sonksen, 2021). Both authors basically emphasized regulating the secondary market trading of cryptocurrencies. While mandatory registration may control centralized exchanges to some extent, decentralized exchanges operate in a decentralized manner, making it challenging to regulate them solely through platform registration.

Gikay contended, while discussing E.U. law that it is unfeasible to develop a distinct payments services law tailored specifically for cryptocurrencies without impeding their fundamental characteristics, particularly decentralization. Therefore, centralization and the establishment of a state-backed cryptocurrency as potential pathways for future progress, analyzing their merits and the challenges they entail (Gikay, 2018). Gikay's suggestion would basically mean killing the distinctive main feature, i.e., decentralization of cryptocurrency. The prime purpose of any regulation should flourish the emerging technology, not stagnate it. At the same time, Reyes recommended introducing a unique "crypto-legal structures" framework: the ability to establish and enforce legal frameworks for any domain by utilizing smart contracts executed by semi-autonomous cryptographic computer code (Reyes, 2017). Although

smart contracts offer benefits in automating specific transactional aspects, they do not offer a comprehensive solution for regulating cryptocurrencies. A more effective approach to cryptocurrency regulation is the integration of smart contracts with traditional legal mechanisms and regulatory oversight, forming a robust framework.

On the other hand, Kevin and Michael suggested adopting comprehensive law by refocusing on the array of policy objectives outlined in existing laws, and policymakers gain an extra tool to support the formulation of a comprehensive, unified, and appropriately tailored regulatory framework for virtual currencies (Tu and Meredith, 2015). The suggestion of the comprehensive law looks promising. Still, it has several challenges that make it difficult to achieve due to the diverse nature of cryptocurrency, the rapidly changing nature of technology, global jurisdictional variations, and the complex interdisciplinary nature of cryptocurrency.

Observing the effects of cryptocurrency utilization on the financial system, the emergence of novel start-ups utilizing cryptocurrency, and the rise in cryptocurrency-related cybercrimes, we have noticed a gap in the literature concerning cryptocurrency regulation that sheds light on proper regulatory pathways for regulating decentralized cryptocurrency. The present study uncovers a legal landscape characterized by increased convergence among legal systems, streamlined substantive laws, the emergence of novel regulatory entities, a legal culture deeply impacted by computer software developers and a diminishing disparity between the implementation of laws and their formal codifications. This article introduces a conceptual framework for a new legal discourse and jurisprudence, aiming to fundamentally transform the implementation, development, citizen experience, and legal adjudication. This innovative approach is designed to reshape the way law is understood and practiced.

3. Methodology

The study has used the content analysis method to investigate and understand the insight of existing laws, regulations, policy related cryptocurrency. Systemic analysis of the legal texts provides valuable insight that helps refine the diverse difficulties policymakers and decision-makers encounter (Bar-Ziv, 2021). It asserts that this methodology is well-suited for adoption by legal scholars, facilitating the examination of diverse legal texts to reveal their interconnections and gain an understanding of their significance (Zaring, 2006). This approach can enhance the comprehension of the evolution of legal norms, enabling one to understand better and navigate the legal landscape, which promotes legal certainty. As mentioned earlier, the present study aims to assess and examine the potential legislative approach to regulate decentralized cryptocurrency. The existence of divergent regulatory approaches is partially attributed to the challenge of reconciling disparate viewpoints among regulators, regulated entities, and relevant legal authorities in multiple jurisdictions concerning the inherent characteristics and operational aspects of cryptocurrencies. Therefore, in order to effectuate the purpose of the present study, it is imperative to examine different regulatory approaches adopted by various regulatory authorities to regulate cryptocurrency and to analyze these divergent regulatory initiatives, the author has used a secondary database. The author utilized various databases such as Scopus, Web of Science, PubMed, ScienceDirect, DOAJ, JSTOR, and Google Scholar to access

published scientific articles. The study adheres to the recommendations by scholars, specifically emphasizing peer-reviewed journal articles as they exhibit the highest level of research rigor (Kelly et al., 2014; Severin and Chataway, 2021). This is crucial as academia and practitioners rely on such articles to obtain and disseminate information and explore new discoveries (Mulligan, 2005).

In addition, we relied on Google to access gray literature such as reports from international organizations (OECD, BIS, IMF, FSB), white papers, conference papers, and patents and technical standards information and review the reference lists of the papers examined. The reason for utilizing gray literature is that gray literature plays a valuable role in mitigating publication bias, enhancing the thoroughness and timeliness of reviews, and cultivating a balanced understanding of the available evidence (Nair and Borkar, 2023; Paez, 2017).

4. Overview of present regulatory strategies and techniques for regulating cryptocurrency

Cryptocurrency has emerged as the most niche and parochial industry, now believe in having a significant impact on banking, monetary policy, and overall financial stability (European Central Bank, 2012; Nabilou and André, 2019; Nabilou and Prüm, 2018; Prasad, 2018). The potential impact of cryptocurrencies on the traditional financial system is not hypothetical. There are nearly 22932 cryptocurrencies (Hicks, 2023), and 600 cryptocurrency exchanges worldwide (Paz, 2022; Powell, 2023; Tepper and Schmidt, 2022). The crypto market experienced a 64% decline from $2.31 trillion at the beginning of 2022 to $829 billion at the year-end, owing to a series of setbacks (CoinMarketCap, 2023). In January 2023, the total market capitalization for cryptocurrencies finished positively, reaching $1.07 trillion. In January 2023, the entire volume of spot crypto trading amounted to $1.88 trillion, a 50% increase from the $1.25 trillion recorded in December 2022 (CoinMarketCap, 2023). **Figure 1** shows the top ten cryptocurrencies by market share. Bitcoin is still holding the dominant position in the market followed by Ethereum, Bfinance Coin, Tether, Solona, Carsano, XRP, Polkadot, USD Coin, and Dogecoin.

Every 24 hours, USD 94 billion worth of cryptocurrencies are traded (Kathryn et al., 2022). Further, in the last two years, the value of cryptocurrencies increased tenfold, peaking at USD 2.8 trillion, and assets locked in the DiFi space soared 180 times, reaching USD 109 billion (Boissay et al., 2022). In 2023, the number of cryptocurrency users are more than 420 million (Crypto.com, 2023), and it is expected to be 994.30 million by 2027 (Statista, 2023). **Figure 2** shows the total cryptocurrency owner worldwide by region. More than 18000 businesses accept cryptocurrency payments, including big companies like Microsoft, Paypal, Tesla, Starbucks, and Cheapair (Banguis, 2022).

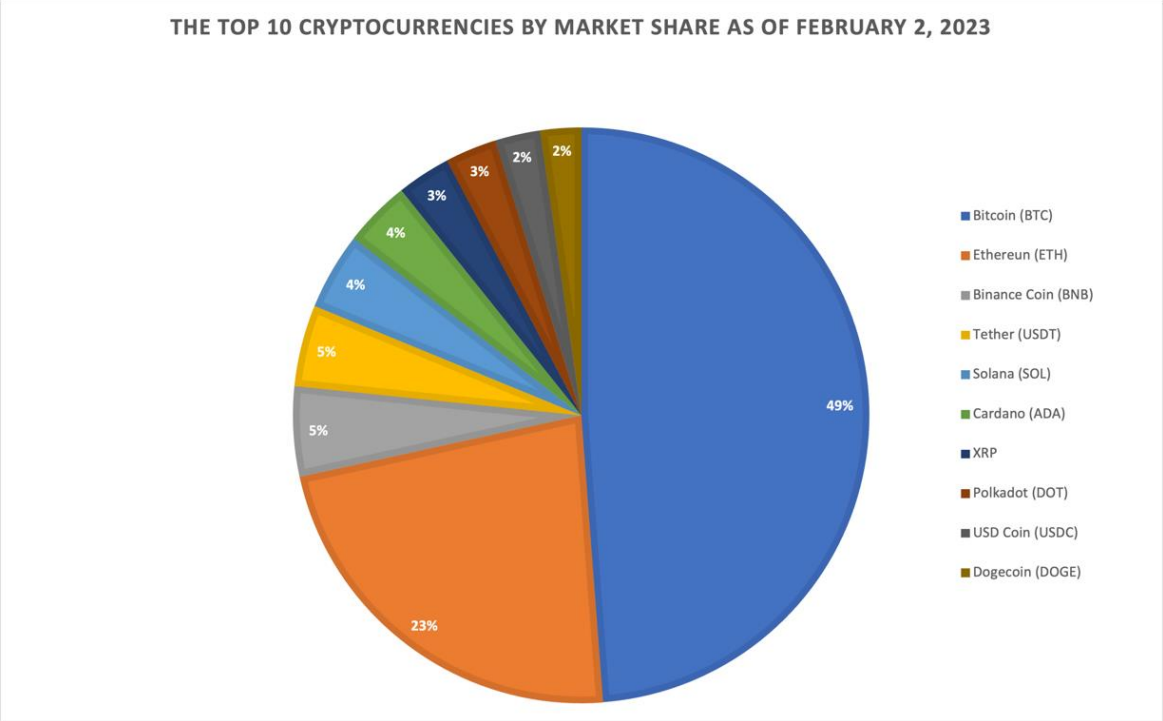

Figure 1. The top 10 cryptocurrencies by market share (CoinMarketCap, 2023).

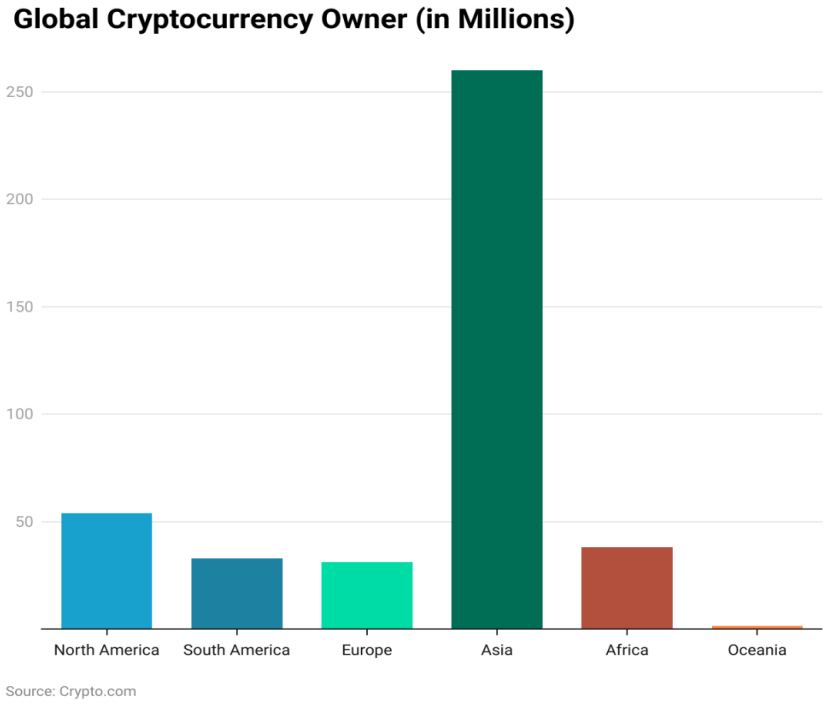

Figure 2. Global cryptocurrency owner (Crypto.com, 2023).

Those figures, on the one hand, are astounding given that cryptocurrencies are still in an early stage of development and acceptance. On the other hand, these statistics are alarming, considering cryptocurrencies are subjected to very little regulatory oversight. The rising interconnection between the existing financial system and the expanding crypto ecosystem raises concerns about spillover effects that could threaten systemic stability (Kathryn et al., 2022). For the time being, cryptocurrency has been

portrayed as a tool for diversification. Now it is becoming a concern for regulators. Scholars, regulators, investors, and blockchain proponents alike engage in the heated debate about what would be the most suited regulatory approach for cryptocurrency regulation. Some of the most outspoken critics, like Nobel Laureate Joseph Stiglitz, urge an outright ban on cryptocurrency (Hochstein, 2017), while others favor a more or less flexible regulatory structure (Atzori, 2017; Bollen, 2016; Grinberg, 2012). On the other hand, there are arguments that cryptocurrencies should not be regulated in any way (Davidson and Block, 2015).

The problem of regulating decentralized cryptocurrency is also exacerbated by border problems. Goodhart and Lastra illustrated two border problems after the global financial crisis: i) the border between regulated and unregulated entities and between regulated and unregulated activities, and ii) the border between national jurisdictions (Goodhart and Lastra, 2010). The extraterritorial nature of cryptocurrency and the national basis of regulatory oversight has become a practical impediment to regulating cryptocurrency. It would be difficult for regulators to develop a comprehensive regulatory approach without synergizing the virtual and financial system with the real-world financial system. Cryptocurrency emerges intending to operate in a non-jurisdictional space (that means cyberspace) by devising automated and decentralized protocols that substitute traditional financial structures in a manner that disrupts the traditional regulatory model (Fairfield, 2014, 2015; Kaal and Vermeulen, 2016). Cryptocurrency poses a significant virtual border problem since its issuing and controlling agency is difficult to trace immediately. Mersch opines that as a distributed software program, Bitcoin will be highly resistant to direct regulation initiatives so long as a community of users respects the service's features (Mersch, 2018).

It is challenging to maintain borderlines when unregulated entities in cyberspace interact with regulated entities in the real world. The exterritorial nature and ubiquitous presence of cryptocurrency present several potential risk factors or externalities to the real world. Such externalities range from fraud (Gandal et al., 2018) to money laundering (Bryans, 2014; Europol, 2016, 2021; Ogunbadewa, 2014), consumer protection (Hofert, 2019), taxation concern (Bal, 2015; Sutherland, 2019), market abuse (Griffin and Shams, 2020), financial crimes, (Choo, 2015; Stokes, 2012), monetary policy (Chorzempa, 2021), and financial stability (European Central Bank, 2012; Panetta, 2022). These concerns have few policy implications around the time of surfacing cryptocurrency. However, presently these challenges seem to have a tangible impact on the financial system considering the adoption, growth, and market size of cryptocurrencies. The challenges also include using common standards and interoperability, governance and privacy issues (De Filippi, 2016), access to central bank money, and scalability (Chen, 2021; Vansh, 2020).

These multifaceted challenges also lead central banks worldwide to introduce their digital currency to minimize the risks of cryptocurrency in the overall financial system. Central bank digital currency (CBDC) issuance has its own potential risks (Adrian and Mancini-Griffoli, 2019; Ali et al., 2019; Broby and Baker, 2018; Panetta, 2022). These potential challenges around cryptocurrency invoke the appeal for the re-examination of the legal status of cryptocurrency and accommodating it within the current regulatory framework. There is no uniform method of categorizing cryptocurrency (Gikay, 2018), which is another barrier to regulating cryptocurrency

in the international and multijurisdictional arena (Allen et al., 2020). Even though the term currency is attached to cryptocurrency, there is broad consensus it does not qualify as currency. Some argue that it should be treated as money (Pacy, 2014a), while others argue that it should be treated as a commodity or means of online exchanging goods and services (Prentis, 2015).

The myriad nature along with price volatility (Mann, 2022) of cryptocurrencies and their potential impact on the financial system have caught the attention of financial and security crime enforcement agencies, including law enforcement agencies (European Securities and Markets Authority, 2017) (i.e., banking and security agencies and commodity market regulating agency) to regulate cryptocurrencies. Until recently, regulators of major jurisdictions have adopted a wait-and-see approach or tried to fit within the existing regulatory framework or constructed 'sandboxes' (Frankenfield, 2020) in which developers of cryptocurrencies can innovate and experiment under the supervision of the regulator. At the same time, some jurisdictions ended up banning cryptocurrencies in anticipation of minimizing financial instability. Such extreme measures of outright interdiction lead crypto businesses to shift their activities to more favorable jurisdictions with less regulatory restriction.

So far, the regulatory response has been sporadic, rhetorical, and in some cases, enforcement driven. Combating the challenges in such a new and disruptive area will undoubtedly take years. Most jurisdictions are still developing regulatory frameworks while imposing restrictions depending on the nature of the uses of cryptocurrencies, such as payments, investments, derivatives, and tax status. The ambiguous nature and a lack of standardized definition lead major jurisdictions to implement overlapping regulatory measures. The current regulatory measure is apparently failing to regulate cryptocurrencies, given that cryptocurrencies are a global phenomenon, and their underlying technologies can be productive in the financial sector and other areas.

The traditional centralized system of regulation is primarily based on command and control (CAC) regulation by the state by using legal rules backed by sanctions (Black, 2019) mechanisms ought not to be feasible for cryptocurrency regulation due to its decentralized nature. Traditional finance is facilitated by a series of intermediaries that centralize functions and financial resources. The work of these financial intermediaries is based on trust and confidence "underpinned by law: rules, institutional regulation, and courts" (Zetzsche et al., 2020). The prime challenge in regulating cryptocurrency is the absence of any concentrated intermediaries similar to the traditional financial system. Although the traditional financial system evolved through the private ordering and self-regulatory frameworks, over time, the state started taking an increasing role due to the failure of the private ordering and self-regulatory approach (Zetzsche et al., 2020). Thus, the traditional financial system is created a single point of failure.

The cryptocurrency ecosystem emerges with the idea of eliminating traditional centralized governance structures, euphemistically called decentralized finance or DeFi. Traditional hub and spoke regulatory mechanisms basically indicate a direct regulatory approach. Regarding regulating cryptocurrencies, a direct regulatory approach means regulating protocol or code, developers, miners, and users. On the other hand, indirect regulation will focus on legitimate users as shadow agents or passive agents of regulatory effort. The unique structure of cryptocurrency introduces

a number of new financial intermediaries, such as wallet providers, exchangers of cryptocurrency to fiat currency, and trading platforms. Although cryptocurrency surfaces with the promise to disintermediate third parties while doing any transaction, it is implausible that cryptocurrency will ever eliminate intermediaries completely (REIFF, 2021). Therefore, targeting intermediaries would be feasible to regulate decentralized cryptocurrency rather than focusing on the miner and developers whose identities are mostly unknown. The following section will discuss the complicacy of regulating cryptocurrency by centralized regulation.

5. Centralized regulation of cryptocurrency and its pitfall

The combination of anonymity and the decentralized nature of cryptocurrency poses governments with formidable challenges in regulating cryptocurrency in the traditional centralized fashion. As all cryptocurrencies rely on the distributed ledger, they can be classified into two categories depending on the updating mechanism of the ledger.

The traditional "command and control" or "spoke and hub" governance mechanism to enforce normative obligations would not be suitable for decentralized cryptocurrencies. The prime question of regulating cryptocurrency is who to regulate and who should regulate it. Given the lack of consensus on the fundamental nature of cryptocurrencies, a uniform approach to their regulation remains elusive. This ambiguity in defining cryptocurrencies complicates the creation of standardized regulatory frameworks, necessitating a more nuanced and adaptable approach to their governance (Prasad, 2018). Various government entities, including tax authorities, securities exchange commissions, banking and financial institutions regulators, and commodity market overseers, have each approached cryptocurrency in diverse ways. This variation in treatment reflects the multifaceted nature of cryptocurrencies and the differing priorities and mandates of these regulatory bodies (Hewitt, 2016; Howden, 2015). The current effort of regulating can be defined as clarification of existing law as applied to virtual currency, the action being taken by each regulatory body independently empowered with implementing the law that might have impacted cryptocurrencies (Casey et al., 2019). The upcoming sections will explore why the conventional direct command and control method is not suitable for regulating decentralized cryptocurrencies. This analysis aims to highlight the unique challenges and considerations inherent in applying traditional regulatory frameworks to the decentralized nature of cryptocurrencies.

5.1. Uncertainty over legal classification

One of the reasons for treating cryptocurrencies differently by different agencies is the lack of legal classification. The precise legal classification of cryptocurrencies is pivotal for formulating regulatory policies and brings legal certainty and the rule of law. As mentioned earlier, a range of new intermediaries has emerged through cryptocurrencies. The functions of these intermediaries are like banks. The lack of explicit nature of cryptocurrencies and specific policies makes it difficult to ascertain the rights and duties of these intermediaries towards their customers. The traditional financial industry has clear rules set by the central authority or banks regarding their

rights, responsibilities, and liabilities. The absence of a clear legal category of cryptocurrencies would spark the differential treatment of various financial institutions towards cryptocurrencies (Johnson, 2021). The argument over the legal categorization of cryptocurrencies "rather than being grounded on evidence and objectivity, tends to utilize radical subjectivity making it difficult to engage in constructive and solution-oriented dialogue" (Gikay, 2018). Pacy argued that regulators and scholars are reluctant to treat cryptocurrencies as money, attempting to accommodate this technology into an existing regulatory framework as something other than money, creating unnecessary complexity and sometimes absurd results (Pacy, 2014b). The most popular cryptocurrencies are hybrid in nature and cannot be classified as traditional currency, assets, or commodities. Legal categorization is imperative but difficult to lay out because these legal categories sometimes overlap in their economic use (Lastra and Allen, 2019). The regulator should be cautious while categorizing the cryptocurrency because legal categorization does not simply reflect a description of reality. Legal categorization indicates the legal cognizability of objects. Assigning one object to a specific legal category could initiate a whole range of legal consequences (Lastra and Allen, 2019), for instance, the determination of the regulatory authority of cryptocurrencies. Therefore, regulators should exercise utmost caution and consider all the relevant complexities associated with cryptocurrencies before categorizing them to avoid subsequent legal ramifications. Despite all the uncertainty over the legal classification, cryptocurrencies are still used for payment purposes. Moreover, the uncertainty over regulating power among different agencies is seemed to be a significant hurdle to centrally regulating cryptocurrencies. Besides, the policy stance among jurisdictions is still fragmented.

5.2. Technological challenges for regulating cryptocurrencies

Blockchain technology is at the core of operating decentralized cryptocurrencies. With the blessing of blockchain technology, developers can operate cryptocurrency activities from almost any location, and the protocol can instantly be made available across borders. Blockchain can be divided into permissioned and permissionless ledgers, depending on the number of entities allowed to be validators (Schuster, 2021). In permissioned blockchain, a number of validators are fixed and approved by a governing body or a consortium of institutions. On the other hand, in a permissionless blockchain, there is no fixed set of validators. In addition, blockchain can also be categorized as a private or restricted ledger or a public ledger (Park, 2017). Only authorized parties can access the information stored on the blockchain in the private ledger. In contrast, anyone has full access to the public blockchain. Permissioned blockchains are typically private, whereas permissionless blockchains are public.

Furthermore, In the realm of public blockchains, challenges are encountered at both the technological creation and regulatory stages. At the technological front, public blockchains often face congestion (Sokolov, 2021) due to high user traffic, leading to slower transaction processing. This slowdown adversely impacts the network's overall efficiency. Additionally, there's a noticeable scarcity of public blockchains, which are predominantly utilized in financial sectors, especially for cryptocurrencies. Their expansion into other industries, however, has not been as

significant (AlShamsi et al., 2022). The regulatory issues reflect the same challenges as public blockchains. Since these blockchains are globally accessible, their use is not confined to a single regulatory jurisdiction. As a result, no single regulator can isolate a part of this technology for local governance. This situation leads to a complex scenario where local regulations might impact the entire user network, such as cryptocurrency traders, without the ability to exclude foreign regulatory influence. This can result in a fragmented regulatory landscape, where multiple local authorities impose their rules, potentially leading to an over-regulated, inefficient market (Jabotinsky, 2012). The concern is heightened by the possibility of conflicting regulations, creating legal uncertainties and contradictions.

Whereas permissioned blockchains or restricted distributed ledgers are controlled by a central authority. The current structure of financial regulation needs no major overhaul to regulate permissioned blockchain-based cryptocurrencies, as regulators can enforce the current regulation by targeting the owners of the ledger or the nodes with access to and the authority to validate it. Therefore, the traditional centralized direct regulation can apply to cryptocurrencies issued on restricted distributed ledgers to achieve regulatory objectives.

The cascading concern over regulating cryptocurrencies is that decentralized permissionless blockchain-based cryptocurrencies have no single authority that the regulator can target as they have no sovereign entity. As cryptocurrencies like bitcoin are online and borderless and not backed by any specific institution, that becomes a significant challenge for regulators to design suitable regulatory framework. It is also equally difficult to find any specific issuing authorities of cryptocurrencies as some issuing institutions have neither developers nor real corporate entities. The anonymity feature makes the issue more complicated as the identity of the developers or miners is unknown. Therefore, designing a traditional top-down regulatory framework for decentralized permissionless blockchain-based cryptocurrencies would be ineffective.

In this respect, traditional command and control direct regulation means regulating either developers or miners or protocol, which is difficult to effectual and impracticable considering the nature of these cryptocurrencies.

5.3. Regulatory arbitrage

However, it is essential to note that despite the absence of an identifiable issuer, several third parties operating within the cryptocurrency ecosystem could be easily identifiable. The New York Bitlicense is an example of such an intermediary where cryptocurrency-related services are provided. Thus, the regulators can target these intermediaries as a point of regulation. These intermediaries can be useful surrogate regulators in regulating cryptocurrencies as they will be the connecting point to convert cryptocurrencies into fiat currency. The regulators should target and implement the regulation to the point where the link between cryptocurrencies, banks, and payment institutions is made (Broby and Baker, 2018). That means the intermediaries will act as surrogate regulators to implement the regulation concerning cryptocurrencies. The idea is nearly similar to the traditional financial institutions' regulation. However, this type of indirect regulation is not devoid of challenges, and one such challenge is regulatory arbitrage. Regulatory arbitrage defines as shifting

business activities from a heavily regulated environment to a comparatively light or unregulated environment to circumvent unfavorable regulation or maximize profits by taking advantage of regulatory differentials. Strong financial regulation has frequently prompted attempts to arbitrage new innovation, and regulatory arbitrage is occasionally facilitated by intricate financial innovation (Omarova, 2012).

As mentioned, the operation of cryptocurrencies does not necessarily limit to any national boundaries. The developers can operate their activities from anywhere in the world. Due to the borderless nature of cryptocurrencies, regulatory efforts of a particular jurisdiction will become ineffective. For instance, when China imposed stricter regulations and banned ICOs, business activities based on cryptocurrencies witnessed a sharp shift from China to other jurisdictions. This nascent industry has created border problems within the traditional financial framework and a potential regulatory arbitrage among international jurisdictions (Goodhart, 2008; Goodhart and Lastra, 2010). The traditional top-down regulatory approach would not bring any effective solution in the sphere of the cryptocurrency ecosystem because of its quickly shifting business capability across the border. Besides, with centralized direct regulation, the regulator needs to target the developers or miners, the identity and location of who is sometimes difficult to ascertain due to the anonymous and decentralized nature of cryptocurrencies.

There is no straightforward solution to prevent regulatory arbitrage, though regulators can minimize the problem. In the cryptocurrency sphere, the regulator should focus on a decentralized regulatory framework, which means the regulator should target the point where cryptocurrencies convert to fiat currency. There is no guarantee that the decentralized indirect regulation will prevent regulatory arbitrage. However, to some extent, it can prevent the whole cryptocurrency industry from shifting to a jurisdiction with lower regulatory restrictions because decentralized indirect regulation will target middlemen, intermediaries, or institutions connecting the virtual world with the real world. One of the rationales for targeting the intermediaries is that it would be difficult for intermediaries to locate their business activities quickly. In addition, the cost of relocation of these intermediaries would also be higher.

6. Decentralized regulation and feasibility of regulating decentralized cryptocurrency

Cryptocurrencies operate primarily in isolation from established institutional settings and other infrastructure because they exist in their own digital, borderless universe. Their legal domicile may be offshore or impossible to define with precision if they have one. Simply put, the major challenge is that permissionless cryptocurrencies such as Bitcoin do not naturally fit into current legal frameworks. Most notably, no identifiable legal organization or person may be brought under the bounds of the regulation. Technically, blockchain-based cryptocurrencies need access by at least one country to operate.

The permissionless cryptocurrencies do not fit well with the traditional financial regulatory framework that largely hinges on the direct regulation of intermediaries. For instance, cryptocurrency transactions conducted between users through unhosted

wallets would not be subject to banking regulation requirements, including Know-Your-Customer (KYC) and anti-money laundering reviews. The applicability of banking regulation and other associated regulations hinges on the participation of intermediaries-hosted wallets, exchanges, and other specified services.

Therefore, it is pertinent to say that policymakers should consider regulating permissionless cryptocurrencies through decentralized indirect regulation. Indirect regulation indicates regulating the crypto market through intermediaries. The concept of indirect regulation as a suitable method for governing decentralized cryptocurrencies arises from the notion of fragmented knowledge and information asymmetry between regulators and the regulated, as defined by Julia Black. This approach acknowledges the complex nature of cryptocurrency markets and the challenges in maintaining regulatory oversight due to the uneven distribution of information and understanding between regulatory bodies and cryptocurrency entities (Black, 2001). It is assumed that the government has complete knowledge of the market and can formulate perfect policies and regulations to encounter new problems. The state believes "it can command and control, to be the only commander and controller, and to be potentially effective in commanding and controlling" (Black, 2019). That assumption is not entirely true, at least in the case of blockchain-based permissionless cryptocurrencies. The knowledge gaps between regulators and regulated or information asymmetry can also be called the Hayekian knowledge problem (Hayek, 1945).

As mentioned earlier, a plethora of actors are involved with cryptocurrencies operation playing a distinct role, and the responsibilities of these actors are best known to the entities actively involved in the crypto ecosystem. Decentralized regulation focuses on building a bridge between the system and its environment. Decentralized regulation is a "process of coordinating, steering, influencing, and balancing interaction between actors/system, and of creating new patterns of interaction which enable social actors/systems to organize themselves, using such techniques as proceduralization, calibration, feedback loops, redundancy, and above all countering variety with variety" (Black, 2001). Intermediaries in decentralized cryptocurrencies work as a connecting point where the virtual world meets with the real world. Therefore, decentralized indirect regulation would be the most feasible option for regulating blockchain-based permissionless cryptocurrencies.

However, there are two distinct yet connected types of blockchain network governance: on-chain and off-chain governance. The on-chain blockchain is operated by "governance by the infrastructure," which entails incorporating certain governance rules directly into the protocol running a particular blockchain-based network. In contrast, the off-chain blockchain is run by establishing a method for decision-making that operates outside the network protocol (de Filippi and Lavayssière, 2020). Decentralized regulation only applies to off-chain blockchain-based cryptocurrencies because no intermediaries are involved in the on-chain-based network protocol. Transactions on the on-chain blockchain happen directly between transacting parties in real-time.

To successfully apply decentralized regulation in the crypto ecosystem, the regulators need to minimize the information asymmetries between regulators and regulatees. To minimize the knowledge gap, the regulators have to identify the

potential parties and institutions equipped with the necessary expertise in the sector. These institutions will lead regulators to identify all parties regularly operating in the cryptocurrency marketplace. The regulator will relegate power to other agencies to implement rules and regulations to implement indirect regulation. For instance, under the indirect regulatory approach, the central bank and other authorized financial institutions or payment institutions would work as surrogate regulators and implement rules on behalf of the regulators. In such cases, banks and payment operators would impose rules on the entities and intermediaries effectuating cryptocurrency transactions or establishing a relationship between virtual money and fiat currency (European Central Bank, 2012).

Decentralized regulation through financial intermediaries and its challenges

Banks can facilitate various cryptocurrency-related services, such as payment processing, rendering escrow services, providing international cash transfers, facilitating accounts and wallets, establishing proprietary trading desks or derivative products, and exchanging money for bitcoin (Mogul et al., 2020). Presently, the banking industry is not entirely associated with cryptocurrency services. The banking industry might provide such services in the future. However, few regulated crypto banks are now in operation gaining popularity (Rivers, 2022). Besides, retail banking clients and institutional investors are leaning towards the cryptocurrency ecosystem and the DLT that underlies it, especially in the blockchain. For instance, JPMorgan Chase introduced its cryptocurrency called JPM Coin (Reiff, 2020), Morgan Stanley offered blockchain-based investment products along with wealth management clients' access to bitcoin funds (Mason, 2021), and Goldman Sachs already has a digital asset team and also now offer loan backed by bitcoin (Yang, 2022). Wall Street banks are expanding their crypto services and products, including wealth management, trading, and investment banking.

Although the banking industry is inclined to involve in the crypto market, considering its potential to contribute to the current financial market, there are still several risks to banks entering the cryptocurrency ecosystem. These risks may emanate from concerns over protecting customers or investors, maintaining financial integrity, or potential systemic risks. The cryptocurrency ecosystem seems like a retail payment system; however, it could cause systemic risks for established financial systems as they become more widespread because it is not backed by any regulation or closely supervised by any regulatory authority. The regulatory framework of the present financial system is more rigorous and intensive than other regulated sectors. For instance, the banking industry is subjected to on-site auditing and off-site inspection of banks' performance. Banks must adhere to strict rules and standards to maintain their financial soundness. The banking supervisory authority increases surveillance and may act when banks don't meet minimum standards.

Regulating cryptocurrencies through banks seems like a feasible option. However, banks' involvement with the crypto market may still cause risks regarding credit, maturity, and liquidity of their assets. Deposit-taking and maturity transformation are two crucial functions of banks. Maturity transformation (taking deposits and on-

lending them) is considered an integral part of banking to ensure an adequate supply of liquid funds, and traditional fractional banking relies on banks to ensure the adequate inflow of money (Schich, 2019). If banks are involved in cryptocurrency transactions, there is a likelihood that the maturity and liquidity transformation will be disrupted. Cryptocurrency like Bitcoin is far less liquid than other asset classes (Bajpai, 2021). The widespread acceptance, frequency of transactions, and price stability would lessen the liquidity problem. However, banks' involvement in the crypto market they are exposed to high liquidity risk. Besides, the central bank in a country has regarded as a lender of last resort, giving banks access to unlimited sources of liquidity. On the other hand, cryptocurrencies have no such lender of last resort with unlimited sources of liquidity. For instance, the bitcoin supply is already capped; therefore, it cannot work as an unlimited liquidity provider.

In addition, borrowing and lending in cryptocurrencies and using cryptocurrencies as collateral by banks also cause regulatory concerns—The collateral is a security that provides the lender with a means of securing repayment of the loan should the borrower default under the terms of the agreement, since numerous remedies allow the lender to take and sell the collateral in fulfilment of the debt. Banks would incur significant risks by taking cryptocurrencies as collateral. This is due to price volatility or extreme and sudden movement of price, and their price is speculative and often relies on consumer demand. On top of it, there are no backing assets or other tangible value. Particularly in situations where crypto-assets make up a sizable component of the secured collateral, banks must consider and implement appropriate protection against potential risks caused by market volatility. When the value of cryptocurrencies drops noticeably, the value of the collateral also drops, affecting the loan-to-value ratio and putting the lender at risk of not getting paid back in full in the event of a default. Therefore, banks need to be cautious in creating suitable systems and procedures to obtain extra collateral from borrowers in the case of a change in value. Any principal-based crypto-asset exposures on the part of systemic institutions, mainly if the assets involved are unbacked, might put capital at risk and, if the exposures are large enough, have a potential impact on investor confidence, lending, and financial markets (Hermans et al., 2022). Further regulatory issues are yet to be seen once banks' engagement is widespread in the crypto ecosystem. There is still doubt about how far banks will be involved in the crypto market in the future as international organizations still have concerns that cryptocurrencies could pose a significant risk to financial stability (Financial Stability Board, 2022a, 2022b) and "systemic risk increases in line with the level of interconnectedness between crypto-assets and the traditional financial sector, the use of leverage and lending activities" (Hermans et al., 2022).

One of the purposes of the creation of Bitcoin is to establish a new payment method system by disintermediating the traditional payment system. It can be said that Bitcoin and other decentralized cryptocurrencies are established payment systems. Traditional payment systems still dominate in this area. However, recent trends show that payment institutions are eager to get involved in cryptocurrency businesses (Auer et al., 2022). Considering cryptocurrencies' current market share and associated risks, it is pertinent to say that cryptocurrencies will not replace the traditional payment system. Still, they may do so in the near future. However, cryptocurrencies can be used

as a parallel payment system. Although the coexistence of centralized and decentralized payment systems would ensure an additional layer of redundancy and boost the overall payment system's resilience, it may sacrifice the advantages of economies of scale that come with using a single payment system and pose threats to the credibility of the unit of account if those alternative cryptocurrencies are widely adopted (Prasad, 2018).

The question automatically arises of whether the monetary system or central bank of a jurisdiction would allow a parallel payment system outside the traditional payment system over which the regulator has no control. The existence of many payment systems may increase the stability of the financial system as a whole and lessen the risk of counterparty liability for the payment hubs. In times of confidence crisis, however, many systems without government backing could be severely challenged and function as avenues for risk transmission. Additionally, decentralized electronic payment systems are vulnerable to technical flaws that could cause significant economic and financial harm (Prasad, 2018).

According to the report of BIS, Due to the fragmentation of the public blockchain, cryptocurrency could never be a reliable payment method. Here fragmentation indicates that crypto cannot replace the social role of money (Boissay et al., 2022). Financial products developed and traded in blockchain technology have been entangled with several technical issues, for example, scalability, speed, practicality, and securities. These problems raised real concerns about the sustainability of this technology in the financial arena in the long run. The fragmentation in the crypto ecosystem is in sharp contrast to traditional payments, which are literally fortified with a strong network effect. One of the main benefits of a traditional payment system is that the more users adhere to a particular payment platform, the more enticing it is for new users to join the platform. A strong payment network reduces expenses, enhances service quality, and encourages financial inclusion (Boissay et al., 2022).

7. Blockchain scalability solution and a potential avenue to regulate decentralized cryptocurrencies

One technical deficiency of blockchain, cryptocurrency's underlying technology, is scalability. The scalability issue of blockchain arises from the inherent limitations of blockchain. However, the "Layer 2" solutions concerning the scalability of cryptocurrencies have become popular and are believed to be improved transaction speeds, thus allowing products to be scaled. For example, Bitcoin Lightning Network would believe to be solved Bitcoin's scalability issues without compromising security and privacy. Lightning network technology allows users to execute transactions off-chain (outside of the Bitcoin blockchain) with other Bitcoin users privately rather than processing every transaction on the main blockchain (Fyookball, 2017).

The growth of cryptocurrencies as an alternative to conventional currency necessitated an increase in transaction speed, controllability of circulation, and exchange rate stability. The solution to this problem is not straightforward. There are arguments that the lightning network solution could lead to the centralization of the network as the lightning network exclusively applies to Bitcoin and its network forks (June, 2020). If such an assumption is true, then the lightning network solution is one

of the ways to regulate Bitcoin through the banking system. Banks, payment institutions, and other financial organizations can create a payment channel or join in the second layer of transactions with customers. Lightning Network nodes capable of routing transactions are established by integrating individual payment channels between the involved parties.

Consequently, the Lightning Network is the result of interconnecting numerous payment networks. As for security, Lightning Network still benefits from the Bitcoin security protocol as Lightning Network is considered the second layer of the Bitcoin blockchain. Banks and payment institutions participating in Lightning Network can work as surrogate regulators. When banks are started to run the offline channel for transactions with consumers, they will automatically come under an obligation to comply with payment services law. In such a situation, the central bank, in its supervisory power, can oversee the activities of commercial banks involving cryptocurrency transactions. Consequently, the regulators will be able to realize their policy objectives by focusing on financial institutions' gatekeeping operations.

The high volatility, forecasting difficulty, and scalability make cryptocurrencies high-risk assets that could have risk spillover to the current payment system. Despite such risks, cryptocurrencies have their benefits regarding transaction speed and cost. Besides, the existence of parallel payment would strengthen the payment service stability. Multiple payment systems would diversify the payment market, and customers would have more options to choose from. Moreover, a decentralized payment system is also devoid of any centralized failure and can be proved effective during a natural disaster. Therefore, instead of stagnating this innovation by outright interdiction, policymakers should accommodate this innovative payment system as parallel to the existing payment system to realize the maximum benefits of this nascent innovation by bringing it under regulatory oversight.

To regulate decentralized cryptocurrencies, instead of using a single regulatory approach, using multiple would yield better regulation. As mentioned, risks emanating from decentralized cryptocurrencies take various forms, and the appropriate strategies to address these risks are likely to be context-specific. Which sorts of strategies policymakers take would be feasible to minimize risks highly depends on the characteristics of the risk associated with cryptocurrencies under consideration. The nature and usability of cryptocurrency attract different governmental agencies to regulate it. Therefore, regulators should develop a smart regulatory approach that applies to a wide array of circumstances (Jiang, et al., 2022). The paper suggests regulators should take advantage of diverse, unrecognized opportunities, strategies, and techniques to achieve an effective cryptocurrency policy. For instance, the present paper suggests that regulators should empower intermediaries (both commercial and non-commercial) to act as surrogate regulators, minimizing risks posed to the current financial stability while spending less money and freeing up limited regulatory resources that can be redistributed in situations when direct government involvement is the only option.

8. Conclusion

Currently, regulators have begun to explore different regulatory options relating to cryptocurrency. Many of these options have concentrated on centralized cryptocurrencies such as stablecoin. Still, there is uncertainty over regulating decentralized cryptocurrency. The lack of a uniform approach among different jurisdictions also makes it difficult to form an international approach that could help to lay out an international instrument for regulating decentralized cryptocurrency. Policymakers face unique difficulties in establishing a consistent, coherent, and appropriately-scaled legal and regulatory framework for virtual currencies are brought to light by efforts to comprehend the risks connected with decentralized cryptocurrencies. Therefore, to develop an acceptable legal and regulatory framework, policymakers must address all the challenges posed by such currencies to comprehend both the functionality and risks of decentralized cryptocurrencies.

The present paper highlights the traditional direct command and control regulatory approach to regulating cryptocurrencies and its limitations in producing efficient results. The absence of specific target institutions and the decentralized and borderless nature of these currencies make the traditional direct regulatory approach ineffective. On the other hand, the paper also shows the policy option of indirect regulation, whereby regulators will divert their attention to intermediaries, such as banks, payment institutions, cryptocurrency exchanges, and wallet providers, involved in the crypto ecosystem. Although one of the intentions of the creator of cryptocurrency is to remove the middleman in financial transactions, the complete disintermediation is, in reality, a myth. Complete disintermediation can only be possible when cryptocurrency is widely used and accepted like fiat currency.

Universal acceptance of cryptocurrency is yet to be seen, and presently, cryptocurrency only accounts for a small portion of the world economy compared to fiat currency. In addition, people who are not technologically knowledgeable enough to fully understand how cryptocurrencies operate will eventually divert to intermediaries to transact and exchange cryptocurrency. Intermediaries are an important component of the financial market (Allen and Santomero, 2001). As intermediaries are not government-based, they are being driven by the market. They are able to reduce information asymmetry between the government and the market. Therefore, intermediaries would be suitable surrogates empowered with regulatory functions from the government. As mentioned earlier, the traditional regulatory approach means directly targeting miners or node operators who can exist anywhere in the world. Besides, if these node operators are not part of any regulated agency, the government cannot regulate them directly. Therefore, the regulator should focus on institutions establishing businesses around the cryptocurrency ecosystem. Regarding regulating decentralized cryptocurrencies, policymakers need to introduce a creative approach that will enable the application of complementary couplings of policy options and participants specifically customized to fulfill the requirements of various concerns relating to decentralized cryptocurrencies. This implies a much more creative, adaptable, and pluralistic approach to regulating decentralized cryptocurrencies than has thus far been used by the majority of governments.

These findings provide valuable insights for legal scholars, economists, and policymakers regarding the significance of gatekeepers, the efficacy of regulation, and the potential for socially beneficial private arrangements within a relatively anonymous and decentralized setting. The paper limited its discussion to two regulatory approaches: the traditional command and control and the indirect regulatory approach, empowering participants in the best position to act as surrogate regulators. Future studies can be conducted based on regulatory design principles of self-regulation and co-regulation. Self-regulation and co-regulation, using business interests and non-governmental organizations, finding substitutes for direct government regulation, and enhancing the effectiveness and efficiency of more traditional forms of direct government regulation.

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References

Adrian, T., Mancini-Griffoli, T. (2019). Central Bank Digital Currencies: 4 Questions and Answers. International Monetary Fund Website. Available online: https://blogs.imf.org/2019/12/12/central-bank-digital-currencies-4-questions-and-answers/ (accessed on 19 January 2022).

Ali, S., Jiang, J., Hassan, S. T., Shah, A. A. (2022). Revolution of nuclear energy efficiency, economic complexity, air transportation and industrial improvement on environmental footprint cost: A novel dynamic simulation approach. Nuclear Engineering and Technology, 54(10), 3682–3694. https://doi.org/10.1016/j.net.2022.05.022

Ali, S., Naseem, M. A., Jiang, J., et al. (2022). "How" and "When" CEO Duality Matter? Case of a Developing Economy. SAGE Open, 12(3), 215824402211161. https://doi.org/10.1177/21582440221116113

Ali, S., Zhang, J., Abbas, M., et al. (2019). Symmetric and Asymmetric GARCH Estimations and Portfolio Optimization: Evidence from G7 Stock Markets. SAGE Open, 9(2), 215824401985024. https://doi.org/10.1177/2158244019850243

Allen, F., Santomero, A. M. (2001). What do financial intermediaries do? Journal of Banking & Finance, 25(2), 271–294. https://doi.org/10.1016/s0378-4266(99)00129-6

Allen, J. G., Rauchs, M., Blandin, A., Bear, K. (2020). Legal and Regulatory Considerations for Digital Assets. In Cambridge Centre for Alternative Finance.

AlShamsi, M., Al-Emran, M., Shaalan, K. (2022). A Systematic Review on Blockchain Adoption. Applied Sciences, 12(9), 4245. https://doi.org/10.3390/app12094245

Al-Shikarchy, M., Gheorghiu, L. (2017). Canadian Taxation of Cryptocurrency ... So Far. Glowing WLG. Available online: https://gowlingwlg.com/en/insights-resources/articles/2017/canadian-taxation-of-cryptocurrency-so-far/ (accessed on 5 December 2021).

Atzori, M. (2017). Blockchain technology and decentralized governance: Is the state still necessary? Journal of Governance and Regulation, 6(1), 45–62. Portico. https://doi.org/10.22495/jgr_v6_i1_p5

Auer, R., Farag, M., Lewrick, U., et al. (2023). Banking in the Shadow of Bitcoin? The Institutional Adoption of Cryptocurrencies. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4416784

Ayadi, A., Ghabri, Y., Guesmi, K. (2023). Directional predictability from central bank digital currency to cryptocurrencies and stablecoins. Research in International Business and Finance, 65, 101909. https://doi.org/10.1016/j.ribaf.2023.101909

Bajpai, P. (2021). Liquidity of Bitcoin. Investopedia. Available online: https://www.investopedia.com/articles/investing/112914/liquidity-bitcoins.asp (accessed on 14 July 2021).

Bal, A. (2015). How to Tax Bitcoin? Handbook of Digital Currency, 267–282. https://doi.org/10.1016/b978-0-12-802117-0.00014-x

Banguis, D. (2022). Adopting Cryptocurrency & Blockchain to Fuel Growth in 2022. FinTech Magazine. Available online: https://fintechmagazine.com/crypto/adopting-cryptocurrency-blockchain-to-fuel-growth-in-2022 (accessed on 14 June 2022).

Bar-Ziv, S. (2021). A Content Analysis Approach to Intellectual Property Research. Handbook of Intellectual Property Research, 473–486. https://doi.org/10.1093/oso/9780198826743.003.0031

Bech, M. L., Garratt, R. (2017). Central bank cryptocurrencies. Available online: https://www.bis.org/publ/qtrpdf/r_qt1709f.htm (accessed on 7 October 2022).

Beessoo, V., Foondun, A. (2019). Money Laundering Through Bitcoin: The Emerging Implications of Technological Advancement. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3468300

Black, J. (2001). Decentring Regulation: Understanding the Role of Regulation and Self-Regulation in a "Post-Regulatory" World. Current Legal Problems, 54(1), 103–146. https://doi.org/10.1093/clp/54.1.103

Black, J. (2017). Critical Reflections on Regulation. Crime and Regulation, 15–49. https://doi.org/10.4324/9781351126816-2

Boissay, F., Cornelli, G., Doerr, S., Frost, J. (2022). Blockchain Scalability and the Fragmentation of Crypto (Issue 56). Available online: https://www.bis.org/publ/bisbull56.htm (accessed on 10 May 2023).

Bollen, R. (2016). The Legal Status of Online Currencies Are Bitcoins the Future? SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2736021

Bossu, W., Itatani, M., Margulis, C., et al. (2020). Legal Aspects of Central Bank Digital Currency. IMF Working Papers, 20(254). https://doi.org/10.5089/9781513561622.001

Braeden, A. K. (2018). Regulating the Future of Finance and Money: A Rational U.S. Regulatory Approach to Maximizing the Value of Crypto-Assets and Blockchain Systems. Bocconi Student-Edited Legal Papers, 11, 1. Available online: http://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=132723698&lang=pt-br&site=eds-live&scope=site (accessed on 15 May 2022).

Brito, J., Castillo, A. (2013). Bitcoin: A Primer for Policymakers. Mercatus Center: Geroge Mason University, 29(4), 3–12.

Brito, J., Shadab, H. B., Castillo, A. (2014). Bitcoin Financial Regulation: Securities, Derivatives, Prediction Markets, & Gambling. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2423461

Bryans, D. (2014). Bitcoin and Money Laundering: Mining for an Effective Solution. Indiana Law Journal, 89(1), 441–472.

Caliskan, K. (2022). The Elephant in the Dark: A New Framework for Cryptocurrency Taxation and Exchange Platform Regulation in the US. Journal of Risk and Financial Management, 15(3), 118. https://doi.org/10.3390/jrfm15030118

Casey, B., Farhangi, A., Vogl, R. (2019). Rethinking Explainable Machines: The GDPR'S 'Right to Explanation' Debate and The Rise of Algorithmic Audits in Enterprise. Berkeley Technology Law Journal, 34, 143. https://doi.org/10.15779/Z38M32N986

Chawki, M. (2022). Cybercrime and the Regulation of Cryptocurrencies. Advances in Information and Communication, 694–713. https://doi.org/10.1007/978-3-030-98015-3_48

Chen, D. (2021). Understanding the Scalability Issue of Blockchain. Unstoppable Domain. Available online: https://medium.com/unstoppabledomains/understanding-the-scalability-issue-of-blockchain-b104c9b6efc1 (accessed on 25 February 2023).

Choo, K.-K. R. (2015). Cryptocurrency and Virtual Currency. Handbook of Digital Currency, 283–307. https://doi.org/10.1016/b978-0-12-802117-0.00015-1

Chorzempa, M. (2021). China, the United States, and Central Bank Digital Currencies: How Important Is It to Be First? SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3765709

Chu, D. (2018). Broker-dealers for virtual currency: Regulating cryptocurrency wallets and exchanges. Colum. L. Rev., 118, 2323.

CoinMarketCap. (2023). Cryptocurrency Prices by Market Cap. Available online: https://coinmarketcap.com/ (accessed on 11 June 2023).

Crypto.com. (2023). Global Cryptocurrency Owners Grow to 425 Million Through 2022. Crypto.Com. Available online: https://crypto.com/company-news/global-cryptocurrency-owners-grow-to-425-million-through-2022 (accessed on 13 January 2023).

Cumming, D. J., Johan, S., Pant, A. (2019). Regulation of the Crypto-Economy: Managing Risks, Challenges, and Regulatory Uncertainty. Journal of Risk and Financial Management, 12(3), 126. https://doi.org/10.3390/jrfm12030126

Daniel Broby, Baker, S. (2018). Central Banks and Cryptocurrencies. Available online: https://pureportal.strath.ac.uk/en/publications/central-banks-and-cryptocurrencies-centre-for-financial-regulatio (accessed on 14 June 2023).

Davidson, L., Block, W. E. (2015). Bitcoin, the regression theorem, and the emergence of a new medium of exchange. Quarterly Journal of Austrian Economics, 18(3), 311–338.

De Filippi, P. (2014). Bitcoin: a regulatory nightmare to a libertarian dream. Internet Policy Review, 3(2). https://doi.org/10.14763/2014.2.286

De Filippi, P. (2016). The Interplay Between Decentralization and Privacy: The Case of Blockchain Technologies. Journal of Peer Production, Alternativ(7), 1–18.

De Filippi, P., Lavayssière, X. (2020). Blockchain Technology: The Great Awakening, 185–222. https://doi.org/10.2307/jj.2353884.9

Dhali, M., Hassan, S., Mehar, S. M., et al. (2023). Cryptocurrency in the Darknet: sustainability of the current national legislation. International Journal of Law and Management, 65(3), 261–282. https://doi.org/10.1108/ijlma-09-2022-0206

Didenko, A. N., Buckley, R. P. (2022). Central bank digital currencies as a potential response to some particularly Pacific problems. Asia Pacific Law Review, 30(1), 44–69. https://doi.org/10.1080/10192557.2022.2045706

Eichengreen, B., Viswanath-Natraj, G. (2022). Stablecoins and Central Bank Digital Currencies: Policy and Regulatory Challenges. Asian Economic Papers, 21(1), 29–46. https://doi.org/10.1162/asep_a_00843

European Central Bank. (2012). Virtual Currency Schemes. Available online: http://www.ecb.europa.eu/pub/pdf/other/virtualcurrencyschemes201210en.pdf (accessed on 4 July 2022).

European Securities and Markets Authority. (2017). The Distributed Ledger Technology Applied to Securities Markets.

Europol. (2016). Changes in modus operandi of Islamic State terrorist attacks. Review held by experts from Member States and Europol on 29 November and 1 December 2015 (Issue January).

Europol. (2021). DarkMarket: world's largest illegal dark web marketplace taken down. Available online: https://www.europol.europa.eu/media-press/newsroom/news/darkmarket-worlds-largest-illegal-dark-web-marketplace-taken-down (accessed on 8 August 2022).

Fairfield, J. (2014). Smart Contracts, Bitcoin Bots, and Consumer Protection. Washington and Lee Law Review Online, 71(2), 35–50.

Fairfield, J. (2015). Bitproperty. Southern California Law Review, 88(4), 805.

Favole, J. (2021). It Can't Be 'Decentralization or Bust'. CoinDesk. Available online: https://www.coindesk.com/policy/2021/12/16/it-cant-be-decentralization-or-bust/ (accessed on 12 August 2022).

Feinstein, B. D., Werbach, K. (2021). The Impact of Cryptocurrency Regulation on Trading Markets. Journal of Financial Regulation, 7(1), 48–99. https://doi.org/10.1093/jfr/fjab003

Financial Stability Board. (2022a). FSB warns of emerging risks from crypto-assets to global financial stability. Available online: https://www.fsb.org/2022/02/fsb-warns-of-emerging-risks-from-crypto-assets-to-global-financial-stability/ (accessed on 16 February 2022).

Financial Stability Board. (2022b). International Regulation and Supervision of Crypto-Asset Activities. Available online: https://www.fsb.org/2022/07/fsb-issues-statement-on-the-international-regulation-and-supervision-of-crypto-asset-activities/ (accessed on 11 July 2022).

Foley, S., Karlsen, J. R., Putniņš, T. J. (2019). Sex, Drugs, and Bitcoin: How Much Illegal Activity Is Financed through Cryptocurrencies? The Review of Financial Studies, 32(5), 1798–1853. https://doi.org/10.1093/rfs/hhz015

Frankenfield, J. (2020). Crypto Regulatory Sandbox Definition. Investopedia. Available online: https://www.investopedia.com/terms/c/crypto-regulatory-sandbox.asp (accessed on 15 March 2022).

Fyookball, J. (2017). Mathematical Proof That the Lightning Network Cannot Be a Decentralized Bitcoin Scaling Solution. Medium. Available online: https://medium.com/@jonaldfyookball/mathematical-proof-that-the-lightning-network-cannot-be-a-decentralized-bitcoin-scaling-solution-1b8147650800 (accessed on 27 June 2017).

Gandal, N., Hamrick, J., Moore, T., Oberman, T. (2018). Price manipulation in the Bitcoin ecosystem. Journal of Monetary Economics, 95, 86–96. https://doi.org/10.1016/j.jmoneco.2017.12.004

Gikay, A. A. (2018). Regulating Decentralized Cryptocurrencies Under Payment Services Law: Lessons From European Union Law. Journal of Law, Technology & the Internet, 9(1), 1–35.

Goodhart, C. (2008). The Boundary Problem in Financial Regulation. National Institute Economic Review, 206, 48–55. https://doi.org/10.1177/0027950108099842

Goodhart, C. A. E., Lastra, R. M. (2010). Border Problems. Journal of International Economic Law, 13(3), 705–718. https://doi.org/10.1093/jiel/jgq042

Griffin, J. M., Shams, A. (2020). Is Bitcoin Really Untethered? The Journal of Finance, 75(4), 1913–1964. Portico. https://doi.org/10.1111/jofi.12903

Grinberg, R. (2012). Bitcoin: an innovative alternative digital currency. Hastings Sci. & Tech. LJ, 4(1), 50.

Haffke, L., Fromberger, M., Zimmermann, P. (2019). Cryptocurrencies and anti-money laundering: the shortcomings of the fifth AML Directive (EU) and how to address them. Journal of Banking Regulation, 21(2), 125–138. https://doi.org/10.1057/s41261-019-00101-4

Hassan, S., Dhali, M., Mehar, S. M., Zaman, F. (2022). Islamic Securitization as a Yardstick for Investment in Islamic Capital Markets. International Journal of Service Science, Management, Engineering, and Technology, 13(1), 1–15. https://doi.org/10.4018/ijssmet.315592

Hayek, F. A. (1945). The Use of Knowledge in Society. The American Economic Review, 35(4), 519–530.

Hermans, L., Ianiro, A., Kochanska, U., et al. (2022). Decrypting financial stability risks in crypto-asset markets. European Central Bank.

Hewitt, E. (2016). Bringing Continuity to Cryptocurrency: Commercial Law as a Guide to the Asset Categorization of Bitcoin. Seattle University Law Review, 39(2), 619–640.

Hicks, C. (2023). Different Types of Cryptocurrencies. Forbes Advisor. Available online: https://www.forbes.com/advisor/investing/cryptocurrency/different-types-of-cryptocurrencies/ (accessed on 15 March 2023).

Hochstein, M. (2017). Bitcoin 'Ought to Be Outlawed,' Economist Joseph Stiglitz Says-CoinDesk. Available online: https://www.coindesk.com/markets/2017/11/29/bitcoin-ought-to-be-outlawed-economist-joseph-stiglitz-says/ (accessed on 20 August 2022).

Hofert, E. (2019). Regulating virtual currencies (130; IMFS Working Paper Series).

Hossain, M. B. (2023). Acquiring an awareness of the latest regulatory developments concerning digital assets and anti-money laundering. Journal of Money Laundering Control, 26(6), 1261–1268. https://doi.org/10.1108/jmlc-10-2022-0147

Howden, E. (2015). The Crypto-Currency Conundrum: Regulating an Uncertain Future. Emory International Law Review, 29(4), 741–798.

Hsu, S. (2017). After Cracking Down on Bitcoin, China Contemplates Its Own Digital Currency. Forbes. Available online: https://www.forbes.com/sites/sarahsu/2017/10/19/will-china-host-the-worlds-biggest-state-backed-digital-currency/?sh=374c3d711231 (accessed on 18 January 2023).

Huang, Y. (2022). Virtual Currencies, ICOs and Central Bank Digital Currencies in China. Law and Practice of Crowdfunding and Peer-to-Peer Lending in Australia, China and Japan, 125–141. https://doi.org/10.1007/978-981-19-3834-4_7

Huang, Y., Mayer, M. (2022). Digital currencies, monetary sovereignty, and U.S.–China power competition. Policy & Internet, 14(2), 324–347. Portico. https://doi.org/10.1002/poi3.302

Isaac, A., Ostroff, C. (2020). Central Banks Move Closer to Issuing Digital Currencies. The Wall Street Journal. Available online: https://www.wsj.com/articles/central-banks-warm-to-issuing-digital-currencies-11579796156 (accessed on 18 January 2023).

Jabotinsky, H. Y. (2012). The Structure of Financial Supervision: Consolidation or Fragmentation for Financial Regulators? A Game Theoretical Perspective. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2007856

Johnson, K. N. (2021). Decentralized Finance: Regulating Cryptocurrency Exchanges. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3831439

Jones, L. (2021). Beyond the Hype: A Practical Approach to CryptoReg. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3874133

June. (2020). The TPS Race: How Leading Cryptocurrencies Are Overcoming the Scalability Problem. Medium. Available online: https://medium.com/blue-swan-media/the-tps-race-how-leading-cryptocurrencies-are-overcoming-the-scalability-problem-b3d2b93363c1 (accessed on 17 March 2020).

Kaal, W. A., Vermeulen, E. P. M. (2016). How to Regulate Disruptive Innovation—From Facts to Data. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2808044

Kelly, J., Sadeghieh, T., Adeli, K. (2014). Peer Review in Scientific Publications: Benefits, Critiques, & A Survival Guide. EJIFCC, 25(3), 227.

Kethineni, S., Cao, Y. (2019). The Rise in Popularity of Cryptocurrency and Associated Criminal Activity. International Criminal Justice Review, 30(3), 325–344. https://doi.org/10.1177/1057567719827051

Lannoo Karel, K., Blockmans, S., Kopitsch, R., et al. (2021). Regulating crypto and cyberware in the EU (Issue 31).

Lastra, R. M., Allen, J. G. (2019). Virtual currencies in the eurosystem: Challenges ahead. International Lawyer, 52(2), 177–232.

Mann, J. (2022). Bitcoin Falls to Its Lowest Level Since Late 2020 Amid Crypto Selloff. Insider. Available online: https://www.businessinsider.com/bitcoin-falls-lowest-price-since-late-2020-amid-sell-off-2022-6 (accessed on 22 December 2022).

Mason, E. (2021). Morgan Stanley Co-Leads $48 Million Investment to Bring Blockchain to Capital Markets. Forbes. Available online: https://www.forbes.com/sites/emilymason/2021/06/21/morgan-stanley-co-leads-48-million-investment-to-bring-blockchain-to-capital-markets/?sh=8ad3836ae1d1 (accessed on 21 June 2021).

Matsushita, M. B. B. N. (2023). Cryptoactives Taxation and Legal Limitations of The Economic Power. Singular. Sociais e Humanidades, 1(4), 34–40. https://doi.org/10.33911/SINGULARSH.V1I4.144

Mersch, Y. (2018). Virtual Currencies Ante Portas. European Central Bank. Available online: https://www.ecb.europa.eu/press/key/date/2018/html/ecb.sp180514.en.html (accessed on 20 March 2022).

Millard, C. (2018). Blockchain and law: Incompatible codes? Computer Law & Security Review, 34(4), 843–846. https://doi.org/10.1016/j.clsr.2018.06.006

Mogul, Z., Kronfellner, B., Buser, M., et al. (2020). How Banks Can Succeed with Cryptocurrency. BGC. Available online: https://www.bcg.com/publications/2020/how-banks-can-succeed-with-cryptocurrency (accessed on 5 November 2020).

Mookerjee, A. S. (2021). What if central banks issued digital currency? Harvard Business Review, 1–10.

Mulligan, A. (2005). Is peer review in crisis? Oral Oncology, 41(2), 135–141. https://doi.org/10.1016/j.oraloncology.2004.11.001

Nabilou, H. (2019). How to regulate bitcoin? Decentralized regulation for a decentralized cryptocurrency. International Journal of Law and Information Technology, 27(3), 266–291. https://doi.org/10.1093/ijlit/eaz008

Nabilou, H., André, P. (2019). Central Banks and Regulation of Cryptocurrencies. Review of Banking and Financial Law, 39(July), 1–53.

Nabilou, H., Prrm, A. (2018). Ignorance, Debt and Cryptocurrencies: The Old and the New in the Law and Economics of Concurrent Currencies. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3121918

Nair, A., Borkar, N. (2023). Significance of including grey literature search in systematic reviews and meta-analyses. Saudi Journal of Anaesthesia, 17(2), 295. https://doi.org/10.4103/sja.sja_635_22

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Available online: https://nakamotoinstitute.org/bitcoin/ (accessed on 10 January 2022).

Nivedha, S. (2022). Progression of Cryptocurrency: A Taxation Concern. International Journal of Law Management & Humanities, 5 Issue 1. Available online: https://heinonline.org/HOL/Page?handle=hein.journals/ijlmhs15&id=322&div=&collection= (accessed on 10 January 2022).

Ogunbadewa, A. (2013). The Bitcoin Virtual Currency: A Safe Haven for Money Launderers? SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2402632

Omarova, S. T. (2012). License to Deal: Mandatory Approval of Complex Financial Products. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1996755

Ozili, P. K. (2022). Decentralized finance research and developments around the world. Journal of Banking and Financial Technology, 6(2), 117–133. https://doi.org/10.1007/s42786-022-00044-x

Pacy, E. P. (2014a). Tales from Cryptocurrency: On Biocoin, Square Pegs, and Round Holes. New England Law Review, 49, 121–144.

Pacy, E. P. (2014b). Tales from Cryptocurrency: On Biocoin, Square Pegs, and Round Holes. New England Law Review, 49.

Paez, A. (2017). Gray literature: An important resource in systematic reviews. Journal of Evidence-Based Medicine, 10(3), 233–240. Portico. https://doi.org/10.1111/jebm.12266

Panetta, F. (2022). For A Few Cryptos More: The Wild West of Crypto Finance. European Central Bank. Available online: https://www.ecb.europa.eu/press/key/date/2022/html/ecb.sp220425~6436006db0.en.html (accessed on 6 February 2022).

Park, A. (2017). Managing Blockchain Transparency: Strategies for a Private/Open World. Available online: www.blockchainresearchinstitute.org. (accessed on 10 March 2022).

Pavlidis, G. (2021). Europe in the digital age: regulating digital finance without suffocating innovation. Law, Innovation and Technology, 13(2), 464–477. https://doi.org/10.1080/17579961.2021.1977222

Paz, J. (2022). The Best Global Crypto Exchanges. Forbes. Available online: https://www.forbes.com/sites/javierpaz/2022/03/16/the-best-global-crypto-exchanges/?sh=9f7057e742c0 (accessed on 16 March 2022).

Powell, F. (2023). 10 Best Crypto Apps & Exchanges of June 2023. Forbes Advisor. Available online: https://www.forbes.com/advisor/investing/cryptocurrency/best-crypto-exchanges/ (accessed on 1 June 2023).

Prasad, E. (2018). Central Banking in a Digital Age: Stock-Taking and Preliminary Thoughts. In Huchins Center on Fiscsl & Monetary Policy. Available online: http://prasad.dyson.cornell.edu/doc/CentralBankingDigitalAge_Brookings.April18.pdf%0Ahttps://www.brookings.edu/research/how-will-fintech- (accessed on 20 March 2022).

Priem, R. (2020). Distributed ledger technology for securities clearing and settlement: benefits, risks, and regulatory implications. Financial Innovation, 6(1). https://doi.org/10.1186/s40854-019-0169-6

Reiff, N. (2020, March). JPMorgan to Launch JPM Coin. Investopedia. Available online: https://www.investopedia.com/jpmorgan-to-launch-jpm-coin-4587182 (accessed on 20 March 2022).

REIFF, N. (2021). Blockchain Won't Cut Out Intermediaries After All. Investopedia. Available online: https://www.investopedia.com/tech/blockchain-wont-cut-out-intermediaries-after-all/#citation-1 (accessed on 25 March 2022).

Reyes, C. (2017). Conceptualizing Cryptolaw. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2914103

Rivers, M. L. (2022). The World's First Regulated Crypto Bank Braces for Flood of Institutional Money. Forbes. Available online: https://www.forbes.com/sites/martinrivers/2022/04/21/the-worlds-first-regulated-crypto-bank-braces-for-flood-of-institutional-money/?sh=491d9d121da2 (accessed on 21 April 2022).

Schich, S. (2019). Do Fintech and Cryptocurrency Initiatives Make Banks Less Special? Business and Economic Research, 9(4), 89. https://doi.org/10.5296/ber.v9i4.15720

Schuster, E. (2020). Cloud Crypto Land. The Modern Law Review, 84(5), 974–1004. Portico. https://doi.org/10.1111/1468-2230.12603

Scott, B. (2015). Visions of a Techno-Leviathan. The Politics of the Bitcoin Blockchain. Policy Paper, 4.

Senarath, S. (2022). Development of Virtual Currency and ICOs in Australia. Law and Practice of Crowdfunding and Peer-to-Peer Lending in Australia, China and Japan, 41–65. https://doi.org/10.1007/978-981-19-3834-4_4

Severin, A., Chataway, J. (2020). Purposes of peer review: A qualitative study of stakeholder expectations and perceptions. Learned Publishing, 34(2), 144–155. Portico. https://doi.org/10.1002/leap.1336

Sokolov, K. (2021). Ransomware activity and blockchain congestion. Journal of Financial Economics, 141(2), 771–782. https://doi.org/10.1016/j.jfineco.2021.04.015

Sonksen, C. (2021). Cryptocurrency Regulations in ASEAN, East Asia, & America: To Regulate or Not to Regulate. Washington University Global Studies Law Review, 20.

Spaeth, W., Peráček, T. (2022). Cryptocurrencies, Electronic Securities, Security Token Offerings, Non-Fungible Tokens: New Legal Regulations for "Crypto Securities" and Implications for Issuers and Investor and Consumer Protection. Developments in Information & Knowledge Management for Business Applications, 217–238. https://doi.org/10.1007/978-3-030-95813-8_10

Statista. (2023). Cryptocurrencies—Worldwide. Statista. Available online: https://www.statista.com/outlook/dmo/fintech/digital-assets/cryptocurrencies/worldwide#revenue (accessed on 8 May 2023).

Stokes, R. (2012). Virtual money laundering: the case of Bitcoin and the Linden dollar. Information & Communications Technology Law, 21(3), 221–236. https://doi.org/10.1080/13600834.2012.744225

Sultan, N., Mohamed, N., Martin, M., Latif, H. M. (2023). Virtual currencies and money laundering: existing and prospects for jurisdictions that comprehensively prohibited virtual currencies like Pakistan. Journal of Money Laundering Control, 27(2), 395–412. https://doi.org/10.1108/jmlc-02-2023-0024

Sutherland, A. (2019). Cryptocurrency Economics and the Taxation of Block Rewards. Taxnotes Federal, 165(5), 749–771.

Tepper, T., Schmidt, J. (2022). Best Crypto Exchanges of March 2022. Forbes Advisor. Available online: https://www.forbes.com/advisor/investing/cryptocurrency/best-crypto-exchanges/ (accessed on 8 May 2023).

The Economist. (2015). The Trust Machine. The Economist.

Tu, K., Meredith, M. (2015). Rethinking Virtual Currency Regulation in the Bitcoin Age. Washington Law Review, 90(1).

Vandezande, N. (2017). Virtual currencies under EU anti-money laundering law. Computer Law & Security Review, 33(3), 341–353. https://doi.org/10.1016/j.clsr.2017.03.011

Vansh, S. (2020). A Deep Dive into Blockchain. Available online: https://towardsdatascience.com/a-deep-dive-into-blockchain-d1eb753fb74c (accessed on 19 June 2022).

Ward, O., Rochemont, S. (2019). Understanding Central Bank Digital Currencies (CBDC).

Wexler, R., Abramowicz, M., Ayres, I., et al. (2018). Liberty, and Trade Secrets: Criminal Justice System. Stanford Law Review Life, 70(May), 1343–1429.

Kathryn W, Arushi G, Sandra W. (2022). Cryptocurrency Regulation: Where Are We Now, And Where Are We Going? Available online: https://www.weforum.org/agenda/2022/03/where-is-cryptocurrency-regulation-heading/ (accessed on 12 June 2022).

Wright, A., De Filippi, P. (2015). Decentralized Blockchain Technology and the Rise of Lex Cryptographia. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2580664

Wronka, C. (2023). Crypto-asset activities and markets in the European Union: issues, challenges and considerations for regulation, supervision and oversight. Journal of Banking Regulation. https://doi.org/10.1057/s41261-023-00217-8

Wu, B., Duan, T. (2019). The Advantages of Blockchain Technology in Commercial Bank Operation and Management. Proceedings of the 2019 4th International Conference on Machine Learning Technologies. https://doi.org/10.1145/3340997.3341009

Xie, R. (2019). Why China Had to Ban Cryptocurrency but the U.S. Did Not: A Comparative Analysis of Regulations on Crypto-Markets between the U.S. and China. Wash. U. Global Stud. L. Rev., 18(2), 457–489.

Zaring, D. (2006). The Use of Foreign Decisions by Federal Courts: An Empirical Analysis. Journal of Empirical Legal Studies, 3(2), 297–331. Portico. https://doi.org/10.1111/j.1740-1461.2006.00071.x

Zetzsche, D. A., Annunziata, F., Arner, D. W., Buckley, R. P. (2021). The Markets in Crypto-Assets regulation (MiCA) and the EU digital finance strategy. Capital Markets Law Journal, 16(2), 203–225. https://doi.org/10.1093/cmlj/kmab005

Zetzsche, D. A., Arner, D. W., Buckley, R. P. (2020). Decentralized Finance. Journal of Financial Regulation, 6(2), 172–203. https://doi.org/10.1093/jfr/fjaa010

Zetzsche, D. A., Buckley, R. P., Arner, D. W. (2017). The Distributed Liability of Distributed Ledgers: Legal Risks of Blockchain. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3018214