

Lehr, William

Conference Paper

Smart Contracts: Myths and Implications for Economics and Financial Regulation

31st European Conference of the International Telecommunications Society (ITS): "Reining in Digital Platforms? Challenging monopolies, promoting competition and developing regulatory regimes", Gothenburg, Sweden, 20th - 21st June 2022

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Lehr, William (2022) : Smart Contracts: Myths and Implications for Economics and Financial Regulation, 31st European Conference of the International Telecommunications Society (ITS): "Reining in Digital Platforms? Challenging monopolies, promoting competition and developing regulatory regimes", Gothenburg, Sweden, 20th - 21st June 2022, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/265650>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Smart Contracts: Myths and Implications for Economics and Financial Regulation

William Lehr¹

MIT

EuroITS June 2022

** preliminary draft, comments welcome **

Table of Contents

1. Introduction	2
2. Smart Contracts : towards a broader perspective	4
2.1. AI, 5G, and SCs as converging clusters of technologies.....	5
2.2. Evolution of the SC ecosystem.....	8
2.2.1. Toward a Layered Architecture.....	11
2.2.2. SC ecosystem is not new but refocused response to existing challenges.....	14
3. Myths and Misconceptions.....	15
3.1. SCs are not smart, contracts, blockchain, or cryptocurrency	15
3.2. SCs eliminate intermediaries: neither feasible nor desirable.....	18
3.3. SCs complete markets and ensure execution.....	22
3.4. SCs decentralize economic power and promote competition.....	23
4. Smart Contracts and FINTECH.....	24
4.1. Domains of Policy Concern.....	25
4.2. Cryptocurrencies and Evolution of Money and Digital Payments.....	30
5. Summing Up and Future Directions.....	36
6. References	38
7. Figures and Exhibit.....	44

Abstract

This paper seeks to situate an understanding of the long-term implications of Smart Contract (SC) technologies as a cluster of technologies that together with AI (shorthand for software applications) and 5G (shorthand for networked ICTs) will prove important for enabling a future wherein any task may be automated. Although the “any task can be automated” future is far off and AI, 5G, and SC technologies are still evolving rapidly, this paper argues for timely consideration of the policy implications for SCs. Like those other technologies and to a perhaps even greater extent, SC technologies (which include cryptocurrencies, blockchain, and smart contracts as distinct elements) have been the focus of excessive hype that has given rise in the academic and mass media press to misconceptions about what is important about SCs that this paper seeks to identify and dispel. In an effort to start to understand the challenges and likely trajectory for SC regulation, this paper focuses on FINTECH and the policy challenges that are emerging there related to SCs. The overall conclusion is that lots more needs to be done, and while it is clear that SCs will play an important role in FINTECH’s future and the regulation of

¹ William Lehr <wlehr@mit.edu> is the corresponding author. Dr. Lehr would like to acknowledge that financial support for this research was provided by FINTECH@MIT. All opinions expressed and errors included herein are the responsibility solely of the author.

that future will require significant focused research attention, it is unclear how useful such research will be as a template for addressing the challenges that will emerge as SCs migrate to other sectors where the economic implications are expected to be much larger. The paper concludes with speculations about where key trends in SC technologies seem to be going.

JEL: D86, K12, L14, O3, D51, D52, D4, G2, P00, P48

KEYWORDS: Blockchain, 5G, Smart Contracts, Digital Markets, Cryptocurrencies, Regulation, FINTECH

1. Introduction

The hype engine² associated with the Bitcoin cryptocurrency revolution has spawned significant hopes³ and fears⁴ for our global Digital Economy future.⁵ The emergence of Smart Contracts (“SCs”)⁶ amplify both the hype and the potential, posing a pressing problem for policymakers seeking to craft sound regulatory policies.⁷ Therefore, there is value in seeking to reduce the

² The academic literature is recent and large, with over 80% published in 2019 or later and technical (i.e., in IEEE journals). The trade and popular press have struggled to keep up and informed analyses of the economics and policy, which of necessity require multidisciplinary expertise, is early stage.

³ Hopes include the potential for blockchain economics to enable better Pareto Optimal re-distribution of the fruits of economic activity by enabling new ways to decentralize and distribute control over economic decision-making.

⁴ Fears include the threat that the potential redistributive impacts of blockchain economics to lead to Pareto Optimal outcomes will be derailed by market failures. (Those failures include non-convexities, irreversibilities, and imperfect information that result in missing markets. Missing markets prevent prices from adjusting to fully account for externalities and preclude first-best outcomes from being realized ex ante or ex post, relative to the set of potential futures.)

⁵ We are in the midst of a global transition to a Digital Economy in which a greater share of economic activity is dependent on and directly impacted by the use of ICTs. The effects of this transition impacts everyone whether they are direct adopters/users of ICTs or not. Earlier, the Industrial Revolution involved machines augmenting and replacing human labor. Digitalization, enabled by ICTs, and more recently by “Networked Softwarization” (my locution for the process by which ICT functionality is moved from hardware to software and is networked to enable virtualization) is the next step in Automation and the potential implications for human capital and its role within the economy is profound.

⁶ This paper builds on ideas developed in Lehr (2021) which explains how Smart Contracts relate to blockchain and crypto-currencies, and makes the case for why Smart Contracts (hereafter, “SCs”) are a critical enabling technology that amplifies the transformative and disruptive potential of blockchain and crypto-currencies. Although Lehr (2021) makes the case for why it is important to understand that blockchain, crypto-currency, and SCs are separable concepts with different economic implications, I will use SCs as shorthand for their joint economic implications (see Lehr, W. (2021) “Smart Contracts, Real-Virtual World Convergence and Economic Implications,” TPRC49: Policy Research Conference on Communications, Information and the Internet (www.tprcweb.com), September 2021, available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3898129).

⁷ Lehr (2021) and many of the sources cited therein provide support for the significant potential that SCs have to benefit or harm global economic welfare and there are good reasons to believe that the evolution of SCs will exhibit significant path dependence that regulatory policies have the potential to impact.

noise by highlighting several of the myths (or misconceptions) associated with SCs and the implications of those for regulatory policies directed at SCs. In addition to tackling those challenges in this paper, and because of the saliency of capital markets and to simplify the explication, I will focus on how the misconceptions relate to the more focused regulatory challenge for Financial Regulation of SCs.⁸

The paper proceeds in three sections. In §2, I set forth my view of how the cluster of technologies that comprise the SC ecosystem relate to the two other important technology clusters – AI and 5G – that together with SC are critical to enabling a digital future wherein it will be feasible to automate *any* task.

In §3, I highlight several misconceptions regarding the economic implications of SCs. Among the myths that I will address are the view that disintermediating all economic agents, an oft touted benefit of SCs, is either feasible or desirable. Other related myths include the idea that SCs complete markets or ensure execution; that SCs will render traditional legal institutions irrelevant; that the focus of attention should be on permissionless blockchains; and that SCs are either “Smart” or “Contracts.” Collectively, these misconceptions make it more difficult to make progress toward sound regulatory policy.⁹

Then, in §4, I turn to examining the policy challenges for SCs associated with financial sector regulation as an illustrative test case of those challenges. For regulators of financial services (banks, exchanges, service providers), as for many other sectors, SCs have the potential to be a disruptive force and raise the challenge of the extent to which SC innovations are just new wine that will fit in old bottles, or if entirely new regulatory frameworks and institutions are called for. This is first a question of definition or classification, which leads to questions about the assignment of jurisdiction.¹⁰ Regardless of which regulatory authority is deemed responsible,

Unfortunately, the hype (spawned by ignorance and self-interested promotion) creates significant noise that makes it difficult to identify or coordinate on the right regulatory path. That is, the SNR is quite low but potentially a huge risk to failing to get the regulatory policy right: too stringent (or asymmetric) regulation may block the realization of benefits; while too laissez faire regulation may result in lock-in to bad path. This is well-understood in domain of standard setting, search, and coordination economics.

⁸ Finance has always been an early adopter of ICT innovations and the same is true with respect to SCs. The proliferation of cryptocurrencies, crypto-asset exchanges (including NFTs), the rise of Initial Coin Offerings (ICOs), etcetera are relevant examples. This renders FINTECH a useful target for insights into the regulatory challenges posed by SCs. Also, finance is the oil that facilitates wealth accumulation and transfers, and has the potential to remedy or accentuate market failures, and so the evolution of capital markets enabled by SCs and shaped by financial regulation may prove critical for regulation and the SC evolution overall. Finally, many of the lessons a focus on financial regulation will yield are applicable generally to the regulatory challenges posed by SCs across most (if not all) policy domains.

⁹ For example, they challenge efforts to reach actionable decisions (which is substantially less than consensus) and distract focus (and resources).

¹⁰ For example, in the U.S., the Commodity Futures Trading Commission (CFTC) has declared cryptocurrencies to be commodities (rather than currencies or investment vehicles) with potential implications for their use as legal tender and the transparency and disclosure requirements imposed on cryptocurrency users and value chain participants. At the same time, states and even municipalities are passing laws and regulations that restrict or enhance the potential to use FINTECH that are uncoordinated

SCs will pose new difficulties for crafting all-important disclosure and transparency reporting requirements and the assignment of liability for violations (e.g., with respect to KYC, AML, and ATL rules that are key components of banking regulations).¹¹ The self-certifying, anonymity that a cryptocurrency affords that facilitates the bypassing (disintermediation) of financial intermediaries (like banks) significantly complicates the enforcement of financial regulations.

The paper concludes in §5 which offers summary comments and speculations about future trajectories for financial regulation and the wider implications alternative paths may have for the SC ecosystem and global economy.

2. Smart Contracts : towards a broader perspective

Smart Contracts (SCs) are often characterized narrowly as economic contracts instantiated as executable computer code on a blockchain.¹² A broader (longer-range) perspective is that SCs are a key enabling technology for AI automation or borrowing from the Internet “hourglass” metaphor – the narrow waist connecting the real and virtual worlds.¹³ With this more expansive view, SCs can be seen as a *foundational technology*¹⁴ for automating the control of *Smart-X* applications.¹⁵

with national policy. Similar chaos is occurring globally. Moreover, in light of the potential for SCs to bypass intermediaries (including regulatory or sovereign authorities), the feasibility of financial regulation at different levels of jurisdiction are challenged.

¹¹ Financial regulation depends heavily on mandatory disclosure and transparency regulations for financial securities that are intended to protect consumers from fraud and risk, and to facilitate regulatory enforcement actions, but the assignment of responsibility (liability) depends on the ability to successfully manage identity (which conflicts with anonymity). Know-Your-Customer (KYC), Anti-Money Laundering legislation (AML), and Anti-Terrorist Legislation (ATL) are each specially challenged and important in light of the rise of SCs.

¹² For example, a representative definition is:

“A *smart contract* is a self-executing contract with the terms of the agreement between buyer and seller being directly written into lines of code. The code and the agreements contained therein exist across a distributed, decentralized blockchain network. The code controls the execution, and transactions are trackable and irreversible. *Smart contracts* permit trusted transactions and agreements to be carried out among disparate, anonymous parties without the need for a central authority, legal system, or external enforcement mechanism” (see <https://www.investopedia.com/terms/s/smart-contracts.asp>).

¹³ See Lehr (2021, 2022) for further elaboration of this more expansive view.

¹⁴ A *foundational technology* is more than merely a “disruptive technology” in so far as it has the potential to create new foundations for our economic and social systems, whereas a disruptive technology is one that impacts existing business models, and was terminology coined by HBS Professor Clayton Christiansen in the *Innovator’s Dilemma* in 1997. The characterization of a “foundational technology” follows on Lakhani’s and Iansiti’s (2017) description of blockchain’s potential impact.

¹⁵ Lehr (2022) makes the case that AI represents the future of software applications that when combined with networked ICTs, as exemplified by the aspirations for 5G+ networks, create the potential for Smart-X automation, where X represents *any* human task. Historically, narrow AI (and pre-AI software applications) have focused on substituting for human tasks that are amenable to digital automation, including repetitive,

2.1. AI, 5G, and SCs as converging clusters of technologies

This more expansive perspective is certainly not achievable today or any time soon, but is based on a horizon perspective of what ambitious AI and digital connectivity/computing infrastructure (in short-hand, “5G”) are building toward. As Lehr (2022) argues, sufficient progress has been made in the most developed markets and in selected usage contexts so that we are arguably at the end of the beginning of realizing the digital connectivity infrastructure (or *networked ICTs*) and *softwarization of ICTs* of which AI is the culmination. Both are necessary to support the next stage in real/virtual world convergence.¹⁶

AI, 5G, and SCs – as used herein – are signifiers for clusters of related technologies, each of which is distinct but are closely related within their clusters in terms of the underlying technologies and expertise engaged in their development. For example, “5G” refers broadly to the Internet/telecommunications networks that support mobile broadband digital connectivity that has been continuously improving through successive generations of networking technologies.¹⁷ Today’s 5G cannot even deliver the requirements called for by ITU (2015). Enabling those will necessitate the deployment of additional capabilities like Multiaccess Edge Computing (MEC) and other more advanced capabilities that are still in development. Moreover, the networking community is already hard at work on specifying the capabilities for 6G and beyond networks.¹⁸

predictable tasks that are amenable to mathematical expression in computer code. With the addition of AI technologies like Machine Learning (ML), Natural Language Processing (NLP), and Computer Vision (CV) the range of human tasks amenable to Smart-X has been expanding, with the expectation that general AI, and ultimately, super-intelligent AI may be feasible in the more distant future (beyond several decades or more).

¹⁶ “*Networked ICTs*” is shorthand for realizing the vision of *always/everywhere connectivity to digital computing, storage, and communications resources for everything on demand*; while “*softwarization of ICTs*” refers to the ability to implement any ICT-task in software, with the inherent benefits that that delivers in terms of enabling virtualization, delocalization of functionality, and the faster clock-cycle with which software-based implementations of digital functionality can evolve.

¹⁷ The “5G” borrows from the nomenclature of successive generations of mobile telephony technologies that proceeded at approximately decade-long intervals from the 1G analog voice-only mobile telephones of the 1980s through the converged mobile “smartphone” devices implementing the first generation of 3GPP 5G standards in 2019. With each generation of cellular technologies, and mirroring similar developments in Internet and related technologies, the capabilities and capacity of embedded and networked digital computing, communication, and storage has expanded. These networked ICTs provide the foundation for supporting ever-more-ambitious and capable software applications. The combination of Networked ICTs and smart software applications enables Smart-X automation.

¹⁸ NextG (2022) provides the roadmap for the NextG Alliance, which is working on preparing North American standards and commercialization strategies for 6G and beyond. NextG identifies enabling “AI-native” networks as a key goal. Indeed, enabling the ITU (2015) requirements of 5G networks (e.g., 1msec latency) is expected to depend on AI technologies to manage MEC and other network capabilities (e.g., real-time network management). The deployment of today’s 5G services (mostly 4G+ mobile networking) already incorporates a host of wired and wireless, fixed and mobile, Radio Access Network (RAN), and core network technologies (e.g., Network Function Virtualization (NFV), etc.) that are comprised of distinct clusters of technologies and developments.

Similarly, “AI” refers broadly to a basket of related technologies, including Computer Vision (CV), Natural Language Processing (NLP), Robotics, and most recently, Machine Learning (ML) and various AI-augmented decision-support systems (e.g., recommendation bots and inference engines that enable software-based decision support that mimics or augments human cognitive decision-making activities).¹⁹ Many of these sub-categories of AI are used in mix-and-match combinations with each other and with other pre-AI ICT technologies as part of ICT systems. Although in many cases, AI offers a better ICT alternative to legacy ICT methods (e.g., ML replacing other statistical methods for analyzing data), AI can prove useful in facilitating digital automation that may primarily depend on non-AI ICT technologies. For example, AI can help configure, select, and simplify human interactions with complex ICT systems (e.g., NLP overcoming language barriers; CV obviating the need for manual data entry; or recommendation systems helping to navigate complex forms). In so doing, AI can contribute to expanding the contexts where ICTs of all kinds (AI and non-AI) can be used to automate (augmenting or substituting for) human tasks.

In keeping with this horizon vision of where our expanding capabilities for implementing digital automation are going (rather than where we are today), SCs are also at the nexus of a clustering of distinct but related technologies that will facilitate the *automation of automation* (or, equivalently, the automation of the control of semi-autonomous ICT systems). Those technologies include: cryptocurrencies, blockchain, and computable contracts.²⁰ In much of the

¹⁹ Today’s AI applications are all narrow AI, but work continues to develop general AI. The narrow AI focuses on using AI technologies to address specific domain problems, whereas general AI is focused on creating systems that could pass the Turing Test – that is, demonstrating human-level cognitive capabilities in responding to questions that would be distinguishable from human responses. First, as Surden (2019) and others have pointed out, AI and other ICT systems can accomplish tasks that human’s may have done previously by virtue of their “cognitive” (human intelligence) capabilities. Consequently, those ICT systems may be appropriately identified as exhibiting “intelligence,” but utilizing other strategies that need not mirror human intelligence either in the means or capabilities. This suggests that the Turing Test, while interesting, is a Red Herring that ultimately has little relevance in assessing either the current or future potential for AI-augmented automation. Today, AI and pre-AI ICT technologies can already automate a wide-range of both physical and cognitive tasks that previously required human or other non-ICT augmented action. Moreover, the range of tasks is expanding by virtue of the continuing advances in all ICT technologies and digitalization of the global economy. This expansion is occurring both in terms of the types of tasks that are amenable to automation (i.e., no longer just simple, repetitive, easily predictable tasks, but also, increasingly complex tasks dependent on real-time feedback from the local environment); as well as the contexts wherein automation may be implemented (i.e., in countries, industrial sectors, firms, and by individuals where ICT-automation was previously technically or economically infeasible). AI technologies like CV, NLP, and smart agents (bots) can assist in overcoming language, physical, and cost-based barriers to digital automation in a growing range of usage contexts. Therefore, to call today’s AI narrow is not equivalent to saying that the scope of AI applications is narrow.

²⁰ Lehr (2021) highlights some of the key distinctions and antecedents distinguishing these clusters of technologies and their economic relevance. Since writing the earlier paper, additional work has come to my attention providing further insights.

(1) For example, Gerhardt and Thaw (2020) focus on the role of the SC ecosystem that was launched by Nakamoto (2008) with the introduction of Bitcoin and the first blockchain protocol as Blockchain 1.0. The key innovation they focus on is the role of blockchain as a novel Distributed Verification Technology

literature about SCs and in the narrow definition offered at the start of this section, these three clusters of technologies in their own right are often conflated, but as is so often the case, the SC “forest” resolves into the complexity of “trees” as one delves deeper.

The promise of SCs in the simple characterization is touted by optimistic proponents as a new tool for enabling the distributed/decentralized management of all (any) types of economic activity. Decentralized Autonomous Organizations (DAOs) are the ultimate vision of what SCs might enable in industrial organization.²¹ If realized, this might be seen as a technology to replace bricks-and-mortar intermediaries (whether those be national governments, digital platform providers, or banks). The technology of SCs promises to expand the perceived benefits of Bitcoin and related cryptocurrency innovations to reduce transaction costs and entry barriers that constrain competition to an ever-wider-range of economic activity, potentially spanning the entire range of value-chain activities.²²

(DVT). That was followed by the Ethereum generation of SC platforms that Gerhardt and Thaw characterize as Blockchain 2.0. Blockchain 2.0 expanded the range of tasks that could benefit from DVTs, but remained limited because it retained the focus on a platform-specific token that limited interoperability and more general applicability of the DVT innovation. (In the case of Ethereum, Ether is the platform-specific cryptocurrency token used by SCs implemented on the platform). Gerhardt and Thaw propose moving to “Blockchain 3.0” to address this limitation, by recognizing that the DVT functionality and what it is applied to (a data structure) are logically separable. Whereas the data structure may be linked to a cryptocurrency token, it can also refer to something quite different and more general (e.g., a bundle of arbitrary property rights), greatly expanding the scope of SCs.

(2) Additionally, Surden (2012) and Clack (2018) highlight the potential for computability or instantiation of agreements in code can have benefits for automated processing of contracts (especially financial contracts) that are separable from and do not depend on blockchain or cryptocurrencies, although those technologies may complement computable contracts.

(3) Finally, Ali and Narula (2020), focusing on how money has evolved see in blockchain the potential to create Money 3.0 or “programmable money” that represents the third stage in the evolution of money from analog/paper money (Money 1.0) to the first generations of digital money which includes credit cards and other forms of intermediary-moderated forms of electronic moneys (Money 2.0). Money 3.0 based on DVT technologies and supported by other digital payments infrastructure has the potential to greatly expand the capabilities that “money” can play in global economies.

²¹ That is, DAOs are seen by some as a wholly new form of organizational structure that previously did not exist (Davidson, De Fillippi and Potts, 2018).

²² Figure 1 reproduces a diagram of the Value Chain concept from the Harvard Business School which breaks down the business tasks/functions into support and primary activities into components that may be evaluated for their contribution to the firm’s competitive advantage. This framework may also be used to evaluate industry value-chains comprised of multiple firms with B2B and B2C interactions within a larger industry sector or economy context. And, once one takes account of the capabilities for digital technologies to blur private/public, work/leisure, employee/consumer, etc. boundaries that delineate individual lives and task responsibilities, this framework may even be applicable to individuals. For every box in the diagram there are on-going AI applications at various stages of development with some only in pilot implementations, whereas in other cases, at-scale industry-wide commercial implementations are working. Similarly, SCs are anticipated for every box, and SCs may provide the foundational technology to link AI or other ICT applications across business processes within firms and across firms in industry value chains. (And, AI-powered agents may negotiate SCs with other ICT systems, including the AI agents of other

However, as is often the case, SCs have attracted excessive hype and so there is a big gap between the long-term potential and reality of SCs. In the summer of 2022, recognition of the excessive hype is readily apparent in light of the significant downturn in cryptocurrency valuations and the business prospects of NFTs, cryptocurrency, and many blockchain-related enterprises (exchanges, service providers, etc.). From the valuation heights of 2021 when the global market valuation of cryptocurrencies was approaching \$3T and the leader, Bitcoin (BTC) exceeded \$64k, valuations have collapsed by more than 2/3rds by mid-2022.²³ Most of the most prominent innovations in the SC ecosystem as narrowly construed have been associated with Financial Technology (FINTECH) and many of those have given rise to numerous examples of fraud, financial failures, and other errors that call into question the significant promise touted by proponents.

2.2. Evolution of the SC ecosystem

Following the introduction to the world of Bitcoin and the Blockchain in Nakamoto (2008), the first phase of the ecosystem's growth from 2008 to 2012 was characterized by the emergence of Bitcoin (BTC) as a novelty with most of the use focused on illegal gray/black market eCommerce on platforms like Silk Road (e.g., for drug purchases).

The second phase of growth from 2012 to 2015 saw the emergence of efforts to add SC-like functionality and the capability to support derivative securities and improve the performance of blockchain mediated transactions through the introduction of "colored coins" and the first "stablecoin," Tether which was pegged to the US dollar in an effort to address the extreme

individuals to help navigate through increasingly digital space, and in so doing, alter human's perceptions and understanding of their environment and themselves.)

²³ The market capitalization of global cryptocurrencies exceeded \$2.86T and Bitcoin (BTC) was trading above \$64k in November 2021. As of June 14, 2022, the global market cap had fallen to \$0.945T and BTC to \$21k – over 67% decline in just 6 months, representing the extreme volatility of cryptocurrencies. Also, the market for cryptocurrencies is highly concentrated and skewed toward the most popular crypto coins with BTC accounting for approximately 44% and the top 10 coins accounting for 79% of the total market capitalization of the 13k-plus coins that are being traded globally as of June 2022. (See <https://www.coindesk.com/price/bitcoin/> and https://www.coingecko.com/en/global_charts, visited June 14, 2022). Additionally, the trade news has been full of stories of firms in the SC ecosystem laying off employees, discussing the collapse of leading stable coins like TerraUSD or UST in May 2022, and predicting further declines (see, for example, "TerraUSD collapse will 'probably be the end' of most algorithmic stablecoins, crypto exec says," CNBC News, June 2, 2022, available at <https://www.cnn.com/2022/06/02/ust-debacle-will-probably-be-the-end-of-algorithmic-stablecoins.html>; "Coinbase's layoffs suggest crypto's problems are spreading: The industry heavyweight cuts 18 percent of its workforce, a potent sign of a space under duress," Washington Post, June 14, 2022, available at <https://www.washingtonpost.com/business/2022/06/14/coinbase-layoffs-bitcoin-price-crash/>; or, "Crypto firms are slashing jobs right and left. So why is Binance hiring?" Fortune, June 13, 2022, available at <https://fortune.com/2022/06/13/crypto-layoffs-hiring-freeze-binance-expanding-cz-changpeng-zhao/>).

volatility of cryptocurrencies that posed a threat to their use in eCommerce and as a medium of exchange.²⁴

The third phase of growth from 2015 to today has witnessed multiple boom/bust cycles and the introduction of numerous FINTECH innovations. Those included the launch of the Ethereum platform in 2015 – the first major SC platform which augmented its blockchain with a Turing complete language (Solidity) for encoding SCs. This provided the infrastructure platform needed to create a platform for creating multiple DAOs and other SC projects. DAOs are one of the poster-child applications for demonstrating the potential of SCs to empower a wholly new organizational structure for “firm-like” economic entities, wherein economic control can be fully decentralized based on the rules embodied in the DAO’s SC code. Unfortunately, the DAO project was hacked in 2016, putting at risk \$150m in Ethereum funds that were raised to support the DAO. In addition to highlighting the fact that the ecosystem was far from stable, the DAO hack led to the first major fork that split the blockchain into the Ethereum Classic (the original) and Ethereum blockchains.²⁵

Other innovations during this period of rapid growth included Initial Coin Offerings (ICOs) which were introduced in 2016 and offered a cryptocurrency/blockchain alternative way to raise equity capital (comparable to Initial Public Offerings or IPOs). ICOs were seen as a lower-transaction cost alternative to venture capital and more traditional IPO mechanisms for financing new ventures. ICO capital raising efforts peaked in 2018 after raising upwards of \$20B in funds for new ventures.²⁶ and a host of other innovations such as Non-fungible Tokens (NFTs), numerous protocols and innovations offering alternatives to existing blockchain and SC offerings, and the launch of many Decentralized Finance (DeFi) and Decentralized Application (DeApp) platforms. This explosion of market interest and innovation helped drive a boom in the market value of SC ecosystem assets that peaked in the 3Q2021. In addition to projects launched by an expanding array of new ventures from across the globe, including numerous side-projects

²⁴ In 2014, Tether was created as a fiat-backed stablecoin that was pegged 1:1 to the US dollar, although as of March 2019, the tokens are no longer 100% backed by US dollar deposits (see <https://messari.io/asset/tether/profile>). “Colored coins” were tokens that were linked to meta-data that allowed them to be linked to other assets (e.g., bonds, stocks) that could be traded on the Bitcoin blockchain. The Bitcoin protocol allows a small amount of metadata code to be stored with the Bitcoin transaction records stored on the Bitcoin blockchain, and in so doing, serve as an early version of a SC platform (see https://en.bitcoin.it/wiki/Colored_Coins).

²⁵ See “What was the DAO?”, Cryptopedia, updated March 16, 2022, available at <https://www.gemini.com/cryptopedia/the-dao-hack-makerdao>; or “Understanding the DAO Attack,” Coindesk, updated March 9, 2022, available at <https://www.coindesk.com/learn/2016/06/25/understanding-the-dao-attack/>.

²⁶ Cohney, Hoffman, et al. (2019) offer a masterful review of ICOs that highlights their rapid growth, potential importance, but also their “not-ready-for-prime-time” current state and the many regulatory issues that ICOs pose for financial regulators. Although precise statistics on ICO activity are difficult to find, one source reports that ICOs grew from approximately \$95 million in funds raised in 2016 to \$21.6 billion in 2018, thereafter declining (see <https://bitni.com/site/coin-schedule/stats>, visited 6/15/22). According to Gensler (2018), there were 4,500 ICOs proposed, of which most did not raise any money. Of the 2 to 3 thousand that did raise funds (contributing to the totals cited above), less than half remain active. Gensler points to estimates that from 25% to possibly as many as 75% of those ICOs may be scams.

by existing players, a growing range of established financial market participants have launched their own initiatives in this space.

Many of these initiatives appear to be nothing more than Ponzi schemes, including many of the initiatives to promote new tokens and services in the NFT and other novel token markets. Through well-orchestrated social media publicity, long-on-claims-but-short-on-substance white papers, and cross-hyping of projects, new tokens were launched and publicized for their future expected value appreciation. Such efforts seek to induce investors to adopt so-called “HODL” strategies (short for “hold-on-for-dear-life”), in which investors are induced to purchase tokens (BTC or other crypto assets) as long-term investments that the investors are expected to keep even through market downturns in the expectation of reaping future gains.²⁷ Too often such campaigns are nothing more than “pump-and-dump” efforts to deliver short-term profits to the entities launching the tokens and their early investors at the expense of those who wait too long to exchange their tokens once it becomes clear that future appreciation will not be forthcoming. Sometimes the sponsors are simply overly optimistic, or the projects fall victim to hacks or other unforeseen attacks; and sometimes the sponsors are simply criminals seeking to exploit an unregulated and poorly understood market that is ripe for criminal exploitation.

Moreover, when many of the best known NFT collections are associated with low-resolution digital cartoon images of apes (Bored Ape Yacht Club or BAYC), kitties (Cryptokitties), or Cryptopunks,²⁸ it is hardly surprising that many view the NFT craze as nothing more than a gambling or speculative investment market and pop-media phenomenon that is likely to blow over like “pet rocks” and other fads have in the past.²⁹ Efforts by celebrities/artists like Melania Trump and Madonna to launch NFTs were good at generating media attention, but were underwhelming in their potential to demonstrate real market value.³⁰

²⁷ “HODL” is an example of the slang/short hand used by SC ecosystem participants to communicate on social media platforms like Discord, Reddit, and Telegram. These platforms are also popular among the on-line gaming community and there is significant overlap among the crypto and gaming technical communities. The creation of new vocabulary and slang for a new technical movement or fad is hardly new and is common in financial markets -- but does present a barrier for understanding for those new to the area.

²⁸ For BAYC see <https://opensea.io/collection/bayc-honorary-members>; for Cryptokitties, see <https://opensea.io/collection/cryptokitties>; and for Cryptopunks, see <https://opensea.io/collection/cryptopunks>. These and many other NFT collections are now traded on one of the largest NFT exchanges, OpenSea which was launched in 2017 and claims to be the largest online market today specializing in NFTs with annual trading volume claimed to exceed \$20B.

²⁹ For example, many NFTs when launched capture little value but may suddenly become valuable as collector items when they become hot on secondary market trading. For example, EtherRock NFTs began trading for values in excess of \$100k in August 2021 (see <https://thenewscrypto.com/ethereum-pet-rock-nfts-are-being-sold-for-more-than-100000/>). And one clipart NFT of a rock sold for more than \$1.3 million worth of Ether (the Ethereum token) in August 2021 (see <https://www.cnbc.com/2021/08/23/people-are-paying-millions-of-dollars-for-digital-pictures-of-rocks.html>).

³⁰ For example, Melania Trump launched an NFT collection that she proposed to auction for \$180k in early 2022, but it looks like a month later, she was the only customer (see “Looks Like the Auction of Melania Trump’s First NFT Was Such a Dud She Had to Buy the Thing Herself,” Artnet, February 11, 2022, available at <https://news.artnet.com/market/did-melania-trump-buy-her-own-nft-2071931>). Later, Madonna teamed up with the digital artist Beeple to produce a controversial nude NFT of Madonna giving

The boost to interest in the SC ecosystem that fueled the rise in investment in numerous projects, including the run up in cryptocurrency valuations, as well as the subsequent crypto-collapse of mid-2022 can be explained as due in part to multiple exogenous (to the SC ecosystem) events. First, the Covid pandemic and resulting government efforts to inject stimulus funding to offset the Covid-related economic contraction did two important things: it forced people to spend more time on-line looking for entertainment and opportunities to offset Covid-induced economic losses while at the same time providing people with a ready supply of cash for investment schemes. The NFT and cryptocurrency investing craze were made-to-order opportunities for a speculative bubble to emerge. Moreover, the war in the Ukraine, growing concern about climate disasters fueled by the continued record-breaking bad weather news, the continuation of the Covid Pandemic, and concerns about the political future of Trump populism in the U.S. and abroad are threatening a global recession, potentially as bad as or maybe even worse than what happened in 2008. With the collection of bad economic news on the horizon, it is hardly surprising that crypto-market values are down from the highs of 2021, along with most other financial markets.

In addition to these exogenous events, and despite the many bad, not-yet-ready-for-primetime infrastructure, and numerous examples of criminal activity in the SC ecosystem, it is apparent to many savvy ICT market participants that there is real value in the SC ecosystem that may be realized once the early growing pains are worked out. However, it is far from certain precisely what the real value opportunities or innovations are that SCs may deliver. This is complicated by the fact that the entire SC ecosystem remains in flux with very little stability at any level in the architecture.

2.2.1. Toward a Layered Architecture

One view of the SC ecosystem is of a layered architecture. At Layer 0, we have the basic digital ICT infrastructure that comprises the “5G” networks identified earlier. This includes the Internet and associated data center and cloud computing infrastructure which provides the network connectivity and computing and digital storage resources on which the SC software applications run.

birth to a tree and insects. Beeple, or equivalently, Mike Winklemann, came to mass media attention when one of his NFTs sold for \$69 million at a Christie’s Auction, eclipsing his previous top price for a print of \$100 (see “Beeple sold an NFT for \$69 million,” The Verge, March 11, 2021, available at <https://www.theverge.com/2021/3/11/22325054/beeple-christies-nft-sale-cost-everydays-69-million>).

Madonna defended her participation in the project as consistent with her role as a path-breaking artist, pioneering a new art form in typical headlining-grabbing Madonna fashion (see “Madonna defends nude NFT: 'I'm giving birth to art and creativity and we would be lost without both'”, Entertainment, May 12, 2022, available at <https://ew.com/music/madonna-defends-nude-nft/>). Unfortunately for their effort, the auction proceeds for the Beeple-Madonna collaboration were not impressive and were seen as further evidence that the NFT market may have peaked (see “High-profile NFT auctions from Beeple, Madonna flop amid crypto crash,” New York Post, May 24, 2022, available at <https://nypost.com/2022/05/24/nft-auctions-from-beeple-madonna-flop-amid-crypto-crash/>).

The first layer (Layer 1) of the SC ecosystem is comprised of the blockchain, or distributed digital ledger, which records the transactions and stores the meta data on which the SC operates. The Bitcoin blockchain is the best known example of a Layer 1 implementation.

The second layer (Layer 2) is comprised of general purpose SC platforms like Ethereum, which also has its own blockchain and cryptocurrency, Ether (ETH), that is the fuel that users need in order to pay to execute SCs on the Ethereum Layer 2 distributed computing infrastructure.

Layer 3 applications are implemented on top of Layer 2 platforms and those may themselves offer versions of general-purpose platforms such as the DAO project (a general purpose platform to implement customized, project-specific DAOs), DeFi platforms on which to implement multiple types of decentralized FINTECH applications, and various types of Exchanges (for trading cryptocurrencies and including Decentralized Exchanges or DEXs, which are the DeFi version of exchanges). There are also lots of ancillary services and providers offering specialized consulting, information, or other SC-related services³¹ to those seeking to develop SC applications or participate in the SC ecosystem as users of the sundry services and capabilities being developed. Some of the providers of SC platforms bundle or integrate services provided by other providers, and many of the investors/developers/owners of platforms, protocols, or entities engaged in the SC ecosystem are involved in multiple ventures, at multiple levels, and often with unclear connections. Furthermore, at all three levels in the strawman architecture proposed above there are multiple contenders and efforts underway to further refine or alter the structure of the layered architecture.

For example, with over 13k crypto tokens being traded and with the potential to use these to accomplish a wide array of both financial and non-financial tasks, interoperability across tokens is needed. Such interoperability is necessary for multiple reasons. First, much of the software infrastructure in the SC ecosystem should be shared to minimize total transaction costs and enable the realization of scale and scope economies. Interoperability among tokens makes it easier to re-use software. Additionally, the ability to transfer value among interoperable tokens helps reduce lock-in and attendant hold-up or moral hazard costs. Obviously, an alternative to having many crypto-tokens and multiple blockchains is to have a single blockchain, but that would be counter to the fundamental notion that entry in the SC ecosystem should be open. If there were only a single blockchain allowed, then that would represent a fundamental gate-keeping restriction on the SC ecosystem's openness. The ability to have multiple blockchains is also important to enable innovation, which is important since Layer 1 blockchains are in the midst of foundational innovations.

For example, the original blockchain protocol that gave rise to Bitcoin was based on the Proof-of-Work (PoW) consensus protocol,³² which is based on the computing-resource-intensive

³¹ For example, the execution of SCs often depends on getting information from sources that are “off-chain” or external to the blockchain and the SC code (e.g., a real-world measurement such as weather conditions or prices in financial or other markets). The sources of such information are referred to as “Oracles” that may be implemented using other SC services or provided by trusted off-chain intermediaries.

³² The version of the PoW protocol used by the Bitcoin blockchain is sometimes referred to as the Nakamoto consensus protocol to distinguish it from other consensus protocols, including PoW protocol refinements that differ from the one Nakamoto proposed in his 2008 paper. These alternative consensus protocols are

solution of a cryptographic puzzle. As BTC has grown, so too have the computer resources needed to generate consensus as additional transaction blocks are recorded to the block chain distributed ledger. Critics argue that PoW is not green-tech since its energy consumption is excessive;³³ and alternative consensus protocols such as those based on Proof-of-Stake (PoS) may be better. More about this later but suffice it to say that even the basic technologies on which Layer 1 depends are open to innovation and are in flux. For example, in May 2022, Ethereum began the migration of its blockchain from PoW to PoS (and like PoW, many options for PoS consensus algorithms are possible). The same is true for the options at every layer – multiple contending technical designs and implementations are being advanced by competing and sometimes collaborating parties. All this calls into question the fundamental three-layer architecture posited above.

Of course, with multiple blockchain technologies and versions, and competing versions of Layer 2 and Layer 3 platforms and applications, there have been efforts to define new lower-layer protocols to provide a basic interoperable, common infrastructure for the SC ecosystem. For example, the Polkadot protocol was advanced in 2016 by Gavin Wood, one of the developers of Ethereum, to provide a cross-chain interoperability layer that would allow multiple, incompatible blockchains to transact with each other (and hence support SCs across heterogeneous blockchains). This might be viewed as a sub-layer to the Layer 1 blockchain protocols or as an alternative Layer 1 or Layer 2 platform.

The effort to define a stable architecture or at least stable layers has multiple motivations. First, a stable architecture would enable standardization to progress and to allow developers of capabilities focused on particular layers to specialize, while taking into account what services they can expect to be provided by lower layers and what services they need to provide to higher layers. The stable architecture can help reduce investment uncertainty and hence lower total costs. Additionally, sponsors of whatever technology or design is adopted as part of the stable architecture may anticipate realizing first-mover and network externality benefits relative to competing technologies. Not surprisingly, the sponsors of technologies in the SC ecosystem frequently tout their sponsored solution as the best and most worthy of wide-scale adoption and implementation. These competing claims may be based on true beliefs or strategic efforts to bias the evolution of SC markets in privately favorable (but not necessarily socially favorable) directions. In either case, they make it difficult to identify the right technical strategies and reach consensus on a stable architectural design.

typically advanced as offering better performance (e.g., are more energy efficient, more secure, more scalable, faster, etc.).

³³ The energy used by BTC blockchain ranks it as the 28th biggest energy users among nations (more than the Ukraine, less than Argentina) and represents 0.59% of global electricity consumption. Whether that is a reasonable expenditure depends on how valuable a contribution you think BTC is to the global economy. See “Bitcoin’s Energy Consumption Is A Highly Charged Debate – Who’s Right?” Forbes, May 10, 2021, available at <https://www.forbes.com/sites/lawrencewintermeyer/2021/03/10/bitcoins-energy-consumption-is-a-highly-charged-debate--whos-right/?sh=2063b3f67e78>.

2.2.2. SC ecosystem is not new but refocused response to existing challenges

The excessive media hype, the unsettled and rapidly changing technology, architecture, and industry structure associated with the SC ecosystem is understandable. The Bitcoin phenomenon and the prospects for this new clustering/coalescing of ICT developments is still quite recent and addresses a key challenge confronting the global transition to a Digital Economy. The challenge, however, is not new: *how to sustain and promote trust in a global economy that is increasingly dependent on and managed by digitally connected ICTs?*

The rise of concerns over privacy and cybersecurity are longstanding. Significant technical and policy efforts to address those concerns existed long before Nakamoto's 2008 paper birthed today's SC ecosystem. For example, the need to develop digital alternatives to paper currency, and enhance digital payment systems to enable more granular, faster, and lower-transaction payments (than credit card or other electronic payment systems enabled) is longstanding. Similarly, the advances in cryptography that are so critical to both cryptocurrencies and to the trust properties of blockchains and SCs have been developing for decades. Also, network researchers have been working on enabling alternative ICT system architectures that facilitate decentralized and distributed control – two separate but often complementary capabilities – for decades.

In ICT systems and in economics, control, action, and ownership can be decentralized and/or distributed independently. That is, control can be separated from action (e.g., remote control in ICT, delegation in economics), and both can be separated from ownership (which, perhaps, is only relevant as an economic concept and refers to who are the claimants of the effects of an action³⁴). Distributed systems can be under centralized control, or via governance mechanisms like voting, centralized systems can be under distributed control. Of course, distributed systems can also be under decentralized local control, and in so doing, be “semi-autonomous”. The “semi-” is appended because the components of a distributed system are still part of the larger system and that system (except in a trivial extreme case) imposes constraints on the behavior of the local components (sub-systems) that limits their full autonomy. That is true both of economies and ICT systems.

An economy is just a collection of economic agents that interact, subject to the constraints imposed by the institutional arrangements that help structure the economy (norms, history, laws, and government institutions). The digital economy transformation underway is blending the real economy and ICT systems in ways that create the potential for new ways to organize control, action, and ownership rights. These bundles of property rights (data structures) can be either more or less distributed and either more or less decentralized.³⁵

³⁴ For example, intellectual property rights (IPR) such as copyright and patents, are intangible property rights that are defined in law to address the economic problem confronted by investors in the creation of information content which requires up-front investments that may be difficult to recover. The IPR assigns ownership rights to the creators that may be transferred or shared with others to sustain markets facilitating the recovery of those up-front investments.

³⁵ See Gerhardt and Thaw (2020) for more on where SC platforms need to go (and Footnote 20 *supra*).

For example, Bitcoin enabled a bearer instrument for digital micropayments that did not require an intermediary (so direct peer-to-peer exchange of a form of digital currency). The invention of NFTs expanded the capabilities of the basic framework to facilitate the transfer of a broader class of digital assets (i.e., in the first instance, small digital art productions). FINTECH's leading role in pushing for the growth of more robust and capable SCs to further expand cryptocurrencies as tools for a wider class of financial derivatives is both natural and obvious. The longer-range hope (expectation) is that SCs will enable infrastructure that can support the transfer of general digital assets tied to "real" (non-digital, non-virtual) world assets, whether those be tangible or intangible property.

ICTs expand the space of technically and economically feasible options for organizing economic activity and property rights. SCs are perhaps most interesting because of their promise in enabling an ICT automated way to reconfigure property rights and control (enforce) the rules governing the use of those rights and their interactions. However, SCs are tools that may be employed to achieve diverse goals and there should be no presumption that SCs will necessarily advance social goals or economic efficiency. In the next section, I address some of the myths and misconceptions that make it difficult to make sense of where SCs may go and to focus attention on what may be most important.

3. Myths and Misconceptions

3.1. SCs are not smart, contracts, blockchain, or cryptocurrency

First, it is worth pointing out that SCs are not "smart" in the sense that they include AI or cognitive capabilities. Indeed, Nicholas Szabo, who is credited with coming up with the idea for Smart Contracts in 1997, over a decade before Nakamoto (2008) launched Bitcoin and Blockchains, later claimed he wished he had chosen different terminology because of all the confusion resulting from his having used the Smart Contract label.³⁶ Surden (2012) is careful to highlight that the ability to automate tasks that require human cognition when performed by humans – and so are often regarded as requiring intelligence or demonstrating intelligence when completed – may be accomplished by ICT systems that are not cognitive or intelligent in any human sense, but are able to accomplish those "intelligent" tasks by other means. For example, computers are very good at repetitive, simple tasks that are readily represented in mathematical terms. Computers can work on such problems 24/7 and so be available when humans would not be. Humans confronted with the same task, may use cognition to find a short-cut that the computer is neither capable of or needs to complete the relevant task. The digital automation of tasks that previously required humans and may have made use of human cognition predates the emergence of SCs and the blockchain.

SCs are also not true legal "contracts" in the sense that they are necessarily legal (recognized or even allowed by government authorities in all countries or legal jurisdictions) or sufficient in

³⁶ Cohnen and Hoffman (2020) seek to address the confusion by titling their paper "transactional scripts" rather than including Smart contracts in the title, and by so doing, more accurately focusing on what SCs actually do which is enable the automated updating of a distributed ledger with practical applications focused on a relative narrow set of commercial contracting applications with a special focus on contracts associated with financial transactions.

themselves to replace the law, legal institutions, or lawyers. However, SC technologies (including computable contracts) have the potential to significantly augment and enhance the management of economic/legal tasks that previously required lawyer intervention. As noted in Mik (2017) and Werbach (2018), written contracts and SCs are expressions of an agreement and their relevance as evidence of an agreement may ultimately depend on a Court of law, outside of the SC.

Indeed, because SCs may not be regarded as legally enforceable contracts in some contexts but legally enforceable contracts may include portions of the contract agreement that are rendered in code (i.e., computable contracts), Clack et al. (2016) recommend distinguishing between a Smart legal agreement which may be capable of being implemented in code and the Smart contract code. The latter may or may not be linked to a legal agreement but is what is actually executed on a SC platform. This also highlights the fact that SCs will in many cases automate processes that may never be identified as “contracts” whether legal or otherwise. By automating certain tasks, those tasks may be moved into the ICT domain and obviate the need for employing such non-ICT tools and mechanisms as “contracts.” Of course, that does not mean that the now automated task is beyond the reach of the law or regulation, which presumably still has an interest in ensuring that the automated task does not result in socially undesirable outcomes. Precisely how the law (whether via product liability, legacy domain-specific, or AI/SC-specific regulations) seeks to assert governance responsibility is the unanswered research question that we are now having to deal with in real time.

SCs often make use of crypto currencies. Indeed, the creation of Bitcoin as a digital payment medium to facilitate implementation of the compensation component of a contracting arrangement seems in retrospect as an obvious first step toward creating SCs to support more complex financial derivatives, and from there, more general SCs.³⁷ However, SCs do not have to make use of crypto-currencies and efforts to develop a digital payment medium significantly predate and are separable from the challenges of cryptography and certainly blockchains. Some see in Bitcoin an effort to create a particular kind of digital payment medium – one that can replicate many of the features of paper money. That is, create a financial bearer-instrument that can be used as a medium of exchange that supports anonymity. Moreover, by relying on a protocol that controls the supply of the currency, it eliminates the role of the issuing authority and its control in the case of a fiat currency like the US dollar. Goodell (2021) and Goodell et al (2021) highlights the importance of having anonymous bearer digital-currencies for supporting individual autonomy, which he argues is a basic human right that is worth preserving and is related to the need to protect privacy rights.

Enabling digital payments (whether via blockchain or otherwise) offers many potential economic benefits, including the capability for atomic transactions that are faster, more granular, and potentially programmable. Faster payments can reduce risk (e.g., less time for counter-party risk to take effect and for volatility to change values). More granular payments can lower fixed-transaction costs and non-convexities in transactions. Investments and transactions can be continuous rather than lumpy, discrete transactions. That may allow better matching of supply

³⁷ In the narrow context where the entirety of the contract transaction is about transferring monetary value, Bitcoin and its blockchain provides a limited SC capability in its own right.

and demand. Moreover, programmability can allow meta-data to condition payment terms. All of these capabilities are potential benefits from appropriate digital payment schemes, but these capabilities can be delivered separably or in conjunction by non-SC/blockchain techniques. Moreover, having one's technology adopted as a preferred digital payments technology would likely bring with it significant private benefits for the sponsor or owner of intellectual property or sunk investments associated with the technology. Consequently, lots of technology innovators anxiously compete to have their favored technology adopted. Indeed, leading credit card companies and financial institutions may see SCs as posing a competitive threat to their market positions, and seek to provide their own SC solutions (or alternatives) as a way to counter such competitive threats.

It is also important to note that the blockchain innovation is not tied to Bitcoin or cryptocurrencies. Fundamentally, blockchain is a Distributed Ledger Technology (DLT), which may more accurately be characterized as a Distributed Verification Technology (DVT). Gerhardt and Thaw (2020) recognize the Bitcoin and Blockchain protocol as worthwhile innovations, while noting that the really important innovation is Blockchain as a DVT.³⁸ Ali and Narula (2020) discuss the earlier roots of DVT efforts by computer scientists seeking to address the well-known problems of trust in ICT systems. They note that most earlier DVT approaches relied on some sort of voting algorithm and admission process to determine the requirements for being an eligible voter.

In contrast, the Nakamoto PoW consensus protocol underlying the Bitcoin blockchain and adopted by many other blockchains is open in the sense that the protocol does not block who can participate in establishing consensus. However, in practice, as the Bitcoin network has grown, the cost of being a successful miner requires such massive computing resources that it is, in fact, becoming a game that only big miners can play, so it is less open than proponents have touted. Additionally, the energy costs of PoW as a consensus mechanism and scalability and other performance challenges (e.g., speed of updating) have helped motivate interest in alternative solutions or Proof-of-X (PoX) where X can be some other mechanism. One common approach is Proof-of-Stake (PoS). Such PoS systems depend on an admission protocol that determines what stake matters and who gets it – decisions that are typically under the control of those who set up the PoS blockchain. In that sense and because of its dependence on who sets the rules and initializes the establishment of stake, PoS systems are like earlier DVT approaches in that they rely on some sort of voting algorithm and admission protocol for determining who gets to vote. Lots of the cryptocurrencies and other blockchain-based token projects include complex (and often opaque) rules defining who gets to participate and control the operation of the protocols (including power to modify protocol rules). This is like different types of equity shares representing ownership claims on a firm that have different voting, convertibility, or other rights. With SCs, the potential for innovation and differentiation in rights is greatly expanded. This flexibility can enable new types of financial (and other) instruments and transactions; but such

³⁸ According to Gerhardt and Thaw (2020) : “Put simply – while Blockchain is a ‘best paper award’ in computer science, it is a Nobel Prize in economics. By solving the double spend problem, the blockchain concept also allows coordination of productive activity at low transaction cost and in a distributed fashion.” See also Note 20 *supra* for further discussion of Gerhardt and Thaw’s interesting take on blockchains and the need for further innovations.

flexibility can also be abused to shift risk burdens, disenfranchise ownership rights, and sow confusion and create asymmetric information problems.

Fundamentally, the blockchain's promise of enabling fully distributed, decentralized DVT is less convincing than originally promised. Many of the challenges that earlier DVT models, or their centralized trust alternatives (e.g., Protected Computing as advanced by Microsoft) still remain, including the need for trustworthy intermediaries (either directly involved, or on the periphery to set rules and intervene if problems arise to enforce society's rules).

If one strips SCs of the association with Bitcoin, blockchain, and cryptocurrencies, what remains is the potential for SCs as tools for automating control of semi-autonomous systems. SCs are a way to implement a distributed, decentralized virtual computer. When looked at abstractly as an ICT technology cluster, the essence of their impact is in helping to effect automation, which is just the movement of human-decision-making (which is control) into ICT. That control can be unpacked into multiple stages. The application of judgement (deciding what to do) is just one step. SCs need not be decentralized or distributed.

Finally, SCs in today's current case also fail on the practical/technical level to deliver on their touted benefits, which include enabling lower transaction costs.³⁹ Much of the technical literature on SCs relates to efforts to improve the performance of blockchains and SC platforms, which suffer from a range of deficiencies, including vulnerability to cybersecurity attacks (as evidenced by the range of successful hacks and abuses by criminals and fraudsters), scalability issues, speed, stability, and execution issues. Although pilot studies have demonstrated great promise in applications across many context domains and continuous innovations seek to address known deficiencies, there is still a lot of work to do.⁴⁰

3.2. SCs eliminate intermediaries: neither feasible nor desirable.

SCs do enable disintermediation, but that is always limited. It is never feasible to eliminate all intermediaries from a contract or economic activity because contracts and economic activity exist within an economy with history, norms, laws, regulations, and governance institutions that frame and constrain the economic or contracting activity. That precludes the fiction that two parties may interact with total autonomy on a peer-to-peer basis.

Those external, "outside the SC" intermediating forces/actors may be explicitly incorporated into the SC (e.g., the SC makes explicit reference to off-chain or outside-the-SC institutions or recourse in the event of certain outcomes), but even if not explicitly incorporated, the outside-

³⁹ For example, executing a computable contract on a blockchain incurs the significant computing costs associated with distributed execution and is often far more expensive than execution on more traditional platforms. On the Ethereum platform, the cryptocurrency Ether is used as "gas" to compensate the network nodes that contribute computing resources to executing the SC on the Ethereum blockchain, and Ether is itself an expensive and volatile crypto-currency (and volatility adds expense since it can render execution costs uncertain).

⁴⁰ Lehr (2021) points to a number of articles that highlight the many areas where SC performance and capabilities are in need of enhancement. See, for example, Ante (2021), Peng et al. (2021), and Dwivedi et al. (2020) for gaps and deficiencies in the SC toolsets.

the-SC context remains relevant.⁴¹ Hadfield (2017) and Surden (2012) point to how external factors can impact the execution of computable contracts. In contract law, this is sometimes referred to as factors that are outside the four-corners of the contract (i.e., the delineation of what is explicitly included in the written contract and what is not included).⁴² Alston et al. (2021) highlight the fact that SCs cannot escape the law and the governance challenges that confront all complex organizations, as will be discussed further below.

SC disintermediation is valuable because intermediation incurs costs that may be avoided. Typically, intermediaries charge fees for the performance of their intermediation tasks which may arise in multiple ways in organizing transactions between parties. In financial transactions, one important role is to address counter-party risk which arises when two parties seek to exchange value and that exchange cannot be perfectly correlated in time or place. A typical solution is to employ an escrow account. For example, Party A wants to purchase a good or service from Party B, but if Party A pays first, there is risk Party B won't deliver the good; or if Party B delivers the good first, there is risk Party A won't pay. A trusted third-party can stand in the middle and make sure both parties honor the agreement, for example, by collecting the funds from Party A and only releasing them to Party B when the delivery of the agreed goods is completed. Banks and credit card companies perform that function on behalf of consumers and retailers, adjusting the account ledgers and settling accounts among the banks to keep track of payment flows. They typically charge a fee to the parties (e.g., vendors who accept credit card payments for goods are reimbursed for less than the full retail price of goods purchased by the credit card companies, and credit card customers often pay annual fees and high interest rates for unpaid credit card balances).⁴³

⁴¹ A number of researchers, including those active in FINTECH applications of SCs, recognize the mistake of thinking that standalone SCs can substitute easily for legal contracts and recommend different strategems for explicitly incorporating legal considerations in order render the SCs more commercially viable. For example, Clack et al. (2016) suggest separating an SC into two distinct components, the Smart legal contract which is a legal agreement that may be partially expressed in code, and the Smart contract code that is to be executed by computers. The first is intended to establish a foundation for the legal enforcement of rights and obligations (potentially by a Court of law), whereas the second sets forth the actual actions that will be automated. Hammer and Falk (2022) point to the fact that SCs, which may be standalone agreements, may also be incorporated in larger legal contracts (e.g., that may reference and specify the scope of the SC relative to other more standard contracting terms and practices).

⁴² The written contract is an expression of the agreement that a Court may accept as evidence of the agreement, but it is not the agreement and may be subject to challenge (Mik, 2017). That is even more true about SCs because the novelty of SCs lacks the long history of legal adjudication and evidentiary proceedings behind the common or legislative law of written contracts. The parties may seek to limit such challenges by including language in the contract that seeks to exclude from consideration anything that is outside of the four-corners of the written contract, but the efficacy of such strategems is not absolute.

⁴³ Credit cards and other financial intermediaries, as well as digital platform providers, have often been analyzed as two or n-sided markets, wherein the intermediary can realize scale and scope economies and can benefit from network externalities on both-sides of the market from its ability to reduce the matching costs of vendors and customers. These scale/scope economies and two-sided network externality benefits have been cited as a source of market power and force that may push towards winner-take-all market dynamics. By enabling alternative approaches that may enable vendors and customers to interact directly, it is hoped that SCs may offer a way to disintermediate dominant platform providers and thereby facilitate

Following the 2007/2008 global financial collapse and in light of growing recognition of the rise in illegal black/gray market activity and the threat that under-regulated financial markets posed for consumers, regulators around the globe promulgated or reformed financial regulations. In many cases, those regulations were intended to improve the information flow among financial intermediaries and regulators to enhance transparency and better enable market participants to monitor financial markets and potentially detect and mitigate illegal or other harmful activity that might otherwise threaten the stability of financial markets or other policy goals (e.g., support the financing of terrorism, child pornography, or other illegal endeavors). Financial regulations such as Know Your Customer (KYC), Anti-Money Laundering (AML), and Combatting the Financing of Terrorism (CFT) regulations were enhanced to improve the regulability of financial markets.

The additional reporting requirements imposed new data requirements with increased opportunities for data entry errors, duplication of effort, interoperability problems, and higher-transaction costs among institutions with heterogeneous systems and mixed-degrees of manual, human processing. SCs and blockchain distributed ledger technology provides an obvious opportunity for reducing the data processing transaction costs and expanding capabilities for monitoring. Instead of having to collect and enter the data needed to comply with new KYC, AML, CFT and other financial regulations on a per-customer basis for each financial relationship and then making sure that the data is consistent across linked financial relationships, a blockchain offers a common, distributed ledger that disintermediates that activity, and thereby can avoid those transaction costs. More generally, SCs have the potential to provide distributed, common ledger solutions for the creation, storing, and sharing of all sorts of digital record information – not just financial transactions (e.g., Bitcoin) but all sorts of records (e.g., health records, carbon footprint tracking, corporate business records, etcetera). In reducing the duplication of record keeping and disintermediating transaction costs associated with human transcriptions (and their attendant errors), significant transaction and data management costs may be saved. On the other hand, the creation of such integrated/shared datasets can also pose a significant threat to privacy and data security. Those challenges are changed but not eliminated by the introduction of encryption.⁴⁴

Furthermore, it is important to note that although significant progress is being made to develop SC tools to address the challenges of efficient disintermediation, these tools are still in their early stages of development and adoption. To get a sense of the state of such efforts, consider that KPMG was promoting the potential for blockchain as a new solution to reduce the costs of KYC

competition and decentralization of economic power. Unfortunately, SC technologies may also be used to consolidate the market power of digital platforms as discussed further below.

⁴⁴ For example, even if encryption can protect data from man-in-middle attacks, the need to provide key security shifts the data protection problem. Having one key or a thousand keys are both problems requiring economic resources to manage. The challenges of key management need to be balanced against the costs of encryption. While few would doubt that encryption is an extremely valuable tool in promoting data security, the fundamental security problem will continue.

compliance in 2018;⁴⁵ and today, there are multiple financial service providers advancing blockchain-based strategies to solve KYC and other regulatory compliance challenges (including in the DeFi space).⁴⁶ While both legacy financial market participants and new entrants are actively exploring such SC ecosystem solutions to enhancing regulatory compliance efficiency, these are still early stage initiatives that are competing with legacy approaches.

To further illuminate the maturity of such efforts and the quandaries they pose for regulators, consider that FATF-- the international, inter-governmental watchdog and standard setting body for the enforcement of AML and CFT regulations -- only began to address Virtual Assets (VAs) such as Bitcoin and other SC financial innovations in 2018 and promulgated standards for regulating VAs in June 2019.⁴⁷ The FATF's mixed message is that while VAs have great potential to enhance financial market efficiency, lower transaction costs, and expand inclusion, they also offer a powerful tool for criminals interested in monetizing their crimes.⁴⁸ They point to the 2017 Wannacry ransomware attack that made use of bitcoin that was estimated to have caused \$8B in damages globally in the expectation of garnering the criminals \$100 million in illegal gains (which were denied when authorities successfully interceded before the criminals were able to convert their ill-gotten gains. In addition to highlighting the threat that the emerging SC ecosystem's tools pose for AML/CFT regulation, the ability of regulators to catch the Wannacry perpetrators points to holes in the touted anonymity benefits of the SC technologies.

Fundamentally, the mixed attitude of the FATF demonstrates that SCs are a tool for disintermediation that can have either positive or negative social and private welfare impacts, depending on the intermediary bypassed. In countries with corrupt governments or institutions, moving functionality into algorithmic processes mediated by SCs can improve trust and efficiency. For example, human resource managers may use SCs to fight against nepotism, cross-checking HR decisions against pre-agreed process and outcome standards. At the same time, however, criminals or other hostile actors can use SC tools to bypass sovereign governments and regulatory controls resulting in significant social welfare losses that may significantly outstrip the expected private gains of the SC users (as the Wannacry example cited above illustrates).

⁴⁵ See KPMG (2018), "Could Blockchain be the foundation of a viable KYC utility?", available at <https://assets.kpmg/content/dam/kpmg/xx/pdf/2018/03/kpmg-blockchain-kyc-utility.pdf>.

⁴⁶ Clack (2018) identifies the potential of blockchain to address many challenges in global financial markets, but to do so, the ecosystem must confront its own challenges, including developing common data standards and processes. The company R3 which is a blockchain service provider (focused on Distributed Ledger Technologies or DLT, including both permissioned and open blockchains and related systems) highlights a range of case studies on its website, including a "KYC sovereign application solution" that was developed by the FINTECH service provider Synecron (<https://www.synecron.com>) on the R3 SC platform Corda and was piloted in 2018 to allow 39 banks to securely share customer information (see <https://www.r3.com/>, visited 6/2/22).

⁴⁷ The Financial Action Task Force (FATF, <https://www.fatf-gafi.org/>) was founded in 1989 and has over 200 member countries and jurisdictions. FATF promulgated global recommendations (mandatory standards) for AML/CFT in 2012 and regularly updates those rules.

⁴⁸ See https://www.fatf-gafi.org/publications/virtualassets/documents/virtual-assets.html?hf=10&b=0&s=desc%28fatf_releasedate%29, visited 6/17/2022 and FATF (2021).

Finally, most interesting SCs specify contingent execution that depends on future states of the world that depend on off-chain events. The SC only knows what is encoded in the SC and when SCs are coded on the Ethereum platform, they can only be changed by creating a new contract that supersedes the earlier contract. Suppose the execution of the SC depends on the rate of the inter-bank lending rate, the occurrence of some climate event, or some other change in the state of the world. The only way to get that information into the SC is via an oracle that is an intermediary. There are efforts underway to create DeApps for oracles – that is, oracles that are themselves decentralized applications existing on a blockchain so as to mitigate the trust concerns of relying on an intermediary, but once again, the disintermediation benefits are, at best, limited.

3.3. SCs complete markets and ensure execution

One hope is that SCs may make it easier to specify complete contracts, and address an important source of market failures in economics. By allowing the parties to instantiate in computer code that clearly specifies the path of execution in various contingent states (by using if/then constructions), SCs may make it easier for parties to codify their agreement and make it easier to control execution in different contingent states. Moreover, when SCs are included as part of a legal agreement, they may provide useful evidence of the contracting parties' agreement intentions to assist third-party adjudication of disputes.

Unfortunately, real life is inherently complex and complete specification of all contingent states is often combinatorially infeasible even if the parties had perfect shared knowledge about what states might prevail at the time execution is to take place. Moreover, the future is fundamentally uncertain and hence it is not possible to fully specify what should happen in all possible future states. This inherent uncertainty, as well as strategic interests of the contracting parties and their lawyers often seek to leave contract terms ambiguous by design. Perfect predictability and guaranteed execution of pre-specified terms are neither desirable nor achievable in practice.

Whereas SCs may play a real role in addressing incomplete market problems as they arise generally in economics, and more specifically with respect to contracts, SCs cannot eliminate the economic problems that may arise because of incomplete markets. Thus, moral hazard, adverse selection, asymmetric/imperfect information, irreversibilities, and other economic manifestations of problems that may be attributed to the lack of complete markets will continue to exist in the world of SCs, but perhaps in different form. Whether those forms are more tractable (less socially or privately costly) will depend on how the SC ecosystem evolves.

Furthermore, in the more mundane sense of acting as anticipated or intended, SCs may fail to execute because of failures anywhere along the line because of the not-ready-for-primetime status of the SC ecosystem.⁴⁹ Cyberattacks and other software/platform system failures, coding errors, or any of the other problems that impact the reliability of ICT systems can also impact SC execution. Those risks can never be wholly eliminated nor the contingencies they call for fully anticipated or insured for.

⁴⁹ For all of these reasons, Howell & Potgeiter (2021) argue that SCs will not supplant real world institutions.

3.4. SCs decentralize economic power and promote competition

SC optimists see this cluster of technologies as offering tools that have the potential to decentralize economic power, promote competition, and empower end-user autonomy. The preeminent example of this is the Decentralized Autonomous Organization (DAO).⁵⁰ Lessig (2006), Benkler (2008), and Zittrain (2006, 2009) – writing before the emergence of the SC ecosystem -- have all noted the potential for ICT technology to provide tools for redistributing economic power while also noting quite appropriately that socially desirable outcomes are far from foregone conclusions. Both the optimism and the skepticism are warranted.

The tools of SCs can also be used to centralize control, reduce the effectiveness of regulatory remedies, and may render coordination efforts among economic actors even more difficult. For example, the Chinese government has embraced many elements of the SC ecosystem, including the creation of a national cryptocurrency (the digital Yuan) and advancing the use of SC technologies for quality control to enhance food safety, yet have also restricted initiatives that threaten to centralized government control.⁵¹ Thus, the social outcomes from further progress in the SC ecosystem are ambiguous.

Many SC developers are working to develop new architectures, protocols, and platforms to make it at least feasible that SCs could be used to decentralize economic control. For example, Gavin Wood (founder of Polkadot and co-founder of Ethereum) recently described efforts to reform the governance system of Polkadot to make it more democratic. Since the SC ecosystem is evolving in real time, modifications to protocols and other important decision-making is perforce exclusionary. Even if eventually the goal is to make the technology available to everyone, not everyone can participate equally. The first and most obvious barrier to participation is insider knowledge of the project that creates a hierarchy of founders/developers and those who come later as users. The technical direction and control over it is effectively under the control of the innovating developers and the need to protect against errors and problems caused by attackers or ignorant contributors necessitates a level of gate-keeping. Additionally, even if participation is, in principal, open by design (which is not the case for many projects and is explicitly not the case for permissioned blockchains), potential participants need complementary assets (e.g., sufficient digital literacy and digital technology access) to be able to participate. Persistent digital divides will ensure that access will remain asymmetrically available. Thus, at best, the potential for SCs to facilitate the decentralization of economic power will remain a work in process.

Alston et al. (2021) characterize the governance structure of different SC networks as polycentric, leveraging the work of Ostrom (2010), Aligica and Tarko (2012), and others to explore the multilayered nature of internal governance structures ranging from the core protocols to the rules governing participation in changes to the system, including forking of the blockchain.

⁵⁰ For example, see WEF (2022), Davidson, De Filippi, and Potts (2018), and Tapscott & Tapscott (2017), and earlier at Footnote 21 and 25 and surrounding text, *supra*.

⁵¹ See Kshetri (2022). For example, China banned ICOs in 2017, cryptocurrency mining and cryptocurrencies in 2021. China has also been active in exploiting a wide range of surveillance technologies that are seen as threats to personal autonomy and privacy in the Europe and the U.S.

Efforts to promote SC developments highlight the economic challenges that enabling decentralized economic power must confront. For example, Goodell (2021) argues for the importance of anonymity to preserve end-user autonomy, and by extension, the need for a digital currency that provides an anonymous, bearer-bond payment capability like paper money. Anonymity, which may be necessary to enable end-user autonomy and decentralized economic power, poses a challenge for government entities tasked with ensuring public safety and security, including cybersecurity, since criminals and others who intend harm often seek to evade identification. Resolving these issues is not easy as the debates over lawful access to digital information highlight.⁵²

4. Smart Contracts and FINTECH

It is hardly surprising that FINTECH applications of SC technology are among the most advanced. First, the preconditions for the SC ecosystem to evolve depends on the availability of the Layer 0 5G infrastructure. Finance has long been among the most ICT-intensive sectors. The importance of advanced ICT capabilities as a key strategic asset for financial enterprises, as well as the investment community's need to anticipate emerging trends, including those that may transform the economics of technology or other industry sectors, propels the financial sector to be an early adopter of new ICT technologies.

Second, along the path toward an SC future in which SCs will enable the management and transfer of arbitrary bundles of property rights, the creation of the payment infrastructure to support that – that is, FINTECH -- points to a relatively clear roadmap that was traced out over the several phases in development of the SC ecosystem discussed earlier.⁵³

Third, the hope that SC technologies might help decentralize economic power by lowering entry barriers prompted many to see SC technologies as a viable path to compete against legacy incumbents that globally dominate in banking, financial services, and securities markets. The SC ecosystem has rapidly spawned thousands of cryptocurrencies, tens of thousands of SC ecosystem projects, and launched numerous new ventures that in many cases may be little more than an entrepreneurial techie with a website. While much of the hype has been focused on the rags-to-riches (and back to rags) stories that the SC rollercoaster has given rise to, most established financial sector enterprises and policymakers have been working on their own responses. It is easy to find examples of these. All one needs to do is search the web for a major financial sector multinational in conjunction with the terms “cryptocurrency”, “blockchain”, or “smart contracts,” and it is rare that such a search will fail to yield a pointer to some press coverage or internal company news mentioning a project underway to test, deploy, or scale that

⁵² See Goodell (2021), Goodell et al. (2021), and Grennan (2022).

⁵³ The creation of Bitcoin cryptocurrency was the first necessary element: a digital substitute for money, the most basic financial instrument. Although Nakamoto (2008) launched Bitcoin, it was not the first attempt to create digital money, not even by Nicholas Szabo, who is credited with originating Smart Contracts. David Chaum's DigiCash venture launched in the 1989 and Nicholas Szabo proposed BitGold in 1998 (see Saylor Academy, 2022, for a good discussion of the pre-history of Bitcoin). From the creation of a digital substitute for money, FINTECH rapidly progressed to wanting to create derivative securities which eventually lead predictably to the need to create more capable SC platforms. See earlier discussion in §2.2 *supra*.

enterprise's efforts to make use of SC technologies.⁵⁴ This is hardly surprising since the SC ecosystem poses a disruptive shock to the financial sector, although its economic implications seem more likely to impact the distribution of economic surplus produced by the sector than to result in the expansion of surplus generated by the sector.⁵⁵ An area that yields perhaps the greatest hope for SC innovations to expand welfare is in the potential for the technologies to expand economic activity and financial inclusion in developing markets and among communities that have previously had limited accessibility to financial services.⁵⁶ By comparison, the most significant hope for SCs to spawn new valuable innovations seems more likely to be in sectors and realms of economic activity that are lagging in their progress toward a digital future. Those non-financial-sectors may lag because of their eReadiness (in terms of Layer 0 "5G" infrastructure), because of the inherent complexity of the challenges (e.g., financial derivative transactions are more complex than cash transactions; general asset transactions are more complex than financial transactions, etc.), and because of the current state of the technology.

Nevertheless, although the biggest welfare-enhancing, economic value creation potential for SCs seems likely to be in other sectors -- not finance -- FINTECH is a logical place to look to understand what the future for regulatory policy directed at SCs may look like.

4.1. Domains of Policy Concern

Different policy concerns for different sectors

An interesting question that emerges is whether the lessons learned about the likely trajectory of SC regulatory policy from studying FINTECH will be transferrable to other vertical sectors where the dominant policy concerns, industry and governance structures, and history are quite different. For example, in healthcare, a dominant concern is with the preservation of human life; in supply-chains, with managing hand-offs of real goods among multiple parties; and in human resource management, in ensuring fairness and matching candidates to the right tasks. Moreover, in the US and elsewhere, different matrices of regulatory institutions, laws, and polycentric governance entities take leading roles in different sectors, and often with insufficient cross-sector coordination and communication.

⁵⁴ For example (as of 7/27/2022), search for "HSBC blockchain" and get pointed to <https://www.gbm.hsbc.com/solutions/global-liquidity-and-cash-management/digital-innovation-hub/blockchain>; or "Bank of America Smart Contracts" and get pointed to <https://www.blockchain-council.org/news/bank-of-america-reports-chainlink-to-accelerate-the-widespread-adoption-of-blockchain-technology/>; or "NYSE Cryptocurrency" and get pointed to <https://www.nyse.com/nft>. A similar exercise of searching for any large multinational in virtually any sector (from agriculture to healthcare) with "Artificial Intelligence" will point you to similar news.

⁵⁵ That is, it appears to this author as if SCs in FINTECH are more about reallocating rents among financial sector participants than about creating wholly new financial products.

⁵⁶ My opinion echoes the views of other economists concerned about the implications of Artificial Intelligence more generally. For example, see Acemoglu (2021), who has written extensively about the potential for AI to lead to significant productivity growth, but with ambiguous implications for employment and welfare, depending on how the tools are used and to what purpose. Professor Acemoglu does not see the significant AI activity in targeted advertising and financial arbitrage as being among the applications that are most likely to deliver the sorts of world-changing innovations that AI proponents hope for.

Toward risk-based regulations in the face of rapid innovation and uncertain futures

In the case of AI, the European Union (EU) is proposing a framework that seeks to integrate both a horizontal (cross-sector) approach with the legacy, vertical “silos” that have historically characterized policymaking in different sectors.⁵⁷ In light of the rapidly evolving state of the AI ecosystem (a feature that the SC ecosystem mirrors), the EU framework adopts a risk-based approach. That begins by articulating the key socio-economic values that AI policy seeks to promote and mapping those to different policy initiatives or challenges.⁵⁸ Then, AI developments (applications, uses, etc.) are analyzed in terms of the risk they may pose for policy goals. The greater the risk, the greater the regulatory burden that will be imposed on entities seeking to make use of AI in those areas. Applications that are coded “green” will be permitted with minimal regulatory constraints, while those coded “red” may be prohibited or only allowed under strict regulatory controls. Precisely how to map applications and AI developments to the coding scheme, what applying the different risk assessments in practice will entail, and whether the framework will be successful are all works-in-process. The SC ecosystem which is even less mature than the AI ecosystem that it is closely related to seems headed toward a similar risk-based model.

Policy concerns for the financial sector

When it comes to financial regulation and policy, many of the policy concerns noted above for other sectors are also relevant to actors in the financial sector. However, the key motivating policy concerns that are unique to financial regulation include ensuring the stability of the financial system and protecting consumers and businesses from the risk of financial losses due to crime, lack of education, or financial inclusion. The key concerns for financial stability focus on payment mechanisms, lending and borrowing activity, and investments. Because risks associated with finance and the challenges of addressing them existed long before SCs emerged, there are long-established regulatory institutions and approaches for managing these issues. The question engaging experts in financial regulation may be roughly grouped into questions about jurisdiction, disclosure/transparency, and a range of specialized rules, including those related to government efforts to promote security and battle crime.

Determining jurisdiction: mapping new wine to old bottles

With respect to jurisdiction, the first question is what financial policy concern does a FINTECH innovation address and which branch of the financial regulatory apparatus is responsible for that? With respect to the stability of the financial system a first-order concern is the money supply that is used for payments that are a central capability needed by almost all types of economic activity. In the U.S. (and to simplify the exposition, I will focus on U.S. here), the U.S. dollar is a foundational component of the money supply and medium of exchange used for payments.

⁵⁷ See EC (2021).

⁵⁸ The UN’s Strategic Development Goals (SDG) process is analogous, and these international efforts are cognizant of and inform each other. For more on the role of ICTs in SDGs, see Sharafat and Lehr (2017) or <https://www.itu.int/en/ITU-D/ICT-Applications/Pages/ICT4SDG.aspx>.

Managing the supply and ensuring the value of the U.S. dollar as a fiat currency, and indeed, as a reserve currency internationally, is jointly the responsibility of the U.S. Treasury, the Federal Reserve (the nation's central bank) and banking regulators. Alternatively, if the focus is on financial securities such as stocks and bonds and other more complex securities, then the Securities and Exchange Commission (SEC) is the most important national regulator; whereas if the financial instrument relates to commodities, then the Commodity Futures Trading Commission (CFTC) are the relevant regulator. In each case, regulators focus on the financial intermediaries engaged in the relevant type of activity.⁵⁹

When FINTECH innovations like cryptocurrencies and SC-based derivative securities and new business practices emerge and the relevant players change, regulators need to determine whether the innovations map readily to existing regulatory mechanisms, or whether new institutional arrangements are needed. With respect to finance, it looks like in most cases, existing frameworks will suffice and wholly new regulatory institutions and frameworks do not appear to be needed. It is less obvious whether that intuition will apply equally well when SCs expand to become significant in other sectors.

In the U.S. context, it looks like the role of cryptocurrencies as a substitute for money will be dominated by central bank regulation and efforts to create a Central Bank Digital Currency (CBDC). In the context of most cryptocurrencies and derivative securities enabled by SC platforms, these will be classified as securities, and hence, be subject to regulatory oversight by the SEC. And, in the case of Bitcoin, which was previously determined to be a commodity, the CFTC will provide regulatory oversight.

Regulatory challenges in light of skill & knowledge constraints and asymmetries

Although these assignments suggest a relatively straightforward regulatory trajectory, several significant challenges exist. The first relates to the fact that the SC ecosystem is international in scope (and by design threatens the relevance of sovereign jurisdiction) and the technology and industry are evolving rapidly, challenging policymakers' efforts to keep abreast of relevant developments. A similar (and closely related) challenge confronts policymakers' efforts to

⁵⁹ There are a wide variety of financial intermediaries, including banks (many types), insurance companies, exchanges, and financial advisors. In addition to these, there are large array of upstream providers that provide technology, equipment, and services to support financial sector activity. FINTECH spans all of these. It is becoming increasingly challenging (and less relevant) to draw boundaries between the finance sector and the entities that provide the "Layer 0" ICT infrastructure on which global finance depends; and because of the strategic importance of finance for all economic activity, there is lots of specialization in finance applications for other sectors (e.g., healthcare-related v. agricultural v. real estate related financial services). This specialization arises for numerous reasons, including the need to be current on dynamic domain-specific knowledge, regulations, etcetera. For example, consider the difference between insuring a 1lb shipment in a 12-inch cube that might contain grain, diamonds, gun powder, or electronics – the physical challenges of shipping would be a small component of the total insurance costs needed to manage goods with such diverse regulatory and value characteristics. This is analogous to the challenge of providing general purpose network services for traffic with increasingly heterogeneous economics (because of its QoS demands, whose traffic it is, etc.) that helps drive the tension between "private" and "public" networks.

respond to the continuously evolving cybersecurity landscape.⁶⁰ Policymakers are especially challenged because of the global shortage of personnel with the right technical skills to operate effectively in the SC ecosystem. The skills shortages for professionals with strong data science, cryptography, and blockchain expertise is widespread in industry, and governments rarely can offer salaries or opportunities that are appealing to the best talent. In light of the public attention to lurid details and the boom/bust cycles that have characterized cryptocurrency markets and NFTs, and the potential threat SC-enabled financial technology poses for legacy regulations and enforcement capabilities, policymakers and regulators have been scrambling to educate themselves and their constituents about the implications of SC technologies and to frame their regulatory thinking.⁶¹

In the U.S., addressing this knowledge gap has put renewed focus on FinCEN, the U.S. Financial Crimes Enforcement Network,⁶² that was created in 1990 to support federal, state, local, and international law enforcement by analyzing data required by the U.S. Bank Secrecy Act. By the nature of its assignment, FinCEN has had to build capacity in ICT-intensive technologies that is beyond the capabilities of most other regulatory agencies (especially at levels below the national, federal level). FinCEN has taken a lead role in prosecuting several high-profile enforcement actions related to cryptocurrency and SC ecosystem financial activity, signaling to market participants that the use of new technologies by new players does not exempt those activities from regulatory constraints.

DeFi and the challenge of identifying intermediaries to regulate

A special challenge arises in the context of Decentralized Finance (DeFi) because these are services that are implemented via protocol, and ideally, are decentralized such that there is no financial intermediary to identify, and hence regulate. Ellul et al. (2020), Massari & Catalini (2021), Werbach (2021) and others have highlighted some of the special problems that arise with regulating DeFi. In most cases, in practice, it is possible to identify relevant DeFi actors, however many in the development community are arguing that DeFi is so new that burdensome regulations may deter the development of nascent valuable innovations. Many of the players are new, small ventures that would confront asymmetric entry barriers in trying to comply with the burden of legacy financial regulations, thereby threatening financial sector competition, which is posited as one of the key benefits DeFi may deliver. These arguments cannot be rejected out of hand. However, they are claims that would be expected from any new entrant seeking to exploit the cost advantage granted by being able to evade regulatory burdens imposed on incumbents. Moreover, worsening political divides over greater or lesser government regulation in virtually every context, the question of whether and how to regulate DeFi has assumed political dimensions. Proponents of light-handed or no-handed oversight of SC technologies have found supporters at the political fringes on the left and right, with actors in each group seeing SC as a

⁶⁰ The two are closely related since cryptocurrencies are key mechanisms for implementing gray/black market payments to avoid regulatory oversight or engage in criminal enterprises.

⁶¹ For example, see For example, see CFTC (2018), EIOPA (2021), FATF (2021), Federal Reserve (2022), IOSCO (2022), UK (2016), US Whitehouse (2022), Zetsche et al. (2022, for BIS).

⁶² See <https://www.fincen.gov/>.

work-around path to government policies that sustain the status quo and the market position of incumbents.

Focus on Transparency and Disclosure

When regulators struggle to craft frameworks for specific FINTECH intermediaries, much of the detailed focus is initially on transparency and disclosure requirements. Regulators and industry stakeholders debate who should be subject to new, heavier reporting requirements and what information they should be required to disclose to regulators and what should be made public. This makes sense since the first challenge is for market participants to figure out what is really going on in markets in order to separate hype from substance. The efficiency of markets and the effectiveness of regulatory controls depends on the existence of informed stakeholders. Firms and consumers need to have access to the information needed to make informed purchase, production, and consumption decisions. Uninformed consumers who do not understand their choices, rights, and the risks of using or investing in different types of financial instruments are at risk of significant losses either due to their ignorance or as victims of crime.

Regulators need to know what is really going on in order to identify which entities are in regulatory compliance and to detect and stop criminal activity. A significant tool for financial regulation are the apparatus used to manage public disclosures of financial information, including requirements for the publication of annual reports, announcements of significant events, and investor notice requirements that are designed to ensure market participants are informed. To enable these reports to be interoperable and interpretable, the transparency and disclosure rules rely heavily on accounting standards that specify what and how different bits of information should be reported.

With SC-related developments such as Initial Coin Offerings (ICO) that emerged as a new way to raise funds for new ventures in 2017, there was minimal regulatory oversight. ICOs launched as SC tokens were marketed with vague “white papers” that were analogous to the proxy statements that are required for traditional Initial Public Offerings (IPOs) of stock equity. However, the white papers left many important details unaddressed, and their regulatory status as public disclosures was unclear. Indeed, a significant attraction of ICOs was their ability to avoid much of the regulatory burden and other transaction costs associated with using an IPO or other paths for funding new ventures. Lowering the costs of financing can reduce entry barriers (that can help promote competition) and can potentially enable welfare-enhancing innovations that would be infeasible without the reduced financial costs; but bypassing valuable legacy regulations can also simply be a path for fraud or other socially harmful activity. The rise of eBay, Uber, AirBnB, TaskRabbit, and the many other examples of sharing/Gig Economy business models highlights the stresses raised when new ways of doing business confront legacy regulations.⁶³ Cohnney, Hoffman et al. (2019) provide a review of the regulatory challenges posed by ICOs. It appears clear that the SEC and other financial regulators will regard ICOs as instruments subject to the same regulatory authority governing other funding options for new

⁶³ For example, eBay raised issues for tax authorities and financial regulators of exchanges; Uber and AirBnB challenge established regulatory frameworks for travel and lodging industries; and TaskRabbit challenges labor policy frameworks.

ventures, while recognizing the need to consider still-to-be-resolved issues of how exactly to regulate them.

When it comes to disclosure and reporting requirements directed at interdicting crime and the important role that anonymous (or hard to track) finance can play in such activity, regulators impose extensive disclosure requirements on banks, and with the expansion of intermediaries engaged in finance, due in part, to the rise of the SC ecosystem, regulators have extended those obligations more broadly. Banks are subject to a range of reporting and data management requirements such as Know Your Customer (KYC), Anti-Money Laundering (AML), and Anti-Financing Terrorist (AFT) rules that have grown more burdensome since concerns over terrorist and international criminal activity have grown.⁶⁴ Digital technologies have proved helpful for criminal enterprise efforts to evade regulatory authorities. These technologies can be used by criminals to hide their activities by moving the location where activity takes place and employing cryptographic and other networking tools that render the identity of the participants anonymous to authorities.

Not surprising, the efforts to expand regulatory reach and strengthen transparency/disclosure requirements associated with expanded KYC, AML, AFT, and other financial regulations has the effect of stimulating interest in SC technologies. The benefits of a distributed ledger for sharing common data among multiple parties that helps avoid duplicative data entry and copying errors when financial institutions rely on heterogeneous and non-interoperable ICT systems for data management become more attractive as the burden of data and range of parties that need to collect and share data increases.⁶⁵

4.2. Cryptocurrencies and Evolution of Money and Digital Payments

When it was originally conceived and launched, Bitcoin was intended as a digital substitute for paper money, which was itself a substitute for still earlier mediums of exchange that have emerged since the earliest days of human communities. Before considering more carefully the

⁶⁴ A related policy challenge concerns regulation of access to information shared by subjects that are the target of law enforcement or national security agencies. Lawful access to private communications is enabled under regulatory and legislative frameworks such as wiretaps and search warrants, but with more information becoming digital and encrypted, law enforcement and security entities have struggled to keep up and avoid their access to the information and evidence needed to detect and prosecute criminal activity from going “dark.” That is a real problem, but so is the risk of the rise of the surveillance society of Orwell’s 1984. The growth of AI facial recognition capabilities and ubiquitous video capture infrastructure makes it increasingly reasonable for those risks to be realized. International collaborative efforts of national security agencies such as “Five Eyes” (<https://www.dni.gov/index.php/ncsc-how-we-work/217-about/organization/icig-pages/2660-icig-fiore>) have called for new legislative frameworks that expand government capabilities to access encrypted information. See Abelson et al. (2015) and Barker et al. (2021) for further discussion of the lawful access issue. The SC ecosystem will make resolution of those issues even more challenging.

⁶⁵ For example, one growing player in the SC space, R3 has developed a multi-bank KYC solution based on distributed ledger technology (see R3: “Power of 3... trust technology for multiparty applications, connected networks and ecosystems, and regulated markets expertise” (<https://www.r3.com/>, 6/2/22)/

role of digital money and its regulation, it is worth pointing out that this vision has not been realized and is unlikely to be realized.

Bitcoin and most of the cryptocurrencies that it has helped spawn have not been used as a substitute for cash or other digital payments (e.g., credit cards) for point-of-sale (POS) transactions or elsewhere. Instead, most of the transactions in cryptocurrencies have been related to speculation over the future value of cryptocurrencies (so more akin to futures or option contracts than paper cash). Dr. Gensler, chair of the SEC since August 2021, has opined that most crypto tokens are likely to be classified as securities, and hence, readily mappable to existing SEC regulatory frameworks.⁶⁶

Future of Money

As a medium of exchange, money serves multiple purposes: (1) for payments, as already noted; (2) as a unit of account; and (3) as a store of value. Today's cryptocurrencies and their extreme volatility have demonstrated that they are not doing a very good job with any of those roles. The need for digital alternatives to paper money are obvious. First, digital money enables more granular, faster, and flexible transactions and scalable supply. Without money, transacting parties need to exchange goods directly (e.g., a shoemaker gives shoes to farmer for wheat); but money allows indirect exchange. Berg et al (2020) point to Clower's (1967) insight that in a "money economy, money buys goods and goods buy money, but goods do not buy goods." Money emerges because it solves the double-coincidence of wants challenge that arises in a barter economy. That realizes an important transaction cost efficiency and helps to explain why the invention of money is seen as a key facilitator of economic growth, allowing markets to scale and grow in complexity and geographic scope.

Moving to digital payment mechanisms (e.g., credit cards) offers advantages in terms of speed, convenience, security, liquidity, and other transaction cost-related benefits. The ability to lower transaction costs makes it economically feasible to complete transactions involving exchanges with very low values and that greatly expands the range of transactions that can take place and how transactions may be linked over time. When transactions are not suitably granular then matching the quantity demanded and supplied is challenging and purchases are lumpy, requiring inventory stock management. With suitably granular transactions, less transaction-specific value is at risk and the lumpiness of transacting can be smoothed. Transaction risks may be reduced in multiple ways. When smaller transactions can be completed faster, there is less risk for value change and reduced third-party risk management costs.

The emergence of credit cards represented a big improvement over cash in terms of convenience, but the costs of completing credit card transactions remain significant, mostly because of the fees

⁶⁶ See SEC (2022), "Prepared Remarks of Gary Gensler On Crypto Markets Penn Law Capital Markets Association Annual Conference," U.S. Securities and Exchange Commission, April 4, 2022, available at <https://www.sec.gov/news/speech/gensler-remarks-crypto-markets-040422>. Before becoming SEC Chairman, Dr. Gensler was a professor at MIT where his research and teaching efforts sought to advance understanding and educate industry regarding the implications of SC technologies. See Casey et al. (2018), Gensler (2018a), and Gensler (2018b).

charged by credit card intermediaries. The prevailing transaction costs precluded using credit cards for micro-scale transactions, motivating demand for better digital payment alternatives.

The emergence of cryptocurrency and other e-payment schemes has helped enable more granular ePayments and thereby unlock the expanded range of transactions and business model relationships that micro-payments facilitate. First, micropayments bring buyers and sellers one step closer to real-time, just-in-time, on-demand markets. This has implications for economies and markets in all stages of development. Second, micropayments expand the potential for economic inclusion by reducing the scale and transaction costs for purchasing goods and services that challenge the poorest members of society that are most likely subject to budget constraints that limit their consumption behavior. The potential for SC innovation in FINTECH to expand economic inclusion in the developing world is one of the most promising developments. In addition to providing low-cost micropayment capabilities (something that 2G text messaging infrastructure was already enabling in the developing world, albeit potentially at higher cost), SC technologies can help in disintermediating corrupt government and local intermediaries or in providing infrastructure where alternatives are lacking.⁶⁷ Although the potential for FINTECH to help in addressing these important development challenges is real, it is far from a foregone conclusion. In practice, FINTECH may make matters worse, since as noted earlier, the SC technologies can be wielded as tools for strengthening centralized control, erecting entry barriers, and enabling a surveillance economy; or for the opposite purposes – depending on who is in control of how they are used.

Digital payments and double-spending

One key feature of paper money that cryptocurrencies like Bitcoin sought to emulate is its ability to be a bearer bond and therefore provide anonymity, which is a necessary element for approaching the aspiration of true peer-to-peer, intermediary-free, economic commerce.⁶⁸ A dollar bill is self-authenticating⁶⁹ so that the parties to an economic transaction can be secure in knowing that it represents \$1USD in purchasing power that is essentially riskless since it is a fiat currency backed by the promise of the U.S. government. Once one moves to digital currency, the double-spending problem becomes a major challenge. With paper bills, the actual bill ensures that it cannot be used simultaneously by a buyer to purchase \$2 worth of goods. With digital currencies, the double spending problem is more challenging and the traditional approach was to have a centralized mechanism of linked intermediaries to keep track of the spending, adjusting the account ledger for buyers and sellers to prevent double spending. The Blockchain protocol was invented as a Distributed Ledger Technology (DLT) to address this double-spending challenge without requiring a centralized intermediary to manage the accounting.

Preserving anonymity for digital money substitutes

⁶⁷ See de Cunha et al. (2021).

⁶⁸ As I have already explained, even if all other intermediaries are eliminated, the economy in which agents exist serves as an intermediary which is a sufficient reason for why true peer-to-peer, intermediary-free, economic transactions are a theoretical limit we may aspire to but cannot realize in the real world (like perfect competition in economics).

⁶⁹ So long as those using them can distinguish counterfeits.

Another key feature of paper money was the potential for it to support anonymity that precludes tracking of transactions, delivering a level of privacy control to buyers and sellers in cash transactions. With legacy digital money methods using credit cards, bank checking accounts, etc., the centralized intermediaries that keep track of the purchasing power ledgers have access to significant information and control over users which threatens their autonomy. Goodell (2021) and Goodell et al. (2021) argue that a key feature of cryptocurrencies that needs to be preserved and sustained is this anonymity to protect individual autonomy. As Goodell understands, this link between anonymity and individual autonomy is, at root, a question about the management of digital identities and represents a key challenge for the future of SCs as a platform for the management of general economic activity. It is worth noting, that in spite of the often-touted capability for cryptocurrencies like Bitcoin to enable anonymous transactions, the reality is that the ecosystem leaves many touchpoints with intermediaries that makes tracking and re-identification possible. The management of cryptocurrency wallets to hold the private keys that unlock crypto-tokens presents one challenge. Although continuing advances in cryptographic techniques make it ever more difficult to unlock access to encrypted information without the right cryptographic key, key management is a problem that seems unlikely to ever go away: having either one key (e.g., to lock one's wallet account) or a thousand keys (for all of one's digital locks) are both problematic.

A capability of distributed ledgers is that they can provide a trusted, unalterable record and a platform for adding additional information that may be useful in differentiating among different types of money. With paper currency, users of currencies from different countries may take advantage of differences in exchange rates.⁷⁰ This “coloring” of bearer-currencies has also pervaded equity trading where it is increasingly common to have multiple classes of equity shares representing ownership rights in companies, but with different property rights (e.g., voting, trading, exchange, etc.) and different valuations. This ability to program money is a development that financial experts see as part of the future of money. For example, Ali and Narula (2020) discuss how the natural evolution and future of digital money will be programmable money.⁷¹ Berg et al. (2020) go even further, arguing that the history of money as usually told was reasonable as long as the focus was on human-to-human transactions. Exchange via a common one-dimensional medium of exchange was necessitated by the limited cognitive capabilities of humans to handle complex transactions. With computers assisting both sides of the transaction and with money including meta data, much more complex transactions become feasible. Indeed, as Berg et al. (2020) argue, it becomes feasible to engage in goods-to-goods trade, or “hyper barter” as they describe it with AI-agents acting for buyers and sellers due to the complexity of the potential transactions.⁷² The role of money can be decomposed into matrices

⁷⁰ For example, many establishments in Canada will accept U.S. dollars but may vary significantly in the POS exchange rate they use. On a recent trip, when the U.S. dollar was trading at a significant premium to the Canadian dollar, many establishments were happy to accept U.S. dollars as “perfect substitutes” for Canadian currency.

⁷¹ See Neha Narula discuss the future of money in her 2016 [TED talk on the Future of Money](#).

⁷² From Berg et al. (2020):

"Our argument is that cryptocurrencies and blockchain technologies (Böhme et al 2015, Narayanan et al 2016) are coevolving with a suite of computational technologies that will facilitate agent-to-

that can be managed by SC platforms to effect much more complex economic transactions. The full dimensionality or usefulness of such flexibility and complexity is yet to be seen, but the SC ecosystem is putting in place the ICT infrastructure to enable such increasingly complex management and organization of economic activity.

Excess volatility and the rise of stablecoins

Returning to today's cryptocurrency world, it is clear that Bitcoin and other cryptocurrencies have failed in their role as digital substitutes for paper money. The volatility, pseudo-anonymity, and the proliferation of untrustworthy yet still necessary intermediaries in the SC ecosystem have limited Bitcoin and other cryptocurrencies usefulness as bearer-bond payment technologies. To serve as a unit of account and a trustworthy medium of exchange, the extreme volatility of cryptocurrencies poses a difficult problem. Addressing these challenges helped motivate the creation of so-called stablecoins. Many of these were created as fiat currencies, pegged to the value of existing currencies such as the U.S. dollar. These varied with respect to the level of trust they could engender, with early versions claiming to be backed 1-for-1 with U.S. dollar reserves. However, such pegging schemes limited liquidity and increased the cost of using such stablecoins. Other versions were backed by portfolios of cryptocurrencies⁷³ or other resources (e.g., gold) and often at less than 1-for-1 matching. Sustaining such stablecoins, however, required trustworthy intermediaries to ensure the stability of the stablecoins value. DeFi stablecoins were based solely on a protocol that sought to eliminate the need for an intermediary by relying on the network of users to ensure the stability of the value by balancing supply and demand for the stablecoin via the protocol sustaining the network. The collapse of the terraUSD stablecoin in April from its peg to the U.S. dollar highlighted the risk of stablecoins. The most widely traded and successful stablecoin to date is Tether which was launched in 2014 and its cryptocurrency, USDT, is pegged to the U.S. dollar. When terraUSD collapsed, that caused Tether's value to sink below its pegged value to \$0.95, threatening the concept of what a stablecoin is supposed to be.⁷⁴

From stablecoins to CBDCs

Were a stablecoin to ultimately succeed and become a major competitor to the world's fiat currencies like the U.S. dollar, that would have huge implications for sovereign nation monetary policy and regulatory efforts to ensure financial stability. For example, the U.S. derives significant value from the US dollar being a global reserve currency. That induces foreigners to hold dollars that are not used for US transactions, increasing demand for dollars and providing the US with a cheap way to raise funds by increasing the supply of US dollars. If a cryptocurrency stablecoin were to replace the dollar, the U.S. would lose those benefits and

agent trading. The implication, which we elaborate in this paper using a combination of behavioural economics and institutional economic theory (Berg et al 2017, Berg et al 2019), is that we don't actually need a money in this exchange context because it can be mediated with an n-dimensional matrix transfer of digital assets" (see references for full cites noted in quoted passage).

⁷³ Because individual cryptocurrencies are imperfectly correlated, a bundle of cryptocurrencies is less volatile than the individual currencies.

⁷⁴ See <https://www.cnn.com/2022/05/12/tether-usdt-stablecoin-drops-below-1-peg.html>.

control of its money supply. Not surprisingly and as an alternative to stablecoin efforts and the need for digital money, central banks in the U.S. and around the world are looking into the potential to issue their own central bank digital currencies (CBDCs).⁷⁵ In China, the digital Yuan has been quite successful, and its dominance over other digital currencies has been supported by China's decision to ban cryptocurrencies (Kshetri, 2022).

The introduction of a CBDC would represent a major step forward in the evolution of money from paper dollars to digital payments. It would also confront major regulatory challenges, beyond just the obvious technical challenges of implementing a digital infrastructure that could match the transaction-processing power of today's money markets and scale to meet anticipated growth.⁷⁶ The first challenge would be that a CBDC would be a direct liability of the U.S. government, rather than today's digital money that are liabilities of financial intermediaries like banks that are regulated by the U.S. government. The U.S. government reduces the risk and hence protects the stability of dollar bank deposits (digital money) by insuring bank deposits up to a limit and by regulating bank reserve requirements and many other aspects of how banks operate with respect to different types of financial services.⁷⁷ The government's regulations and insurance make bank deposits a low-cost source of funds for banks to use in their lending activity (since banks have significantly less than 100% reserves on hand to cover their cash deposit accounts).⁷⁸ A CBDC that was a direct liability of the U.S. government presumably would be even lower risk and hence would compete with banks for bank deposits, potentially disrupting banking business models.

A second important challenge would be associated with the implications of government control and access to citizen CBDC deposits and the CBDC transaction history of individual citizens. This would be another major step toward enabling a surveillance economy and potentially centralizing government control over the economy. Privacy advocates and others skeptical of increased government control capabilities would be justifiably concerned regarding how individual privacy and autonomy might be protected in a world where a national CBDC becomes a major mode of payments.

While it seems probable that many central banks will move forward with plans to deploy CBDCs, it does not seem probable (to me at least) that the race to deploy CBDCs will demonstrate winner-take-all economics. The move to digital currencies and the related infrastructure, and prospects for payment mechanisms that may support the hyper barter

⁷⁵ See Federal Reserve (2022), ISDA (2022), Reuters (2022), WEF (2020), US White House (2022) for discussions of CBDCs.

⁷⁶ Project Hamilton launched by the MIT Media Lab's Digital Currency Initiative, under the direction of Neha Narula, sought to demonstrate a CBDC transaction processing platform capable of supporting the "throughput, latency, and resilience of a system that could support a payment economy at the scale of the United States" in February 2022 (see <https://dcf.mit.edu/research/2022/2/3/mit-news-title>, visited May 7, 2022).

⁷⁷ The U.S. Federal Deposit Insurance Corporation (FDIC) offers standard coverage of up to \$250,000 per depositor, per insured bank. Coverage varies depending on the type of account.

⁷⁸ That is, the perceived low risk to investors holding bank deposits means that they do not require banks to offer high interest rates on bank deposits to attract the funds.

discussed by Berg et al (2020) suggests a future where there will be a multiplicity of digital money substitutes. This will significantly reduce the ability of individual nations to use control over their fiat money supply as a cheap source of funding.

5. Summing Up and Future Directions

In this paper, I have set forth my view that the future of the digital economy transformation that is underway is increasingly making it plausible (even though far from possible today) that everything may be automatable. By automation, I mean the substitution of machines (computers) for humans in executing tasks. As we approach that future, what we are able and choose to automate and how we automate those tasks will have profound implications for the future of human control over economic activity of all kinds. The plausibility of this “everything automatable” future depends on the joint evolution of three related clusters (ecosystems) of technologies: AI (software applications), 5G (networked ICT resources), and Smart Contracts. This last is itself the result of the convergence of three important technical trends: cryptocurrencies, distributed verification technologies (blockchain), and smart contracts. (All three of which I refer to collectively as the Smart Contract ecosystem). The role of SCs in this tripartite evolution story is to enable the automation of automation, or the automation of the control of semi-autonomous ICT systems.

The emerging SC ecosystem has attracted excessive hype and has been largely unregulated. This has contributed to the volatility of ecosystem investments, perhaps best observed by the extreme volatility and multiple boom/bust cycles that have roiled the ecosystem since Bitcoin was launched in 2008. Because SCs do appear to have real substantive economic implications that will make them important for the future of AI+5G automation, it is timely to consider how SCs may be regulated. This timeliness is warranted because it is expected that digital platforms and the associated markets will be subject to significant network effects, have the potential for hyper scale and scope economies, and exhibit significant asymmetric information problems. Together these features are expected to give rise to both path dependencies and coordination failures that may direct the evolution of the SC ecosystem along socially undesirable paths or simply stymie efforts to advance in any direction.

Like AI, SC technologies are tools that can be used to advance socially desirable or bad outcomes. To move in either direction, coordination will be needed; and to move in good directions, proactive coordination to direct the evolving ecosystem toward socially desirable paths will be needed.⁷⁹ Moreover, given the pace at which these technologies are evolving and the steep learning curves required to gain an appropriate level of understanding of these technologies means that policymakers risk making it even harder to catch up if they delay acting in favor of waiting until the dust settles and the hype/substance distinctions become clearer. Waiting to act risks lock-in to bad growth trajectories, whereas acting prematurely risks making policy decisions that push growth toward bad trajectories (or at least slowing the growth along good paths). In this paper, I have sought to dispel some of the misconceptions in the published

⁷⁹ It seems obvious that the tools of AI and SCs can be exploited by criminals in ways that threaten society. At a minimum, this means that regulatory authorities need to understand the technologies sufficiently to engage in successful enforcement actions to protect society from such abuses.

research and trade press. Let me conclude by offering some hypothesis of my own about what where the SC ecosystem is going.

First, I believe that NFTs, Bitcoin, and Proof-of-Work (PoW) that have become such prominent features of the landscape will be viewed in the not-too-distant future as temporary “fads” or early stage developments that may best be seen in society’s rearview mirror. Although each of these has attracted significant attention and economic activity, each has led to recognition of significant problems that have prompted further refinements and innovations.

Bitcoin has spawned thousands of competing cryptocurrencies and its future as either an investment vehicle or a payment medium is highly uncertain. Much of the activity in other cryptocurrencies has been funded by holders of Bitcoins seeking to diversify their crypto investments and leverage the value of their Bitcoin assets to stake claims in the larger ecosystem. In the early years of Bitcoin, opportunities to use it for payments for goods and services were extremely limited. There are many more options today, but it seems unlikely that Bitcoin will emerge as the preferred digital money substitute. The rise of stablecoins and now the future of CBDCs seems much more likely to assume those roles.

Likewise, the NFT phenomenon had all the markings of a consumer fad produced in our celebrity obsessed modern media culture. Such fads can blow up and attract lots of attention, but then are easily replaced as consumers’ attention shifts to the next fad. The promise of NFTs enabling creators of artist content (music, visual images, etc.) to disintermediate music, movie, and other content distribution/production companies was over-hyped. It seems clear that SCs will prove important – and indeed already are proving important – for incumbents with significant copyright and patent rights – as technical tools for managing more fine-grained assignment of digital use rights. How this will impact the allocation of bargaining power between artists and creative content distribution companies is unclear, but real potential for SCs to alter how we manage intellectual property in the global economy exists.

A key attraction to PoW as a DVT consensus mechanism is that it does not require a gatekeeper by design, in the way that PoS mechanisms do. The PoS gatekeeper imposes a priori limits on aspirations for approaching true peer-to-peer, intermediary-free, transactions. PoS mechanisms are permissioned blockchains, and many viewed those as of limited economic interest, viewing permissioned blockchains as just another form of distributed database technology. They might lower ICT costs but do not herald a future for new forms of organization. That view seems naïve for several reasons. First, despite the theoretical claim that PoW is open and eliminates participation entry barriers, the reality is that PoW is computing (and energy) intensive and the scale economies propels the mining infrastructure toward increased industry concentration. Second, PoW seems so incredibly wasteful in terms of energy that it does not seem sustainable or desirable to retain it as the dominant consensus verification mechanism. Indeed, Ethereum, is shifting its platform from PoW to PoS in 2022.

With respect to the future of digital payments, I have already argued that Bitcoin seems likely to be increasingly less important in the future. I think the same is true for stablecoin initiatives since I believe that the trajectory for the future of digital payments – rightly or wrongly – will be significantly determined by the trajectory for CBDCs. This suggests to me that to understand the

future of money, focus on the challenges and implications of a world where digital payments are dominated by a multiplicity of CBDCs.

Finally, with respect to where the big opportunities are for SCs that have the greatest potential for delivering social welfare benefits, I do not think those are in FINTECH. Most of what SCs will do for FINTECH will be less about creating new types of financial instruments, and instead, will be more about alternative ways to enable financial services that already are being provided using non-SC approaches. Yes, the evolution of SCs is necessary to enable more complex financial derivatives and potentially this will reshuffle competition in the financial sector. It is also possible that SCs will expand inclusion and thereby deliver important benefits in the developing world. It is also possible that SCs may have a significant impact on the allocation of economic value in society, but that has the potential of further exacerbating equity issues if it is used as a tool to further concentrate control of economic activity.

Instead, I think the most important impact of SCs will be in the ICT sector where SCs will be used as critical enabling technologies to tie together semi-autonomous ICT systems. Three areas where I expect that to be especially interesting are in addressing climate change (e.g. in the enforcement of carbon reduction commitments), smart grids (for transport linking highways and EVs, 5G networks, and other resource distribution grids for electricity and water), and in supply chains (to enable decentralized value chains to compete effectively with vertically integrated value chains).

When SCs become important in sectors where the level of ICT sophistication is less advanced than it is in finance, the implications for unexpected outcomes is much greater. In the distant future, SCs may prove to be key technologies for the emergence of AI super-intelligent control of economic activity that may fully cut humans out of the control loop. My concern is that we may fail to live that long because of the potential for SCs to automate “dumb” ICT systems and for that to occur in unexpected places.

One lesson from progress in FINTECH regulatory policy development that I do think provides useful guidance for regulatory approaches toward SC in other sectors is the focus that developers are placing on the design and standardization of open interfaces and templates for interfacing between SC subsystems and between human users and SC platforms. If you don’t know what you may need to fix in the future, it is important to anticipate and build architectures that provide scope for future repairs. Designing the templates and interfaces that may be needed if architectures, business models, and the value/logic chain for processing need to be reconfigured seems like obvious work to be doing now.

6. References

1. Abelson, H., Anderson, R., Bellovin, S.M., Benaloh, J., Blaze, M., Diffie, W., Gilmore, J., Green, M., Landau, S., Neumann, P.G. and Rivest, R.L., 2015. Keys under doormats: mandating insecurity by requiring government access to all data and communications. *Journal of Cybersecurity*, 1(1), pp.69-79. -- <https://academic.oup.com/cybersecurity/article-pdf/1/1/69/7002861/tyv009.pdf>

2. Acemoglu, D. (2021) "Harms of AI," National Bureau of Economic Research (NBER), Working Paper 29247, September 2021, available at <http://www.nber.org/papers/w29247>
3. Ali, R. and N. Narula (2020), "Redesigning digital money: What can we learn from a decade of cryptocurrencies," Digital Currency Initiative (DCI), MIT Media Lab, available at https://static1.squarespace.com/static/59aae5e9a803bb10bedeb03e/t/5e28b4bca9d3422148400c95/1579726012763/Redesigning+digital+money_++What+can+we+learn+from+a+decade+of+cryptocurrencies_%281%29.pdf.
4. Aligica, P. and V. Tarko (2012), "Polycentricity: From Polanyi to Ostrom, and Beyond," 25 Governance 237 (2012).
5. Alston, E., W. Law, I. Murtazashvili and M. Weiss (2021), "Can permissionless blockchains avoid governance and the law?" Journal on Emerging Technologies, Vol. 2, Issue 1, March 2021, available at <https://ndlsjet.com/can-permissionless-blockchains-avoid-governance-and-the-law-2/>
6. Ante, L. (2021) "Smart Contracts on the Blockchain – a Bibliometric Analysis and Review," Telematics and Informatics, 57 (2021) 101519
7. Barker, G., W. Lehr, M. Loney, and D. Sicker (2021), "The Economic Impact of Laws that Weaken Encryption, ANU College of Law Research Paper No. 21.42, April 2021, available at SSRN: <https://ssrn.com/abstract=3866902>.
8. Benkler, Y. (2008) The Wealth of Networks, Yale University Press: New Haven, CT, 2008.
9. Berg, C., S. Davidson and J. Potts (2020), "Beyond Money: Cryptocurrencies, Machine-Mediated Transactions and High-Frequency Hyperbarter," paper presented at CES2020, Cambridge, MA March 2020, available at <https://assets.pubpub.org/d07y7kjc/51581418028859.pdf>
10. Berg, C., S. Davidson, and J. Potts (2019), Understanding the Blockchain Economy: An Introduction to Institutional Cryptoeconomics, Edward Elgar Publishing.
11. Berg, C., S. Davidson, and J. Potts (2017) "The blockchain economy: a beginners guide to institutional cryptoeconomics," available at <https://medium.com/@cryptoeconomics/the-blockchain-economy-a-beginners-guide-to-institutional-cryptoeconomics-64bf2f2beec4>
12. Böhme, R., Christin, N., Edelman, B., Moore, T. (2015) 'Bitcoin: Economics, Technology, and Governance' Journal of Economic Perspectives, 29(2): 213-38.
13. Casey, M., J. Crane, G. Gensler, S. Johnson, and N. Narula (2018), "The impact of blockchain technology on finance: A catalyst for change," International Center for

Monetary and Banking Studies (ICMB), Geneva, 2018, available at <https://voxeu.org/system/files/epublication/Geneva21.pdf>.

14. CFTC (2018), "A Primer on Smart Contracts," LabCFTC, Commodity Futures Trading Commission (CFTC), November 27, 2018, available at https://www.cftc.gov/sites/default/files/2018-11/LabCFTC_PrimerSmartContracts112718_0.pdf
15. Clack, C. (2018), "A blockchain grand challenge: Smart financial derivatives." *Frontiers in Blockchain* (2018): 1.
16. Clack, C.D., Bakshi, V.A. and Braine, L., 2016. Smart contract templates: foundations, design landscape and research directions. arXiv preprint arXiv:1608.00771
17. Clower, R. (1967), "A reconsideration of the microfoundations of monetary theory," *Western Economic Journal*, 6: 1-9.
18. Cohnen, Shaanan, David Hoffman, Jeremy Sklaroff, and David Wishnick. "Coin-operated capitalism." *Columbia Law Review* 119, no. 3 (2019): 591-676.
19. Cohnen, S. and D. Hoffman (2020), "Transactional Scripts in Contract Stacks," *Minnesota Law Review*, 105:319-388
20. da Cunha, P., P. Soja & M. Themistocleous (2021), "Blockchain for development: a guiding framework, *Information Technology for Development*," 27:3, 417-438, DOI: 10.1080/02681102.2021.1935453
21. Davidson, S., P. De Filippi and J. Potts (2018), "Blockchains and the Economic Institutions of Capitalism," *Journal of Institutional Economics*, 14(4), 639-58.
22. Dwivedi, V., V. Pattanaik, V. Deval, A. Dixit, A. Norta and D. Draheim (2021) "Legally Enforceable Smart-Contract Languages: A Systematic Literature Review." *ACM Comput. Surv.*, 54(5), Article 1.
23. EC (2021), "Proposal for a Regulation of the European Parliament and of the Council: Laying down Harmonised Rules on Artificial Intelligence and Amending Certain Union Legislative Acts," European Commission (EC), COM(2021) 206, Brussels, April 21, 2021, available at https://eur-lex.europa.eu/resource.html?uri=cellar:e0649735-a372-11eb-9585-01aa75ed71a1.0001.02/DOC_1&format=PDF
24. EIOPA (2021), "Discussion Paper on Blockchain and Smart Contracts in Insurance," European Insurance and Occupational Pensions Authority (EIOPA), available at <https://www.eiopa.europa.eu/sites/default/files/publications/consultations/eiopa-discussion-paper-on-blockchain-29-04-2021.pdf>

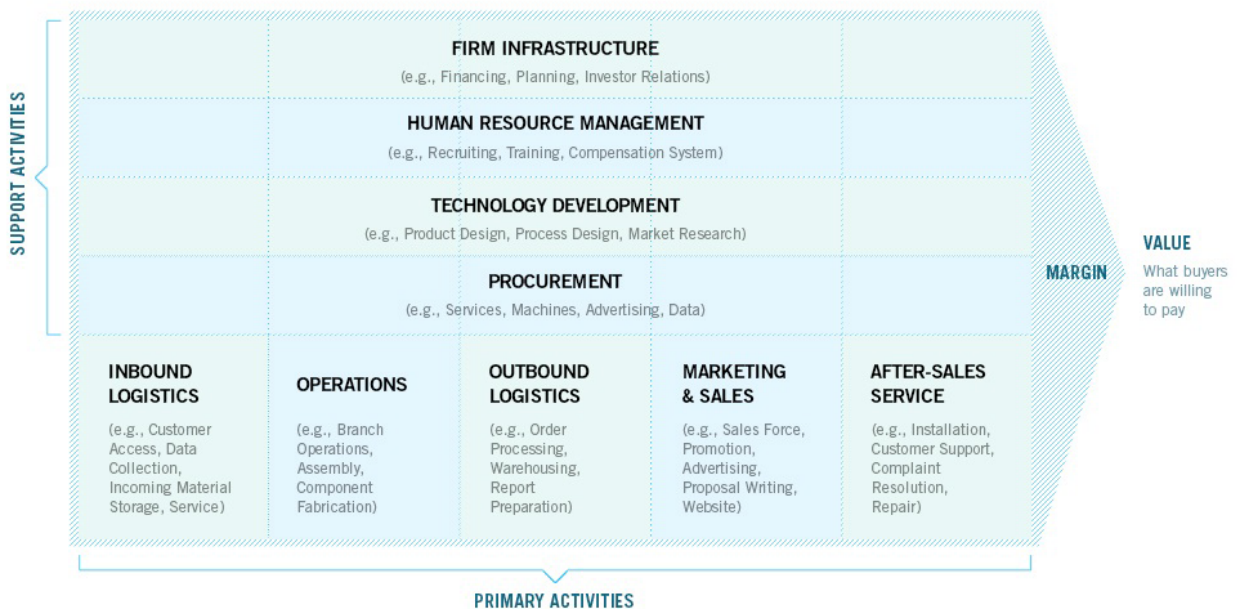
25. Ellul, J., J. Galea, M. Ganado, S. Mccarthy, and G. Pace (2020) “Regulating Blockchain, DLT and Smart Contracts: a technology regulator’s perspective,” In ERA Forum, vol. 21, no. 2, pp. 209-220. Springer Berlin Heidelberg, 2020, available at <https://doi.org/10.1007/s12027-020-00617-7>
26. FATF (2021), “Virtual Assets and Virtual Asset Service Providers: Upgraded Guidance for a Risk-Based Approach,” October 2021, available at <https://www.fatf-gafi.org/media/fatf/documents/recommendations/Updated-Guidance-VA-VASP.pdf>.
27. Federal Reserve (2022) “Money and Payments: The U.S. Dollar in the Age of Digital Transformation,” January 2022, available at <https://www.federalreserve.gov/publications/files/money-and-payments-20220120.pdf>
28. Gensler, G. (2018a), “Blockchain and Money,” MIT OpenCourseWare, available at <https://ocw.mit.edu/courses/15-s12-blockchain-and-money-fall-2018/pages/syllabus/>.
29. Gensler, G. (2018b), "Cryptocurrencies: Oversight of New Assets in the Digital Age," Committee on Agriculture, U.S. House of Representatives, July 18, 2018, available at <https://www.govinfo.gov/content/pkg/CHRG-115hhr30893/html/CHRG-115hhr30893.htm>.
30. Gerhardt, D.R. and D. Thaw (2020), “Bot Contracts,” Arizona Law Review, 62, p.877.
31. Goodell, G. (2021). Decentralised Trust for the Digital Economy, UCL Working Paper, available at <https://arxiv.org/ftp/arxiv/papers/2108/2108.04960.pdf>
32. Goodell, G., H. Al-Nakib, and P. Tasca (2021), “A Digital Currency Architecture for Privacy and Owner-Custodianship,” Future Internet, 13(5), p.130.
33. Grennan, J., 2022. FinTech Regulation in the United States: Past, Present, and Future. *Present, and Future (February 27, 2022)*.
34. Hadfield, G. (2017), Rules for a flat world: Why humans invented law and how to reinvent it for a complex global economy, Oxford University Press, 2017.
35. Hammond, S. (2021), “Fintech, Regtech and the Role of Compliance,” Reuters Special Report, December 20, 2021, available at <https://www.thomsonreuters.com/en-us/posts/investigation-fraud-and-risk/fintech-regtech-compliance-2022-report/>
36. Howell, B. E., & Potgieter, P. H. (2021). Uncertainty and dispute resolution for blockchain and smart contract institutions. Journal of Institutional Economics, 17(4), 545-559. doi:10.1017/S1744137421000138
37. IOSCO (2022), “Decentralized Finance Report,” International Organization of Securities Commissions (IOSCO), march 2022, available at <https://www.iosco.org/library/pubdocs/pdf/IOSCOPD699.pdf>

38. ISDA (2022), "Future of Derivatives Markets: A Roadmap for Innovation," International Swaps and Derivatives Association (ISDA), May 2022, available at <https://www.isda.org/a/6YVgE/The-Future-of-Derivatives-Markets-A-Roadmap-to-Innovation.pdf>
39. ITU (International Telecommunication Union). (2015). 'IMT Vision: Framework and Overall Objectives of the Future Development of IMT for 2020 and Beyond'. Recommendation ITU-R M.2083-0. https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf.
40. Kshetri, N. (2022), "Blockchains with Chinese Characteristics," paper presented at EuroITS, Gothenburg, Sweden, June 19-20, 2022.
41. Lakhani, Karim R and M Iansiti. 2017. "The Truth About Blockchain." Harvard Business Review, 95(1), 119-27.
42. Lehr, W. (2022), "5G and AI Convergence, and the challenge of regulating Smart Contracts," prepared for Bohlin, E. (ed) "EU Leadership in 5G and 6G: Competition, Security and Network Architecture," collection of white papers for European Liberal Forum (ELF), forthcoming Spring 2022.
43. Lehr, W. (2021) "Smart Contracts, Real-Virtual World Convergence and Economic Implications," TPRC49: Policy Research Conference on Communications, Information and the Internet (www.tprcweb.com), September 2021, available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3898129
44. Lessig, L. (2006), Code Version 2.0, Basic Books: New York, 2006.
45. Massari, Jai and Christian Catalini (2021), "Defi, Disintermediation, and the Regulatory Path Ahead," The Regulatory Review, May 10, 2021, available at <https://www.theregreview.org/2021/05/10/massari-catalini-defi-disintermediation-regulatory-path-ahead/>
46. Mik, E. (2017), "Smart contracts: terminology, technical limitations and real world complexity," *Law, Innovation and Technology*, 9(2), pp.269-300
47. Nakamoto, Satoshi. 2008. "Bitcoin: A Peer-to-Peer Electronic Cash System." White Paper, available at <https://bitcoin.org/bitcoin.pdf>.
48. Narayanan, A. Bonneau, J., Felton, E., Miller A, Goldfeder, S. (2016) Bitcoin and Cryptocurrency Technologies, Princeton University Press: Princeton.
49. NextG (2022), "Next G Alliance Report: Roadmap to 6G," report of the NextG Alliance, February 2022, available at <https://roadmap.nextgalliance.org/>

50. Ostrom, E. (2010). Beyond Markets and States: Polycentric Governance of Complex Economic Systems. *American Economic Review*, 100(3), 641-672. doi:doi: 10.1257/aer.100.3.641
51. Peng, K., M. Li, H. Huang, C. Wang, S. Wan and K. Choo (2021) "Security Challenges and Opportunities for Smart Contracts in Internet of Things: A Survey." *IEEE Internet of Things Journal*, 1-1.
52. Reuters (2022), "Cryptos on the Rise 2022," Reuters Special Report, available at <https://www.thomsonreuters.com/en/reports/cryptos-on-the-rise-2022.html>, visited 5/29/22
53. Saylor Academy (2022), "Predecessor Technologies," Section 3.2 of PRDV151: Bitcoin for Everybody, on-line computer science course, available at <https://learn.saylor.org/course/PRDV151>, (accessed 7/27/2022).
54. Sharafat, A. & Lehr, W. (Eds.) (2017), ICT-centric economic growth, innovation and job creation, Geneva, Switzerland: International Telecommunications Union (ITU), available at http://www.itu.int/pub/D-GEN-ICT_SDGS.01-2017
55. Surden, H. (2019), "Artificial Intelligence and Law: An Overview," *Georgia State University Law Review*, Vol. 35, 2019, U of Colorado Law Legal Studies Research Paper No. 19-22, Available at SSRN: <https://ssrn.com/abstract=3411869>
56. Surden, H. (2012), "Computable Contracts," *UC Davis Law Review*, Vol. 46, No. 629, 2012, Available at SSRN: <https://ssrn.com/abstract=2216866>
57. Tapscott, D. and A. Tapscott (2017) "How blockchain will change organizations," *MIT Sloan Management Review* 58, no. 2 (2017): 10
58. UK (2016) "Distributed Ledger Technology: beyond block chain," A report by the UK Government Chief Scientific Advisor, January 19, 2016, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf
59. US WhiteHouse (2022), "Executive Order on Ensuring Responsible Development of Digital Assets," March 9, 2022, available at <https://www.whitehouse.gov/briefing-room/presidential-actions/2022/03/09/executive-order-on-ensuring-responsible-development-of-digital-assets/>
60. WEF (2020), "Central Bank Digital Currency Policy-Maker Toolkit," 22 January 2020, available at <https://www.weforum.org/whitepapers/central-bank-digital-currency-policy-maker-toolkit>
61. Werbach, K., 2018. Trust, but verify: Why the blockchain needs the law. *Berkeley Technology Law Journal*, 33(2), pp.487-550.

62. Werbach, K. (2021) “DeFi Is the Next Frontier for Fintech Regulation,” *The Regulatory Review*, April 28, 2021, available at <https://www.theregreview.org/2021/04/28/werbach-defi-next-frontier-fintech-regulation/>
63. Zetsche, Dirk A., Linn Anker-Sørensen, Maria Lucia Passador and Andreas Wehrli (2022), “DLT-Based Enhancement of Cross-Border Payment Efficiency – a Legal and Regulatory Perspective, Bureau of International Settlements (BIS) Working Papers No 1015, May 2022, available at <https://www.bis.org/publ/work1015.pdf>
64. Zittrain, J. (2009), “Law and technology The end of the generative internet,” *Communications of the ACM* 52, no. 1 (2009): 18-20
65. Zittrain, J. (2006), “The Generative Internet,” *Harvard Law Review*, Vol. 119, p. 1974, May 2006, Oxford Legal Studies Research Paper No. 28/2006, Berkman Center Research Publication No. 2006/1, Available at SSRN: <https://ssrn.com/abstract=847124>

7. Figures and Exhibit



Source: <https://www.isc.hbs.edu/strategy/business-strategy/Pages/the-value-chain.aspx> (visited 6/15/2022)