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Blockchain financial geographies: Disrupting space, agency and scale

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ABSTRACT

The potential of blockchain-technology to disrupt the financial and related sectors by making many intermediaries superfluous is subject of frequent discussions. We analyze the current and potential structural effects of blockchain-based business models. In order to make "disruption" more traceable, we define three dimensions of it: space, agency and scale. Using a combination of Crunchbase data, interviews and participant observation at workshops and conferences, and case studies we outline areas in which companies are seeking to implement blockchain in financial functions and assess the extent to which this represents structural changes in finance and associated advanced producer services (APS). We find that while the expectations for blockchain as a transformative force in finance/APS are high, the actual structural effects are much less clear as we see established industry players (e.g., banks) capturing these efforts and/or new entrants essentially recreating the existing structures and functions of the current financial sector. We outline a number of possibilities as to why to date blockchain has not met these expectations of disruption. We explore how scale emerges as a theoretically fruitful avenue for understanding which phenomena are actually well placed to fundamentally alter the structure of the financial sector including related advanced services. Three case studies on initial coin offerings, real estate investments and the "money memory" associated with blockchain-based currencies show that potentially transformative effects derive from blockchain technology being able to shift scale.

1. Introduction

For several years the financial world has focused on blockchain with headlines like "Blockchain revolution in financial services" and "6 Ways Blockchain Is Disrupting The Banking and Finance Industry". After all, the blockchain vision of circumventing the traditional banking system (Nakamoto 2008) offers a fundamental threat to the financial sector and related APS. For all this attention, however, so far there is very little evidence of practice-changing disruption in the financial world[1] suggesting that finance-focused blockchain efforts accord well with Gartner's "hype cycle model" of new technologies. Particularly the peak of "inflated expectations" (see Fig. 1) that appears as a normal part of the development of a new technology shortly after its inception (see Dedehayir and Steinert 2016). It might be that blockchain technology is now in a sobering phase, nearing the "trough of disillusionment". An even more intriguing question, however, is the extent to which blockchain might follow Amara's (1988) law, i.e. people "tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run". From this background this paper uses available data and case studies to analyze the extent the current hype around blockchain technologies is justified and possible roadblocks complicating this technology's adoption within the financial sector and related advanced producer services (APS) such as accountancy and contract law.

While this leaves out the final outcome of the process, our approach highlights many of the inconsistencies and ambiguities during the adoption process of new technologies, including the fundamental question of whether blockchain will become a ubiquitous and disruptive technology in the financial sector at all. Our approach forces us to single out the basic mechanisms and features of any new technology most likely to make a difference in business geographies and structures, echoing assessments of the commercial internet in its early days (see Zook 2000). Doing this, we analyze and assess the fundamentals of the spatiality of finance and their stickiness in place and space. Thus, we focus less on technological standards or decisions by single firms and instead, evaluate the consequences of this new technology for the spatiality of the financial sector, individual and firm efforts to attract

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[1] To be clear, while this paper focuses on blockchain, it relates to fintech more generally (see Wójcik 2021a, 2021b for a comprehensive overview).

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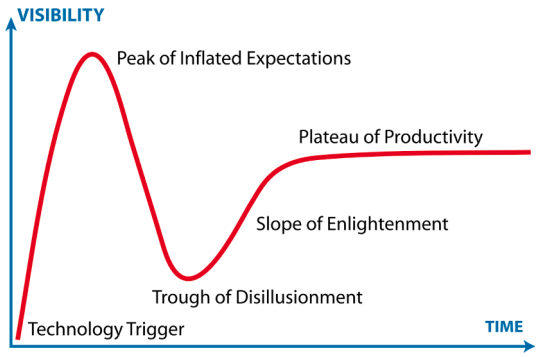

Fig. 1. Hype Cycle Model. Source: Wikipedia Commons, Licensed under the Creative Commons Attribution-Share Alike 3.0.

clients, and the creation of radically different business models. While we focus on blockchain and banking, our approach also works for other potential disruptive innovations (both technical and organizational) within APS more generally and suggests a way forward with similar studies.

The structure of this paper proceeds as follows: first we develop a generalizable theoretical framework focused on three possible areas of disruption, defined as space, agency and scale, to articulate the inherent structural possibilities of any new technology. Applying the framework to blockchain, the financial sector and related services, we first empirically examine the potential changes to spatial organization of the financial industry, namely the financial center hierarchy. Second, using the lens of agency, we consider the often-made rhetorical point around blockchain as a democratizer of finance both in terms of retail financial activities as well as smart contracts which could enable the disruption of the current organization of financial advanced producer services. Lastly, we analyze the ways blockchain enables changes in scale by allowing investment directly in technologies (and not simply firms), expanded opportunities for small-stake investments by changing intermediation services in ways that lower transaction costs, and the implications of individual units of currency possessing complete histories of transactions. We argue that these examples of changing scale highlight the areas with the greatest potential for blockchain to rework financial APS and the financial sector more generally. Less clear, however, is the timing when this may occur and the relative importance of factors driving these changes. While not discounting that blockchain may be less transformative within the finance area than expected, we suggest that a challenge facing blockchain-related reintermediation of activities in many sectors is a fundamental problem of coordination across existing agencies (actors, firms) and space (the locales in which agencies are based) when scale-based changes are attempted. While blockchain provides a set of technical solutions for these challenges, coordination also requires socially based solutions.

2. Space, agency and scale in digital financial geographies

While blockchain technology is infamous for its complexity, of greater importance for this paper is its possible role as a general-purpose technology (akin to the internet) able to transform economic transactions more broadly (Kane, 2017) in ways that disrupt the spatialities of capitalism. The reality of this transformative vision remains to be seen and any changes need not follow a pre-ordained path. This is the normal state of new technologies and the combination of promise and uncertainty makes theorizing about the potential effects of technological change, be it the internet, blockchain, digital platforms or something else, a key task for economic and financial geography. Thus, we first outline a general framework usable to analyse the potential disruption of any emerging technologies on incumbent structures. We do this by adapting Jessop et al's (2008) more general Territory, Place, Scale, and Network (TPSN) approach for the "systematic recognition of polymorphy" and identifying key intertwined building blocks of sociospatial relations. Rather than directly applying Jessop et al (2008) we use our empirical engagement with blockchain companies (particularly data availability) to guide us in selecting concepts that we view as most appropriate for assessing emerging technologies engagement with the economy. Focusing on the well-established concepts of space, agency and scale we argue that in the case of blockchain, scale is a particularly fruitful theoretical lens, especially when understood more broadly than in a hierarchical sense.

2.1. Spatial structures

As one of the fundamental concepts of geography, space is the *de facto* theoretical concept for financial geography ranging from the changing fortunes of financial centers and cities (Taylor, 2000) to the locational advantages of traders' proximity to firm headquarters versus exchanges (Engelen and Grote, 2009) to knowledge generation and transfer associated with technological innovation and advanced/financial services more generally.

The conceptualization of space has evolved from something fixed, across which activity occurs, to an actively produced phenomenon dynamically unfolding across time and space (Massey, 2005). While a relational understanding of space does not require digital technology, it is greatly enhanced by the availability of real-time interaction; enough so that some theorists argue that the network dominates the organization, role and function of material spaces (Castells, 1996). Adding more complexity are the ways material and digital spaces are integrated including the digital trumping materiality (Mitchell, 1996), digital space being deeply embedded and dependent on material space (Graham, 1998) and digital and material spaces being intertwined and co-constituted (Kitchin and Dodge, 2011; Graham, Zook, and Boulton 2013).

In the context of blockchain the multi-dimensional and relational concept of space is useful in a number of ways. For example, how the location of Bitcoin miners (the original and most notable application of blockchain) is shaped by electricity costs, state policies and underground activities (Sinclair, 2021) or how blockchain firms cluster in some well-known financial and tech centers versus other less expected locations (Zook and McCanless, 2021). These are just two of the possible blockchain spaces to analyze via standard (agglomeration, land/labor costs) and newer (electrical costs) factors to better understand the drivers, impacts and outcomes (e.g., complex and often opaque ownership) of blockchain. In this paper, we focus on whether blockchain firms are locating within or outside of established financial centers as an indicator of whether aspects of APS related to finance might be shifting in space.

2.2. Expanding types of relevant agencies

Drawing from work from economic sociology and science and technology studies (Çalışkan and Callon, 2009; MacKenzie, 2008), our framing emphasizes the importance of agency in constructing economic and technological systems. While economic geography might more commonly focus on firms or related organizations for agency, we find it important to broaden this. For example, with blockchain, agency manifests via giving different actants (including humans, firms and software) access to the same - agreed upon - data. In many cases, this involves data that has hitherto been internal to firms, requiring new levels of cooperation, adaptation of current business models and potential changes to how networks and contracting among service providers is structured. Second, the rhetoric around decentralized finance (based on blockchain technology) centers around the inclusion of hitherto un- or underbanked people as a means to enhance their agency. Third, the availability of smart contracts – software designed to interact in pre-specified ways with human users and other smart contracts – is a key element of

blockchain potential dis/re intermediation among account and contract service providers within the financial sector (Cong and He, 2019). Similar traits of performativity are evidenced by financial models (Mackenzie, 2006; Muellerleile, 2013) or artificial intelligence (Lai and Samers, 2020) and reinforces the importance of non-human and software-based agency more generally within financial geography.

This builds from a broader focus on the ways that the agency of software contributes to the creation of space and place (Thrift and French, 2002, Graham, 2005, Kitchin and Dodge, 2011). Examples include Rose's (2017) use of "posthuman agency" to account for the creation of difference resulting from direct human actions, habituated practice and digital layers and forces. Coming from a desire to understand changes in the urban (particularly resulting from "smart city" policies) Rose (2017, 789) argues that we must include "digitally mediated" elements in any analysis in order to account "the reinventiveness and the diversity of urban posthuman agency." In a similar manner Lynch and Del Casino (2020) grapple with how to account intelligence in our analyses of spaces and cities and argue for an approach that recognizes its diversity, something that is "multiple, partial, and situated in and in-between spaces, bodies, objects, and technologies".

From this foundation, this paper highlights both the role of human actors and the (increasing) role of non-human agency in advanced producer services. In short, whether discussed in terms of agency or intelligence, the role of digital technologies/software that autonomously interacts with human and non-human parts of the financial system is an important element of blockchain. While the reality of practice has not matched the overheated rhetoric or tech evangelists (Zook and Blankenship, 2018), increased non-human agency enables efficiency in bookkeeping and legal activities expanding the scale at which subcontracting, supply chains, global production network, resource management or development aid might operate.

2.3. Shifting scales

This expansion of the operative range of non-human agencies also highlights how scale is enrolled as a dynamic arena for changes in APS and financial practices. While not discounting space or agency, we find scale to be a particularly useful theoretical lens for thinking through the changes associated with increased use of any new technology.

To be clear, this is not in terms of a fixed set of categories (global, regional, local) (see Peck, 2002; Marston et al, 2005). Rather we approach scale as a dynamic phenomenon within economic activity that unfolds operationally and hierarchically. In other words, we focus on how the affordances offered by a new technology or innovation affect the scale at which economies and finance can act. For example, many recent digital technologies (including blockchain) have expanded operational scales through better communication and mobility resulting in a "new geographic scale of megaregions" (Glocker, 2018: 4, see also Yeung and Coe, 2015). Similarly, innovations in credit and mortgages practices have resulted in nationally-scaled markets that price risk in "place free terms" (Kear, 2014) and created assets based on single family homes (Fields, 2018). Both of these examples demonstrate how objects noted for their situated and local scale (individual consumer risk and single family houses) are reworked to operate on a national or global scale. Thus, any shifting (or even flattening) of relevant geographic scales associated with blockchain, such as allowing micro-transactions between unknown and spatially distant participants (Nakamoto, 2008), represents a continuation of past trends and power struggles (Delaney and Leitner, 1997) rather than something categorically new.

Next, inspired by feminist work on the importance of the body to the relevance focus of scalar analysis (Hyndman, 2004; McDowell 2011), we theorize scale beyond standard fixed categories of space (global vs local) to highlight where technologically enabled activity might take place. In other words, rather than assuming regions, firms, states, currencies, or specific products are the relevant scale of analysis, we loosen these assumptions to better understand the opportunities and new relational constructs or assemblages (in STS terms) that might emerge alongside a new digital technology like blockchain. By conceptualizing scale in this way we focus on a key question of where blockchain can act (i.e., prying apart things long considered singletary units). With this understanding of scale, assembly lines, firms and even currencies are not simply default categories but potential objects for further differentiation into smaller subsets – specific items in production, identifiable single units of currency, etc. – each connected to distinct networks and material geographies.

This is not a new idea per se, societal and technological change have shifted the relevant scale for analyzing firms, the state and their actions, often to smaller or previously unconsidered components. For example, Amoore's (2011) concept of data derivative builds from the predictive efforts of border control centered not on people or their data, but on "differential curves of normality" that infer likelihood of risk. This expands the relevant scale from the individual crossing the border or the border guard, to also include software algorithms and the developers who create them. From this we argue that the particularities of blockchain requires a careful evaluation of the relevance of scale for financial geography. However, it is challenging to identify and demonstrate these changing scales empirically, particularly given the relative newness of blockchain technology and the lack of a single or set of blockchain ecosystems that can readily be referenced. We outline below examples that illustrate these changes in scale associated with blockchain that make this theoretical conceptualization (along with space and agency) a useful approach. We ultimately theorize this process as a series of dynamic moments of opportunity emerging from blendings of space (material and digital), actors and agencies (humans and software), and most relevantly, scale (the focus of economic activity).

3. Overview on methods

This paper uses a mixed methodology first starting with an analysis of blockchain firms listed in Crunchbase. Crunchbase is a data service that provides information – basic firm statistics, products, founders, executives, funding and investments – on public and private companies. While covering all sectors, it focuses on tech-based companies and is widely used by venture capital firms and business analysts, when evaluating investments. The second element of our method includes participatory observation in practitioners workshops and conferences (see Fig. 2), including conversations with participants during the workshops.

At each event, field notes were recorded digitally (occasionally by hand but input into digital records immediately afterwards), and included the number and estimated demographics of attendees, background on speakers and organizers and details from of keynotes, panels (with several speakers addressing a common topic) and conversations (including some initiated at conferences and continued later). Also informing this paper were formal interviews with blockchain entrepreneurs and investors in Berlin, Frankfurt and San Francisco (34 in total) during 2018 to 2020 with the bulk of interviews in 2019. While we are mostly not drawing directly on these interviews for this paper, they further inform our understanding of the context in which blockchain operates and is understood. Combined these data were used to identify case studies - by the amount of "buzz" these created in the conferences and interviews - of potentially disruptive blockchain-based technologies.

4. The spaces of blockchain in finance

To better understand blockchain adoption within the financial sector we curate a database of companies drawn from Crunchbase. Of interest is both the extent to which blockchain firms are recreating financial systems similar to the existing one (versus innovative financial practices based on blockchain) and how the locations of these firms compare to

Round Table "Tokenization of Real Estate: The Future of This Asset Class?" (Frankfurt School Blockchain Center)	Feb. 19, 2021, online
Conference on Digital Assets and Distributed Ledgers in Financial Services (Fintechconnect.com)	Feb. 16-17, 2021, online
A new EU framework for crypto-assets: implications for Europe's financial services industry (Freshfields Bruckhaus Deringer)	Oct. 2, 2020, online
"Crypto Assets Conference 2020 (CAC20B)" (Frankfurt School Blockchain Center)	Oct. 29-31, 2020, Frankfurt
Blockchain Meetup (Frankfurt School)	Aug. 7, 2019, Frankfurt
DWF Open Office Meetup	Jul. 25, 2019, Berlin
Building Finance 3.0: Real Blockchain Use Cases (Blueyard Capital)	Jul. 24, 2019, Berlin
Sustainable Supply Chains, Positive Blockchain.io Meetup	Jul. 23, 2019, Berlin
Fullnode co-working space Meetup	Jul. 22, 2019, Berlin
Parity & Friends: Substrate, Polkadot, Centrifuge & Open Mic	Jul. 17, 2019, Berlin
Crypto Assets Conference 2019 (Frankfurt School Blockchain Center)	Nov. 11, 2019, Frankfurt
Blockchain for Finance Conference, Europe (FinTech Network)	Oct. 3-4, 2017, Dublin

Fig. 2. List of Participant Observer Field Sites.

more standard financial geographies.

4.1. Building insight from Crunchbase

Crunchbase covers more than 1 million companies globally, ranging from large public firms to venture capital funded start-ups. It is particularly focused on tech-based and fast-growing companies and thus is well suited for studying blockchain companies. Crunchbase collects data from about 4,000 venture capital firms about their respective portfolios; firms can also self-report and ask for inclusion into the database. While not comprehensive, the database is widely used in the tech industry particularly for the US, reflecting its foundation and headquarters. It is likely that the coverage for other countries, particularly China, is less complete. For example, our final sample contains almost 10 times the number of blockchain firms in the US compared to those originating from China even given the significant Fintech presence there (Economist 2021). Nevertheless, two other databases specializing on China,[2] https://www.01caijing.com/ and https://www.fintechdb.com/, both have fewer Chinese blockchain companies listed than we were able to identify in Crunchbase. Therefore, we use Crunchbase as the best available globally-focused source of data but remain cognizant of its potential biases.

To build our database we filter Crunchbase for companies with any of the keywords "blockchain", "distributed ledger", "crypto", "coin", or "token" in their "Full Description". This resulted in 11,209 firms. The firms in this initial cut were very diverse and included companies classified as "Clothing and Apparel", "Manufacturing" and "Healthcare". To narrow our database to just finance, we then filter by the Crunchbase defined field of "Industry Group"[3] to select firms categorized as "Financial Services", "Lending and Investments" and "Payments". This resulted in 5,796 firms as of February 11, 2021.

In order to better understand the operations of firms, Fig. 3 shows the number of firms classified as belonging to Crunchbase-defined "Industries". This variable is populated by over 700 standardized keywords and each firm can be associated with multiple industries.

Industry	Frequency	Industry	Frequency
Bitcoin	1036	Personal Finance	60
Payments	554	Funding Platform	52
Insurance	282	Identity Management	52
Trading Platform	265	Stock Exchanges	50
Banking	253	Lending	48
Ethereum	248	Angel Investment	42
Financial Exchanges	241	Peer to Peer	42
Venture Capital	220	Impact Investing	41
Mobile Payments	201	Transaction Processing	36
Crowdfunding	146	Hedge Funds	35
Virtual Currency	137	Compliance	30
Asset Management	135	Wealth Management	28
Mining	84	Risk Management	21

Fig. 3. Number of Finance-Focused Blockchain Companies by Industry Category. Figure includes Crunchbase Industry Categories with more than 20 entries. Excluded from this figure are Crunchbase Industry Categories that match our keyword filter (e.g., "Blockchain", "Cryptocurrency") or are generic business (e.g.,"Consulting", "E-commerce") or technology (e.g., Information Technology, Software) terms.

Bitcoin is associated with almost a fifth of all firms in our database with "trading platform", "payments", "Ethereum", "virtual currency" and "mining" accounting for another 700 + entries. While these keywords are somewhat "fuzzy", this focus on exchange or payment involving Bitcoin or other cryptocurrencies is consistent with other analyses of the industry. For example, the Cambridge Center for Alternative Finance (Blandin et al, 2021: 12) report that transactions "continued to be dominated by fiat-cryptocurrency trades". It is interesting to note, however, that most of the other industries in Fig. 3 concern well-established areas within the financial sector: banking, financial exchange, venture capital, asset management, payments, compliance, etc., with a few more novel (but increasingly well-established) areas such as crowdfunding and peer-to-peer. In these cases, blockchain represents either a new asset class in an existing framework, or attempts to trim processes within established fields - both of which suggest rather small-step rather than disruptive innovative activities. The CCAF report (2021: 64) makes a similar finding of an "evolution of cryptoasset market structure towards a more traditional setup" as well as noting the growth of decentralized finance (or DeFI).

Two caveats are in order. First, this list is only a partial tally of the ideas discussed and pursued in the area of blockchain finance and excludes projects within large firms (such as banks and big technology providers), firms not recorded in Crunchbase or with descriptions that do not match our filters. Second, some of the conventional terms depicted above can mask financial innovation. For example, "flash loans" – very short-term (seconds), uncollateralized loans tied to a single transaction used for arbitrage transactions and manipulate market prices (see Wang et al. 2021; Schlegel 2020) – are being explored by companies but are not disaggregated as a Industry by Crunchbase; instead likely incorporated in the "lending" category. Nevertheless, based on our participant observation and interviews we conclude that innovative products such as "flash loans" are the exception rather than the rule, and understand Fig. 3 as generally supportive of incremental rather than disruptive adoption of blockchain by the financial sector.

4.2. The temporal and spatial dimensions of blockchain

Fig. 4 shows the distribution of the founding years for the firms in our sample for which Crunchbase provides founding data. The years 2017 and 2018 have by far the highest numbers with a substantial drop in

[2] We wish to thank Karen Lai for her suggestions on this question.

[3] Industry Group is a Crunchbased defined classification of 47 different sectoral categories that is not based on official Census or statistical agency definitions. See https://support.crunchbase.com/hc/en-us/articles/360043146954-What-Industries-are-included-in-Crunchbase-.

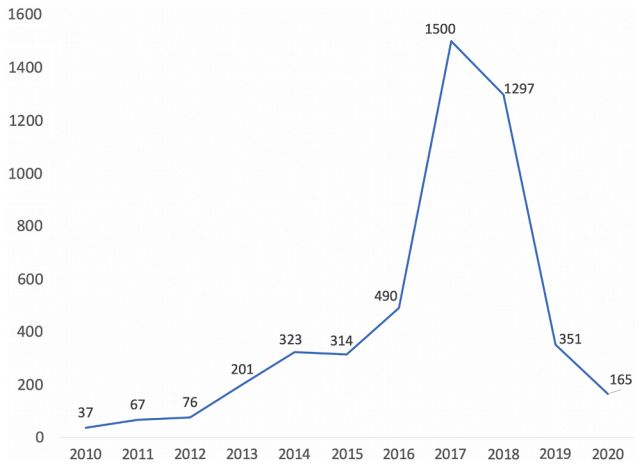

Fig. 4. Number of Finance-Focused Blockchain Companies founded from 2010 to 2020, (n = 4,821). Note: 764 firms in the database did not have a founding date; 207 were founded prior to 2010 (presumably existing firms that added blockchain to their focus); 4 were founded in 2021.

Country	Firms	Country	Firms
United States	1520	Estonia	106
United Kingdom	466	South Korea	87
Singapore	264	Australia	84
Switzerland	196	The Netherlands	81
Canada	194	France	73
China	153	Japan	66
India	135	Brazil	64
Hong Kong	131	Russian Federation	48
Germany	124	Spain	41
Israel	112	Nigeria	37
Other countries	830		

Fig. 5. Country-Level Distribution of Finance-Focused Blockchain Companies, (n = 4,821).

later years. Clearly, the initial blockchain hype has cooled off since the 2017/2018 peak although many of these firms are still in operation. Attention to cryptocurrencies has returned since 2020, tracking the high and volatile price of Bitcoin, and manifesting in new areas such as non-fungible tokens or NFTs. While this latest phenomenon goes beyond the scope of this paper, the sharp decline in Bitcoin's price and NFT activity beginning April 2022 suggests that Gartner's "hype cycle" remains a useful lens through which to view blockchain activity (see Fig. 5).

Using this same selection of firms[4] the country-level distribution shows that the US leads by a wide margin, as we expected given technology dissemination and venture capital availability. The UK comes up second with roughly a third of the US activity, followed by Singapore, a well-known financial center. While the extent of Crunchbase bias is unknown we expect this contributes to the relatively low rank of China (6th) despite its reputation for blockchain activity. The remaining list is largely a collection of countries or large populations and/or developed economies with a few exceptions, such as Estonia and Nigeria, suggesting that the spaces of blockchain are expanding beyond standard financial geographies (see Zook and McCanless, 2022 for further discussion).

To explore this point in more detail, in Fig. 6 we shift to a regional scale to examine the concentration of blockchain firms relative to global financial center rankings (see also Zook and McCanless, 2022)). Crunchbase lists location by city (including some sub-city designations such as Manhattan in New York or Yeoksam-dong in Seoul). In this analysis we aggregate cities to functional regions roughly reflecting commuting distance to adjust for the particularities of the Crunchbase database and construct more comparable regions. The center column of Fig. 6 shows the disaggregated elements (cities) that make up each region. The right-most column shows the city/region's corresponding rank in the global financial center index (GFCI).

London emerges as the leading city-region globally for finance-focused blockchain companies, while New York, GFCI's highest ranked financial center, is ranked 4th. The San Francisco region's shift from 12th in the GFCI to 2nd in blockchain rank, suggests that technology-centered regions are overly represented, an observation supported by the high ranks of Tallinn (Estonia) and Tel Aviv (Israel), two smaller cities in technology-specialized countries but whose positions on the financial center list is much lower, 87th and 41st respectively. Singapore retains its third-place ranking and the Zug-Zurich region of Switzerland (with its enabling regulatory environment, see Zook and Grote 2020) emerges as the last of the top five blockchain city-regions. It is useful to consider which global financial centers are missing from Fig. 6, as only fourteen of the cities are ranked in the 20 for both metrics. Notably absent on the Blockchain list but highly ranked by the GFCI are Shenzhen (8th), Frankfurt (9th), Washington DC (14th), Luxembourg (17th), Dubai (19th), Geneva (20th). It is also intriguing to note that besides London and Zug/Zurich no other European top 20 GFCI financial center appears in Table 6. Additionally, some leading financial centers, e.g., Shanghai, Beijing, Tokyo and New York, rank (considerably) lower in the blockchain ranking than in the financial center ranking.

To be clear we do not intend to take either of these rankings too literally. Chinese centers might be underrepresented in the Crunchbase database while the Z/Yen (2021) rankings rely on surveys with two thirds of respondents located in the Asia/Pacific region possibly translated into a bias towards Asian centers. Additionally, the GFCI scores have, over time, converged and are now very close together: e.g., Zurich (#10) scores 720 points and Geneva (#20) 709 points - meaning that small differences in scores produce large changes in rankings (see Z/Yen 2021). Nevertheless, a relatively clear picture of the global geographies of finance-focused blockchain companies emerges: namely the prominence of tech regions beyond what we might expect given more traditional measures of finance, while some well-established, albeit lower ranked, financial centers are less active in blockchain. If blockchain becomes a leading financial technology force in the future these initial patterns suggest a potential reshuffling, particularly in the case of secondary centers and cities. While these emerging spaces of blockchain remain in flux this analysis highlights that hierarchies of financial centers are subject to disruption.

5. Agency and blockchain

To obtain a more complete picture of the financial sector's adoption of blockchain, we focus on both human agency/actors and non-human agencies (such as smart contracts) to better understand the movers and challenges in blockchain technology adoption by finance-focused firms.

5.1. Two camps within blockchain based finance

Our participatory observation at workshops and conferences revealed a large, global, startup-community joined by similar units within existing firms around the search for applications of blockchain

[4] We are limiting our geographical analysis to firms with founding dates as our examination of the data suggests that this is a good indicator of more substantial firms in terms of size and activity. Shifting to include the full dataset of 5,796 firms did not impact the overall distribution patterns shown in Figures 45 and 6.

Rank	City-Region	Companies	Regional Sub-divisions (for cities within commuting distance AND 2+ companies listed)	Global Financial Center Index Rank
1	London	397	--	2
2	San Francisco Bay Region	366	San Francisco (243), Palo Alto (33), Sunnyvale (14), San Mateo (13), San Jose (13), Santa Clara (13), Menlo Park (12), Mountain View (9), Berkeley (6), Redwood City (6), Fremont (4)	12
3	Singapore	262	--	5
4	New York City	258	New York (231), Brooklyn (21), Manhattan (6)	1
5	Zug-Zurich	141	Zug (104), Zurich (37)	10 (not inclusive of Zug)
6	Los Angeles Region	112	Los Angeles (63), Santa Monica (18), Beverly Hills (5), West Hollywood (5), Venice (4), Walnut (4), Pasadena (4), Manhattan Beach (3), Marina Del Rey (3), Newport Beach (3)	13
7	Tallinn	101	--	87
8	Tel Aviv	87	Tel Aviv (59), Ramat Gan (7), Tel Aviv-yafo (7), Herzliya (7), Giv'atayim (4), Holon (3)	41
9	Toronto	87	--	29
10	Seoul	78	Seoul (45), Yeoksamdong (20), Yongdungpo (5), Seocho (5), Doksansadong (3)	16
11	Hong Kong	71	Note: Shenzhen (19) and Guangzhou (2) are not included with Hong Kong	4
12	Berlin	60	--	45
13	Tokyo	54	Tokyo (50), Roppongi (4)	7
14	Beijing	53	Beijing (47), Haidian (6)	6
15	Chicago	50	--	15
16	Vancouver	47	--	11
17	Paris	45	--	25
18	Moscow	36	--	57
19	Shanghai	35	Shanghai (32), Huangpu (3)	3
20	Sydney	34	Sydney (31), North Sydney (3)	18
	Other	2438	--	

Fig. 6. Regional Distribution of Finance-Focused Blockchain Companies, (n = 4,821). Source: Global Financial Center Index #29 Z/Yen (2021), Note: grey shaded cells in the rightmost column indicate that the region's GFCI rank is not in the top twenty.

within finance, including new products, more efficient processes, and, at the most extreme, entirely new financial ecosystems. The actors in this community can be grouped into two main camps. On the one hand, there are (often self-proclaimed) blockchain "evangelists" who follow a strong ideological canon descending from Nakamoto's original vision of a self-regulating financial ecosphere. Their aim is recreating a product portfolio based on decentralized crypto algorithms that avoids any state-controlled (or otherwise centralized) institutions like central banks or large intermediaries; the so-called "decentralized finance" or DeFi. Much emphasis and pride is put on being "native crypto" and disruption of existing financial systems.

Contrasting this group are the "incumbents", based within the financial sector, who see blockchain as primarily a business opportunity. Established players, such as investment funds, banks, stock exchanges and not least the big accounting firms and consultancies treat blockchain alternatively as a niche asset class (cryptocurrencies) or as a potential means to trim down their administration costs. For them, bridging blockchain-based techniques and incumbent financial services is the focus, often tied to current and future regulation (e.g., note 16). In short, their main aim is a more efficient version of the established system, along with higher profits for themselves.

These two camps recognize the mutual benefits of working together - evangelists developing the technology, and the incumbents able to deliver clients (that the evangelist scene is largely missing). While conflict is certainly evident, e.g., one established consultant noted in apparent disbelief that some of his (then) new employees working for a bank-based blockchain project would label themselves "evangelists" (note 51), the two camps get along fairly well. This is partly driven by need: As the head of a blockchain think tank put it: "So far, there is a lot of talk in the blockchain world, but very little business. Nobody makes

any real money." (interview 34). At the time of writing most blockchain efforts within the financial sector remain in the conceptual or experimental stage; e.g., established banks have issued the first bonds on blockchain without any additional paper trail (see LBBW 2020).

5.2. Experimentation but little adoption

An area with the most potential for blockchain (as identified in many conferences attended by incumbent actors) is the clearing and settlement of financial instruments, or what happens after a securities trade is executed on an exchange. This includes transferring the security from one account to another, payments running in the opposite direction and the calculation of margins; all of which are already fully digitalized and are somewhat dismissed as "back office work". While blockchain evangelists focus on how the technical aspects of blockchain make it a "ideal" solution for clearing and settlement, the "challenges have little to do with technology and a lot to do with business and society" (DuPont, 2019). These challenges to switching from current systems to blockchain were aptly described by a managing director for digital assets of a global bank (note 7): "In clearing and settlement, at least thirteen parties are involved, all of which need to agree to switch to a new - distributed ledger - technology, and all at the same time." For all players this implies heightened uncertainty with some risking lower profits over time, and others facing the end of their current business model. This makes cooperation and a buy-in difficult. The same banker continues: "So far, what happens is that the blockchain becomes something like the fourteenth actor, and does more to complicate things further than to stratify the process." In areas beyond clearing and settlement, blockchain is even further away from implementation for similar reasons. Many people discussed pilot projects but these were less driven by actual business needs, but by "fear of missing out" on the next big thing. As a result, blockchain experimentation abounds, but it is still far from becoming a standard for financial transactions.

The complexity of the adoption challenge was also noted by a group of senior bankers working on blockchain projects at the Conference on Digital Assets and Distributed Ledgers in Financial Services in February 2021 (note 29). They described several layers of difficulties, both internal and external to their firms, that work against the introduction of blockchain-based processes. For example, internally anyone seeking to use blockchain within the bank needs buy-in from several other departments including (but not limited to) business development, financial risk management, operational risk management, IT security, legal and tax department, and regulatory and compliance. Since blockchain technology is laden with technical intricacies, the first step is education of decision makers in the context of a fast-evolving technology. The external challenge of coordination is even more challenging as it requires agreement between several firms. This is easier for pure cost-cutting projects - where everybody can profit - than it is for new, innovative products requiring changes in business models (or the loss thereof) for some players.

Another external concern is regulation: new regulations need to be crafted in order to deal with the new techniques and possibilities of blockchain, and regulators need to be convinced. Somewhat surprisingly to us, regulators were seen (by the panelists and more generally by attendees) as not particularly problematic and accommodating to the experimental character of blockchain projects. This is also evident in policy development as jurisdictions seek to introduce de facto standards. The first EU-wide framework on 'Markets In Crypto-Assets' (MiCA) was distributed for discussion in late 2020, with the goal of being in effect by the end of 2022. As one official from the Directorate-General for Financial Stability, Financial Services and Capital Markets Union (DG FISMA) of European Commission put it: "Europe must now lead the way on digital or it will have to follow the way of others, who are setting these standards for us" (note 67). In a widely regarded move, in 2020 the European Central Bank (also a regulator), publicly announced plans to investigate a "digital Euro" which would be crypto based (ECB 2021). Other central banks published similar plans over the last years (BIS 2021).

A final set of external factors are the needs and concerns of customers and the search for use cases (beyond crypto-currencies) has been a constant constraint challenge. From a broader perspective but in a similar vein, Amazon Web Services' CEO Andy Jassy put it: "We don't yet see a lot of practical use cases for blockchain that are much broader than using a distributed ledger." Indeed, a regular argument deployed is that most problems could be solved with other methods than blockchain (Barbaschow 2017) and as one of the conference attendants (themselves a banker) noted: "nobody cares whether it is blockchain or not, it needs to solve a problem [for business clients]" (note 26). This is in line with the big share of blockchain based start-ups that are working in fairly common finance areas on incremental innovations.

5.3. Imagining new clients for blockchain based finance

Given the ongoing challenge of finding viable applications for blockchain (beyond speculation on cryptocurrencies) there is considerable work by both camps to imagine and find clients. For example, the evangelist side envisions blockchain as a means to connect refugee and the unbanked community more generally, to identification and financial resources operating on a (alternative) a "permissionless" financial system (note, permissionless is a technical term but is also used deliberately political in this context) (Weitzberg et al, 2021). While often couched in terms of financial inclusion, these efforts might also be seen as firm tactics to gain footholds in the international remittances infrastructure (Rodima-Taylor and Grimes, 2019) or mobile money systems (Maurer, 2012) to establish themselves as a key fee-generating intermediary. For example Rella (2019) argues that blockchain based approaches to remittances have contributed to formalization rather than creating more inclusive approaches to cross-border payments.

These kinds of results are in part tied to the thick infrastructure needed in order to participate in "decentralized finance". One would need to have enough money to play around with fiddly, potentially highly volatile currencies, a strong knowledge of crypto currencies and the access to them, time to gain this knowledge, the ability to verify information (presumably via personal networks) in order to protect against scams and misinformation, the understanding that there might be problems like this, the financial capacity to deal with losses, access to a safe internet/computer environment, etc. (And this only to become a consumer in this area, not at all a partner and producer.) It is hard to imagine people who could command all these resources being excluded from the traditional financial system. In short, the scenario imagined by evangelists is far from accessible, and the financial inclusion for the unbanked seems either rhetorical or tactical, perhaps to camouflage the pure libertarian views underlying much of the scene (see Zook and Blankenship 2018).

Shifting to the incumbent viewpoint we see problematic investment systems that seem ill-prepared for retail investors' mass adoption. Investing in blockchain-related assets is dangerous both for its volatility (such as the price volatility of Bitcoin, Ether or thousands of lesser known cryptocurrencies, including the most recent drop in June 2022) and the largely unregulated environment leading to a large amount of scams. Issues include a high number of scams within initial coin offerings (up to 80 percent according to Casey et al. 2018), wide-spread efforts at money laundering (see Zook and Grote 2020), fraudulent crypto currency exchanges and the ongoing use of cryptocurrencies in various criminal enterprises. In short, it is a challenging field for financial sector incumbents to navigate, particularly on behalf of clients.

5.4. Creating DeFi

Despite (or perhaps because of) these challenges in imagining new clients, a widely discussed topic at conferences is the establishment of a blockchain-based, decentralized financial system ("DeFi"). Lacking a unifying document (compared to the original Bitcoin whitepage that started blockchain), DeFi represents efforts to create an open-source, permissionless, transparent financial service ecosystem: available to every-one, operating without any central authority, and reliant upon peer-to-peer (P2P) "dapps" to a great extent. Dapps are blockchain-based applications, or smart contracts, and represent a type of non-human agency (software code) that executes agreements when certain conditions are met. Allegedly they might reduce the need for existing intermediaries like banks (as per the evangelists) and/or back office labor (as per the incumbents) reducing costs and lead to a more frictionless financial system. The software that undergirds smart contracts becomes the equivalent of a legal contract and this non-human agency will resolve every possible dispute as laid out in the code. As dapps themselves exist and act on decentralized blockchains, any single point of failure (or centralized authority) is eliminated, removing potential censorship and or shutdown of services. Of course, this works best in theory (Madeira, 2018) as evangelists struggle to reach workable systems in actual practice.

On the incumbent side, "decentralized finance" endeavours generally means the creation of very similar products and structures to what already exists in the incumbent financial system (Barbaschow 2017). Examples for this include exchanges with similar market making methods, equity- and bond-type financial instruments issued via initial security/token offerings, savings and lending schemes that mimic banks, brokers for buying crypto securities, derivative instruments, investment funds, etc. These products and services resemble the existing financial market to a great extent albeit focused primarily on handling crypto-assets rather than more traditional assets. The DeFi element largely turns on the fact that the record of transactions is stored on a distributed ledger rather than on a bank's or firm's internal system, and a more complicated access to its services (and, eventually, higher risk). In short, for incumbents this is mostly a change in underlying technology rather than practice.

5.5. plus ça change, plus c'est la même chose?

Despite the strong rhetoric of evangelists, incumbent actors experimenting with blockchain business models in finance seem less concerned with disruption and more focused on adopting a new underlying technology to increase internal efficiency, possibly bypass current intermediaries, and perhaps integrate some part of the non-banked population. Indeed, the fact that one of the most successful cryptocurrencies exchanges, Coinbase, is planning for a listing on a traditional stock exchange (Kauflin 2021), is emblematic of the integration of blockchain to finance rather than blockchain disrupting the current system (as per evangelists hopes). Given this, it would be easy to conclude that blockchain will simply fade into the background, another niche asset or accounting technology, but not result in any drastic shift.

While we are sympathetic with this view, we also see a need to analyze how blockchain might usher change within finance, most notably via what Iansiti and Lakhani (2017) characterize as foundational technology.

> "[B]lockchain is not a "disruptive" technology, which can attack a traditional business model with a lower-cost solution and overtake incumbent firms quickly. Blockchain is a foundational technology: It has the potential to create new foundations for our economic and social systems. But while the impact will be enormous, it will take decades for blockchain to seep into our economic and social infrastructure. The process of adoption will be gradual and steady, not sudden, as waves of technological and institutional change gain momentum."

Assuming the validity of this characterization as foundational technology (perhaps enabled by the non-human agency of smart contracts and dapps), the next section explores ways in which this could allow for shifts in the scale at which finance (and the economy more generally) operates.

6. The shifting scales of blockchain

The partial replacement of some intermediaries and more efficient back-office work is unlikely to disrupt the financial system. An arena with more potential, however, are changes introduced to the financial system by blockchain technologies in the scale at which finance can act. We highlight this potential via three case studies: first, Initial Coin Offerings (ICOs) which shift the scale of investment from firms to technologies; second, real estate where the unit of investment shift from whole units (buildings or apartments) to dynamic shares; and third, changes within currency in which individual cash units maintain their own immutable history (money with a memory) that extends the relevant temporal scale of cash.These three cases are a selective choice, and are focused on real practices that while still early on, have already changed the practices of some financial sector actors. While not reviewed here there are more hypothetical areas of blockchain-based finance with more scale changing potential including central bank digital currencies (CBDC), corporate platforms (such as Facebook) attempting to establish their own cryptocurrencies, just-in-time financing for components of finished products, and internet of things based applications.

6.1. Initial Coin Offerings: Scaling investment from firms to technologies

In 2013, a new form of financing emerged - Initial Coin Offerings (ICO) - that differs from conventional start-up financing in that investors mostly do not get shares in a firm in exchange for their capital. Instead they receive vouchers (coins/tokens) for the firms' services or a technological platform to be developed by the firm directly. While providing new money for financing, the lack of control and oversight led to many scam-like ICOs, with investors receiving nothing in return for their investment (Casey et al. 2018). Still Fahlenbrach and Frattaroli (2020) show that the average investor into ICOs made a healthy profit although this finding is driven by a few very successful developments; the median investor still experienced a loss. Somewhat lost in the "ICO as scam" rhetoric are two principal innovations of ICOs, namely the possibilities to tap into different sources of capital for entrepreneurs - reconfiguring established financing practices -, and the chance to invest directly into technologies for investors. We now turn to a deeper dive into this latter point.

The ability for ICOs to shift investments from firms to technologies is based on the format for smart contracts embodied in the ERC20 ("Ethereum Request for Comments") technical standard. ERC20 creates tokens/coins which allows for easy division of investments (facilitating lower investment levels and reselling) theoretically increasing liquidity. In other words, investors need not wait for a standard liquidity event (IPO or acquisition) to profit but might benefit from early success of a technology as demand for a particular ERC token increases. Over time, the functions of the issued coins or tokens have changed; roughly speaking, three different stages can be distinguished (Strategy, 2019). The first wave - started by Ethereum in 2014 - focused on issuing fungible cryptocurrencies as a means of payment or store of value

similar to bitcoin. The second wave consisted mostly of "utility tokens", or vouchers for using technological products and services of the issuing firm after development, although these were also driven by speculation that utility tokens would become cryptocurrencies as well. The third wave brought "security tokens" with most of the characteristics of traditional securities, like fixed or conditional interest payments, equity rights, etc. The first and, in part, second waves allowed investors to invest directly into technology and its associated ecosystem with Ethereum (providing the blockchain and currency used by most other ICOs) being a particularly good example (see Zook and Grote 2020). While investors were also driven by speculation (Fahlenbrach and Frattaroli 2020), ICOs might provide better estimates for the demand for technologies prior to development as well as incentivizing user-investors to become early adopters, helping to drive the acceptance and dissem-inations of new innovations (see Reftoken 2017).

A good example of ICOs allowing for technology developments is the case of the Gnosis, a firm focused on the creation and trading of specialized prediction markets and its ERC token GNO. The Gnosis/GNO ICO stands out for its speed: On April 24, 2017 it took only 15 min to sell all available GNO tokens (about 5 percent of total, the remaining 95 percent held by the firm or founders) raising about USD 12.5 million (paid primarily in Ether or ETH, see Mantinger 2019). This resulted in a market capitalization of about USD 300 million for the firm which was likely further enhanced by the steep appreciation of both ETH and GNO during the second half of 2017, e.g., GNO's price went from around 80 Euro around the ICO to more than 300 Euro by January 2018. Pricing for GNO remains volatile, however, dropping to a low of about 10 Euros over the next year, only to rise again to about 220 Euro in April 2021. In short, the Gnosis ICO channeled considerable resources into a particular technology (for creating prediction markets), while allowing firm founders to remain in control of their company.

The technology in question is based on Hanson's (2000) idea of "futarchy" via the creation of a general prediction market using a larger pool of bets/votes (based on smart contracts) to allow for better fore-casting. In short, the goal of the GNO ICO was a general technological platform (built on blockchain technology) for the operation of a wider ecosystem of applications with all transactions paid for via GNO tokens; a more specific application of the model pioneered by the Ethereum blockchain and ETH. The - voluntarily or involuntarily - "patient" capital provided by the investors in 2017 led to the steady development of the components of an ecosystem for prediction markets despite millions of Euros of yearly expenses and no earnings. Moreover, this shift in in-vestment from shares of a firm, to tokens for future technology use, can provide greater liquidity for investors (although this is certainly not the case for all ICOs) who can also profit directly by greater demand for GNOs, be it on the prediction market platform or speculation. To be sure, there are significant governance problems associated with this, e.g., we remain skeptical as to whether the effort to put "futarchy" into practice will succeed. Nevertheless, this example shows how the technological affordances of blockchain (in this case ERC 20 tokens) can enable in-vestments directly in technology rather than firms.

6.2. *Tokenizing real estate: Scaling down investment size*

Given the large size of (potential) investment opportunities and its comparatively high transaction costs, real estate is an attractive use case for blockchain with much interest in developing fractional ownership via smart contracts. Lowering transaction costs in the investment pro-cess, makes smaller investments - a thousandth of a flat - viable and thus, in theory, retail investors will be able to invest in small pieces of real estate worldwide. Again, much rhetoric focuses on "democratizing" in-vestment in real estate (as compared to buying whole properties or shares of REITs) that come with net worth requirements and minimum investment amounts. As with the "banking the unbanked" discourse noted early, these arguments seem more rhetorical than realized.

Regardless, fractional ownership at this scale might lead to some consequential changes in the operation of real estate investment mar-kets. Plausible scenarios include an increase of retail investors leading to greater demand, which could increase prices for real estate, and with that probably for leases, too. Additionally, establishing a large second-ary market - basically a stock exchange - driven by retail investors to trade the real estate tokens might induce a higher price volatility and thus higher risk, which translates into less construction activity. At present, these concerns are downplayed while the individual advantages for investors are emphasized, namely the risk/return profile of real es-tate investments that might help increase the portfolio returns for retail investors, too (see, e.g., Estating 2021) with any secondary markets remaining very niche (see, e.g., Exporo 2021).

A full transfer of land ownership onto a blockchain, splittable in many smaller units and easily transferable seems to be at least a couple of years into the future though: Land and real estate ownership remains a highly regulated institution with transfer of ownership between two parties a long and cumbersome process requiring up to 3–6 months between initiation and final settlement (Müller and Seifert 2019 for Germany, McMurren et al. 2018 for Sweden). More than 30 countries are currently working on government blockchain projects concerning their land registries, with Dubai and Sweden being the most advanced (JLL 2020). From 2016 onwards Sweden has tested a much-publicized blockchain-based system to coordinate the many different parties and to speed up the process. While the trial was successful in showing the viability of such a system, changes in legislation are still required and so far, the system has not gone live (Baraniuk 2020).

Moreover the conversation from a 2021 round table on "Tokeniza-tion of Real Estate: The Future of This Asset Class?" shows that much work remains to be done. While some participants favoured recording ownership directly on a blockchain, others viewed some kind of inter-mediary as necessary. This latter viewpoint noted the need for centrally managing the respective real estate objects, i.e. finding tenants, writing leases, monitoring maintenance work, dealing with utilities, etc., that would remain regardless of the fractional size of ownership. Ideally this management intermediary would also profit from the value increase of the real estate (to better align incentives with the other owners, note 40) and would basically work like a REIT, buying the real estate and financing it by issuing tokens to investors. In one scenario, these tokens might mimic a direct equity stake with payments linked to lease income from any particular object, but with the possibility of selling/buying tokens in minutes instead of weeks or months, and without real estate transaction tax (see Bozoukova and Sandner 2020). While this process is already in place for institutional investors without blockchain, the goal for tokening real estate is scaling these processes to the retail market. This vision provides little advantage to those seeking real estate to inhabit (and likely brings new challenges and surveillance to residents, see Fields, 2018) but instead would allow retail investors the ability to invest in specific real estate objects across many geographies. In short, scaling down real estate investment could lead to a massive inflow of capital into international retail investment portfolios, and stock exchange-like trading activities of parts of real estates. The conse-quences of this for rents and tenants remain to be seen although the history of real estate investing suggests caution (Fields and Rogers, 2021).

6.3. *Money memories: Scaling in time*

An important feature of blockchain technologies are the traceable and immutable recording of every transaction. While not a smart con-tract in the technical sense, this trait means that each unit of crypto-currency (e.g., Bitcoin or Ether) carries a complete record of every transaction in which it was involved. In this sense, "Money is memory" – a concept in 1996 articulated by Narayana Kocherlakota, then consul-tant and later president of the Federal Reserve Bank of Minneapolis – has been more fully realized than earlier monetary record keeping (O'Dw-yer, 2019). Kocherlakota (1996, p. 28) conceptualized money as a

"primitive" form of memory, writing: "[…] money may only be an imperfect substitute for high quality information storage and access. This 'real world' message serves to underscore that the government's monopoly on seignorage [sic] might be in some jeopardy as information access and storage costs decline." With blockchain based cryptocurrencies we now see how the expanded availability of money memories (a rescaling of time) is taking a largely undifferentiated object (money or cash) and disaggregating it in various ways.[5]

For example, Bitcoins with a tainted history - being used in criminal activity, in the "dark net" or in dealings with sanctioned countries - are not as easily used. The US Office of Foreign Assets Control, (the part of the US Treasury overseeing sanctions), issued a statement in 2018 stressing that compliance obligations are the same, regardless of whether a transaction is denominated in digital currency or in fiat currency: "Persons including technology companies; administrators, exchangers, and users of digital currencies; and other payment processors should develop a tailored, risk-based compliance program, which generally should include sanctions list screening and other appropriate measures." (OFAC 2018). Likewise, there remain open questions about whether units of cryptocurrencies involved in illegal activity - fraud or ransom payments - might be claimed back by the victim.

Given these circumstances, it is no surprise that institutional investors (and some criminals, see Redman, 2020) prefer freshly minted cryptocurrency coins. As a result, coins without a history command a premium of up to 10–20 percent compared to those freely available on exchanges (e.g., Jagati 2019). Similarly, there are firms that offer to "clean" the history of bitcoins by mixing their histories with other coins, the crypto equivalent of money laundering. For example, "Coinjoin" advertises its "Whirlpool" services thusly: "Break the link your coins leave behind with built in CoinJoin available on any platform" (Samourai 2021). Coinjoin's website is likewise illuminating: "We are privacy activists who have dedicated our lives to creating the software that Silicon Valley will never build, the regulators will never allow, and the VC's will never invest in. We build the software that Bitcoin deserves." (Samourai 2021). In response, regulators and more mainstream firms have sought to blacklist the coins associated with firms that provide this sort of mixing service altogether (see Sedgwick 2020).

These examples of temporal scale within cryptocurrencies, premiums for freshly minted coins, and discounts on tainted coins, means that internal currency exchange rates exist, striking at the very fungibility of a currency. Cryptocurrencies' ability to shift scales in time leads to money that is fundamentally different from fiat cash and might have strong consequences for privacy and surveillance: dealings with crypto currencies in distant places and in distant times matters.

7. Framing technological change via space, agency and scale

In this paper we develop a general framework to assess any new technology to fundamentally alter economic and financial geographies. We use this framework fora real-time assessment of the potentially disrupting qualities of blockchain technology in the financial sector framed by a focus on potential changes to space, agency and scale. Given the relative novelty of blockchain the extent and outcomes of adoption remain to be seen. For example, are we simply experiencing a "hype cycle model" (Dedehayir and Steinert 2016) in which the newness of a technology inflates expectations unwarrantedly or something more akin to Amara's law (1988) where short-term expectations are overblown while long-term effects are discounted.

Nevertheless, an early examination of the (potential) process of adoption delivers some advantages. First, it allows a close look at the messy, unsorted and ongoing processes, providing a richer picture of change in the financial sector, without any post-hoc rationalization based on what has become successful and what not. Second, by focussing on the potential long-term development paths, the paper more explicitly deals with "Amara's law". While the suggested specific future developments will be wrong in many cases, broader trends in the financial sector can be identified early, regardless of whether the specific technology is used to implement these changes. Third, and most importantly, analyzing at this early stage requires a grounded framework that can assess how a technology's main characteristics possess the potential for shifting geographies of finance, and the larger economy. Our framework uses the concepts of space, agency and scale to systematize our analysis of the adoption of blockchain technology in the financial sector. While our framing is derived from our empirical engagement with blockchain, we contend that this framework might be usefully applied to analyzing other innovations in real-time for their potential geographical impact.

In this we seek to build upon approaches such as Jessop et al. (2008) interest in recognizing the "organization of sociospatial relations in multiple forms". Given our focus on technological change within economic and financial geographies, we emphasize different dimensions, notably agency (particularly coming from software) and an understanding of scale focused on prying apart elements (technologies, investments, currencies) that hitherto have largely been analyzed as units. In our case, the unresolved and contested implementation of blockchain makes the focus on agency and scale a necessary and fruitful focus for analysis. Later work on blockchain might refocus more on the intriguing spatial dimensions we have documented here, and or seek to better articulate the relational dimensions between the people and places involved in blockchain. Relatedly-one could imagine similar approaches to analyzing the economic geographies of other emerging (and in some cases highly speculative) technologies of Artificial Intelligence, Large Language Models (LLM) and quantum computing. In short, while our empirical focus in this paper was the adoption of blockchain within the financial section, ultimately we see our theoretical framing as a potential means for better understanding any number of dynamic moments brought together by the merging of different articulations of space, agency and scale.

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

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[5] This is not to argue that money had no record-keeping function prior to blockchain. Rather we seek to emphasize that the design of blockchain technology centers on record-keeping (or memory) which fundamentally increases the ease with which transactions can be reviewed. To be clear, some information about specific money's history has been available:, records of debts and obligations on medieval tally sticks, double-entry bookkeeping, paper logs on cash registers, recording serial numbers of cash used in payments etc. (O'Dwyer, 2019). Likewise fiat bank notes can also be marked by criminal activities too, such as the traces of cocaine on the majority of bills. However, the precision and efficiency of doing this has been greatly augmented within cryptocurrencies.

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