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# Mapping the uneven geographies of digital phenomena: The case of blockchain

Matthew Zook
Department of Geography, University of Kentucky

Michael McCanless
Department of Geography, University of Kentucky

## Key messages

- Grounding practices within the materiality of geography is an important technique for studying the complexity of digital phenomena.
- The DIGO (Discourses, Infrastructures, Groupings, and Outcomes) framework uses these categories to guide data selection for locating digital phenomenon in material geographies.
- This article applies the DIGO framework to blockchain (using data about tweets, miners, firms, and ICOs) to show how this digital practice connects to and across material geographies.

*Digital phenomena pose unique challenges to social science researchers investigating the impact of new and changing technologies. In part, this challenge derives from the constantly evolving practices, actants, and geographies enrolled in the digital. When these phenomena are coupled with over-the-top expectations and media hype, initial impressions often mask the complicated and nuanced ways new technologies are put to use. Blockchain (and its original application Bitcoin) represent one of these new, unstable digital phenomena that simultaneously captures public imagination and generates powerful discourses of disruption and change. One way of clarifying the messiness of technologies like blockchain is to ground its practices within the materiality of geography. The DIGO framework proposed in this article uses four broad categories—discourses (measured via Twitter), infrastructures (indicated by Bitcoin mining), groupings (based on firms and exchanges), and outcomes (measured by initial coin offerings)—located in geographic space. Each category is meant to provide insight on blockchain as it unfolds across space and scale. The same framework can guide research on other digital phenomena, based on appropriate measures for each of the four DIGO foci.*

Keywords: digital geography, financial geography, methods, blockchain, cryptocurrency

### Cartographier la géographie des inégalités des phénomènes numériques: Le cas des chaînes de blocs

*Les phénomènes numériques constituent des défis uniques pour les chercheurs des sciences sociales qui étudient l'impact des nouvelles technologies. Ces défis découlent en partie de l'évolution constante des pratiques, des arguments et des géographies qui s'inscrivent dans le numérique. Lorsque ces phénomènes sont associés à des attentes exagérées et à certains types de médias, les premières impressions masquent souvent les façons complexes et nuancées dont les nouvelles technologies sont mises en application. La chaîne de blocs (et son application originale, le Bitcoin) représente l'un de ces nouveaux phénomènes numériques instables qui captivent simultanément l'imagination du public et génère des discours puissants de rupture et de changement. Une façon d'expliquer la complexité des technologies telles que les chaînes de blocs est d'arrimer*

Correspondence to / Adresse de correspondance: Michael McCanless, Department of Geography, University of Kentucky, 817 Patterson Office Tower, Lexington, KY 40508-0027. Email/Courriel: michael.mccanless@uky.edu


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*ses pratiques au caractère tangible de la géographie. Le cadre DIGO proposé dans le présent article utilise quatre grandes catégories—les discours (mesurés au moyen de Twitter), les infrastructures (indiquées par l'exploitation du Bitcoin), les regroupements (fondés sur des entreprises et des échanges) et les résultats (mesurés par l'offre initiale de monnaie)—situées dans des espaces géographiques. Chaque catégorie est censée offrir un aperçu des chaînes de blocs et de la façon dont ils se déploient dans l'espace et à travers les échelles géographiques. Le même cadre peut orienter la recherche sur d'autres phénomènes numériques, en fonction des mesures appropriées pour chacun des quatre foyers DIGO.*

Mots clés : géographie numérique, géographie financière, méthodes, chaînes de blocs, cryptomonnaie

## Introduction

Understanding emergent digital phenomena poses a challenge for geographers as each presents its own unique elements, actants, and associated geographies. Because new digital activities are rarely—if ever—captured in official state data, researchers must rely on information gathered from alternative sources. With this in mind, the overarching aim of this article is outlining an approach for analyzing the "new spaces and geographies" of digital phenomena and practices. To be clear, this is not intended to be a fixed or finalized checklist; instead we seek a replicable, yet adaptable, scaffolding for meaningfully measuring the spatial dimension of new practices bridging materiality and digital spaces. The DIGO framework we propose uses four broad categories—discourses, infrastructures, groupings, and outcomes—that can be located in geographic space (albeit with caveats on accuracy and meaning) to provide insight on how emerging digital phenomena expand across space and scale.

To provide an empirical example of this approach, we focus on the phenomenon of blockchain and its most successful application, the cryptocurrency Bitcoin. In many ways both blockchain and Bitcoin are poster-children for new, unstable, and uncertain digital practices that capture the public's imagination (e.g., the massive increase in cryptocurrencies' value) and generate overwrought proclamations that everything has changed. One way of clarifying the complicated and nuanced use of digital technologies (and tamping down the hyperbole) is grounding these practices within the materiality of its geography.

## The complicated geographies of digital phenomena

The connection between material and digital spaces has long been of interest to geographers, often engaging with simplistic "death of distance" narratives from elsewhere. To counter this, research in geography has analyzed the ways that place persists and materially contributes to the design and use of new technologies. Framed another way, geographic research has approached digital technologies (and the practices and phenomena that utilize and shape them) as much more than simply zero-sum games with the new replacing the old (Batty 1993), and has repeatedly documented the lack of uniform spatial effect (Warf 2001).

The approaches for studying these complicated digital geographies are many, shaped by the nature of the phenomenon and the interest of the researcher. In the early 1990s, as the internet moved mainstream, much Geography-based research focused on shifts of commercial activities online and associated industrial clusters (see Zook 2000). Later, as GPS and Web 2.0 enabled user-generated spatially referenced data, researchers focused on volunteered geographic information (Goodchild 2007), the geospatial web (Elwood 2010), and big geospatial data (Crampton et al. 2013). Within the past decade, the sub-discipline of digital geographies has emerged across a broad range of frameworks and methods (Ash et al. 2018). Indeed, the recent past has seen a virtual explosion of research on digital topics ranging from predictive policing (Jefferson 2018), to how algorithms shape people and their experiences (Amoore 2020), to digitally-mediated cultural production (Rose 2016), to the emergence of fintech clusters (Lai and Samers 2020).

Increasingly, work in digital geographies has sought to understand the role of infrastructure in the creation and management of digital space. For example, Furlong's (2020) concept of "cloudfrastructure" highlights how assemblages of material (fibre optics), historical (military investment), and discursive (data flows) legacies are enrolled in the emergence of a "cloud." Building from the work of Amoore (2018), Mattern (2016), and Hu (2015), Furlong uses cloudfrastructure to question the salience of “visibility” as *the* object of critical analysis. Instead, Furlong argues that analyses of digital infrastructure cannot simply focus on the face value of materiality but must also examine the ways materiality is enrolled in socio-spatial processes of power, history, and capital formation, all of which contribute to the emergence of a phenomena's digital geography. While our approach abridges the full complexity of digital phenomena identified by Furlong (2020) or Crampton et al.'s (2013) call to go beyond locational analysis, we argue it usefully highlights spatial patterns and contradictions via its method of categorization. This is both a worthwhile focus in its own right and essential for identifying fruitful directions for further research.

## Systematizing our approach

There are several precedents for systematizing studies of digital phenomena that engage with the social and spatial relations embedded in materiality. For example, Ash et al. (2018, 3, emphasis in the original) propose a categorization of “geographies produced *through*, produced *by*, and *of* the digital” to capture the ways digital practices intensify their engagement with and around Geography. In this formulation, geographies produced *through* the digital relate to ways that new technologies (such as GIS and geovisualization) are enrolled to produce knowledge, while geographies produced *by* the digital refer to changes in the production of space (both between and within material places), and geographies produced *of* the digital focus on better understanding how virtual affordances (including space) unfold and are used. In a related approach, although one focused specifically on the emerging fintech sector (firms seeking to transform finance via digital technologies), Lai and Samers (2020) frame their analysis in terms of the three dimensions of the fintech cube (building from Gomber et al. 2017). In their approach they highlight three key axes—actors/institutions, technologies, and products/services—and use these categories to classify how fintech activity reshapes financial networks and in/exclusion.

We take inspiration from these approaches, yet recognize that differences between digital phenomena require a flexible approach. Thus, our selection of metrics for the proposed DIGO framework—discourses, infrastructures, groupings, and outcomes—is shaped by the ability to successfully and meaningfully measure them in material space. Luckily the advent of digital phenomena provide opportunities for some metrics that hitherto might have been theoretically important, but exceedingly challenging to capture empirically—e.g., discourse, particularly from non-elites, is often not systematically recorded.

In our formulation, “discourse” consists of various texts (broadly defined as social media, marketing, news reports, chats, everyday documents, manifestos, academic work, etc.) that promote and discuss a digital phenomenon. While not an explicit category in the approaches referenced above—although Ash et al. (2018) are careful to include it as part of their definition of the digital—discourse is well understood as an important enabling foundation for new phenomena, digital and otherwise (Graham et al. 2015). As Lai (2018) argues regarding the financialization of everyday life, discourse makes a key contribution by emphasizing particular mindsets (e.g., responsibilities of individuals, entrepreneurialism, etc.). In short, discourse is fundamental in promoting new digital ideas, be it blockchain or indigenous data governance (see Kukutai and Taylor 2016; McLean 2019; Carroll et al. 2020), and therefore understanding its spatiality is important.

The next category in our approach, “infrastructures,” focuses on the technical components of digital phenomena in materiality (e.g., fibre-optic cables, servers) and digital terms (code, categories, and algorithms). This is akin to Ash et al.'s (2018) interest in geographies produced *by* the digital (changes in the production of space between and within places) and Lai and Samers’ (2020) axis of technologies. In some ways, infrastructure is the most concrete of our four categories (at least in data-gathering terms), although digital phenomena are relatively less visible than other infrastructures (a concern made even stronger given the inclusion of software, protocols, and standards). Nevertheless, researchers have successfully mapped fibre-optic and satellite connections (Warf 2006), backbone and data exchange sites (Malecki 2002), and operating protocols such as domain names (Zook 2000).

The third area of emphasis is “groupings,” or the social structures through which digital phenomena are organized and reproduced. These might include single-establishment firms, local state governments, and neighbourhood community groups, as well as groupings organized across material space (Froehling 1997). These relate to Ash et al.'s (2018) interest in geographies produced *through* the digital (the process by which new knowledge is produced) and Lai and Samers' (2020) axis of actors/institutions. While often manifesting in familiar social and economic units—e.g., work teams, communities, or firms—groupings can confound measurement, particularly as emerging digital phenomena undergo rapid evolution. Examples include how commercial actors organize to commodify geographic data (Alvarez León 2016), and the ways in which an Indigenous community's protests are enclosed, connected, and framed by spatial media (Rivera 2019).

The final category of our approach is "outcomes," the outputs of digital phenomena, including products and services, as well as new practices, networks, and politics. These relate to Ash et al.'s (2018) interest in geographies produced *of* the digital (how the affordances of digital phenomena are put to use), and Lai and Samers' (2020) axis of product/services. This category is purposefully broad to capture the full range of possibilities for new digital phenomena. For example, Richardson (2020) highlights how the geographies of delivery workers, restaurants, and the operators of delivery apps come together to create new and temporary assemblages that depend on localized labour precarity.

We selected these four metrics in our proposed DIGO framework to provide an outline for analyzing the connections between new digital practices and material space. Like any outline, this approach is subject to refinement and clarification. While our focus here is a fairly standard mapping exercise, many of the examples we note above are less explicitly cartographic, instead focusing on the politics of a moment in space-time (Rivera 2019) or the embodiment of new work routines (Richardson 2020). These are extremely important types of interventions as well, certainly relevant to empirical case study of blockchain, but not possible in this article given space constraints.

### Applying the DIGO approach to blockchain

The underlying distributed-ledger technology (i.e., blockchain) is, at its most basic, a form of distributed record-keeping which facilitates transactions without a centralized authority. The original use case for blockchain is the cryptocurrency Bitcoin (Nakamoto 2008), which continues to be its most successful and well-known manifestation. Blockchain technology, however, has also become a social phenomenon with strong ties to libertarianism and beliefs in algorithmic governance (Zook and Blankenship 2018), efforts to reformulate start-up firm financing (Jain and Jain 2019; Bellavitis et al. 2020; Zook and Grote 2020), and attempts by companies and corporations to rework the global financial system (Parkin 2018). These efforts have been compounded in recent years by second- and third-generation blockchain technologies which enable "smart contracts" and a growing ecosystem of decentralized applications (Raval 2016; Dinh et al. 2018) targeting the financial sector (Fernandez-Vazquez et al. 2019).

In short, blockchain is a complex and evolving digital phenomenon. To better understand blockchain (and demonstrate the applicability of our approach), the next section shows the geographies of our four proposed categories: discourse (measured via Twitter), infrastructure (indicated by mining), groupings (based on firms and exchanges), and outcomes (measured by initial coin offerings). We use these results to build a better understanding of how blockchain manifests in the world relative to possible expectations. For example, given its initial use case as a cryptocurrency (with implications for money and finance), one might expect concentrations primarily in global financial centres. In contrast, given its decentralized architecture and libertarian trappings, offshore and otherwise off the beaten track locations may be significant. As the next section illustrates, aspects of each are present as well as elements specific to the structure and function of this particular digital phenomenon.

## Geographies of discourse and attention

Turning first to discourse, we focus on social media discussions to capture a measure of the "attention" or awareness and interest in blockchain from the general public (see Zhao and Huang [2020] for an alternative approach to studying blockchain discourse). While there is no perfect measure of public attention (Poorthuis et al. 2020), the use of social media platforms such as Twitter offer a useful proxy for capturing this aspect of blockchain, with the caveat that the popularity of any social media platform differs across countries.

To demonstrate the utility of this approach we obtained the number of geotagged tweets, by country, containing the term “Bitcoin” for the years 2013, 2016, and 2020. This allowed us to track attention to blockchain's original application from very early stages (2013) to initial popular awareness (2016) through wider public knowledge (2020). Although we reviewed similar tweet data for the terms “blockchain” and “ethereum,” we elected to use Bitcoin as it is the most publicly discussed blockchain-related topic on Twitter, with more than four times the number of tweets as the next most frequently used keyword.

One of the challenges of using non-standard data is maximizing signal and minimizing noise. This is particularly relevant given that the barriers for sending a tweet are minimal. To compensate for that challenge, we used two different measures: number of tweets and odds ratio. The number of tweets captures the overall level of discourse (or attention) and the odds ratio captures the relative level (Poorthuis et al. 2020). More specifically, an odds ratio indicates which countries have higher or lower levels of discourse (defined as tweets containing the keyword Bitcoin) relative to its overall discourse (all tweets). An odds ratio below 1 indicates relatively less attention to Bitcoin, and odds ratios greater than 1 indicate relatively more attention. We also controlled for variance resulting from small samples by removing any countries with fewer than 5 Bitcoin tweets in 2016 or fewer than 10 in 2020. For all odds ratios we checked whether they met the 95% confidence interval for being statistically significant. This is indicated by a “*” in the tables below.

Table 1 shows the odds ratio and number of tweets for the 15 countries with the most Bitcoin tweets in 2020. The United States (US) had the largest number of tweets by far, as well as a relatively higher level of attention (odds ratio of 1.73) than its overall level of twitter activity would suggest. In contrast, Turkey, Indonesia, Brazil, and Spain had many Bitcoin tweets, but did not have odds ratios greater than 1.0 which indicate relatively low levels of attention. The United Kingdom (UK), Canada, India, Germany, Australia, and South Africa represent countries with relatively high attention to Bitcoin early on (2013 and 2016), but where attention has tapered off and in some cases (e.g., the UK and South Africa) is not meaningfully more intense than one would expect given overall levels of Twitter activity. Contrasting this, Nigeria, Venezuela, and Mexico (albeit to a lesser extent) have paid considerably more attention to Bitcoin in recent years. Overall, this suggests an evolving geography of attention (consistent with theories of innovation diffusion)—where some locations of early adoption (seemingly within developed economies) have seen a shift of discourse away from Bitcoin while discourse is intensifying in more peripheral locations (see Crandall 2019).

**Table 1**
Bitcoin discourse by country (ranked by number of 2020 tweets)

| | Odds Ratio | | | Number of Tweets | | |
|---|---|---|---|---|---|---|
| **Country** | **2013** | **2016** | **2020** | **2013** | **2016** | **2020** |
| United States | 2.16* | 1.18* | 1.73* | 14,266 | 34,382 | 51,922 |
| Nigeria | 0.51 | 1.30* | 3.53* | 44 | 68 | 7,458 |
| United Kingdom | 1.94* | 3.69* | 1.00 | 3,210 | 1,001 | 5,975 |
| Turkey | 0.22 | 0.16 | 0.98 | 786 | 175 | 5,206 |
| Indonesia | 0.09 | 0.34 | 0.68 | 509 | 618 | 4,953 |
| Canada | 5.79* | 3.11* | 2.34* | 1,386 | 1,998 | 3,715 |
| India | 7.58* | 1.01 | 0.85 | 457 | 63 | 3,702 |
| Brazil | 0.15 | 0.33 | 0.17 | 508 | 2,142 | 3,150 |
| Spain | 0.89 | 0.83 | 0.81 | 1,209 | 1,128 | 2,923 |
| Venezuela | 0.57 | 1.02 | 3.39* | 168 | 450 | 2,855 |
| Mexico | 0.54 | 0.34 | 1.07* | 312 | 359 | 2,608 |
| Australia | 6.15* | 2.22* | 3.13* | 546 | 106 | 2,523 |
| Argentina | 0.78 | 0.11 | 0.83 | 298 | 27 | 2,495 |
| Germany | 10.56* | 2.74* | 2.45* | 1,136 | 671 | 2,209 |
| South Africa | 2.10* | 2.59* | 1.10* | 185 | 732 | 1,870 |

*Indicates that the odds ratio value is statistically significant to control for small sample sizes.

Table 2 shows the same data as Table 1, but ranked by countries’ 2020 odds ratios which are all considerably higher than those in Table 1. While this is an artifact of the ranking, the differences are quite striking. Malta has 25 times the relative amount of discourse about Bitcoin than the top-ranked country in Table 1 (the US). Given that Table 2 represents the places with the highest relative level of discourse about Bitcoin, it is useful to consider how we might categorize countries into a few broad (albeit not exclusive) groupings. Perhaps clearest are countries known for finance both in terms of small offshore tax havens (e.g., Malta, Isle of Man, Curaçao, Liechtenstein) as well as larger financial centres (e.g., Luxembourg, Switzerland, Singapore, Hong Kong). Less well defined

**Table 2**
Bitcoin discourse by country (ranked by 2020 odds ratio)

| | Odds Ratio | | | Number of Tweets | | |
|---|---|---|---|---|---|---|
| **Country** | **2013** | **2016** | **2020** | **2013** | **2016** | **2020** |
| Malta | 3.44* | 2.36* | 46.34* | 6 | 19 | 1,214 |
| Slovenia | 13.28* | 5.15* | 30.54* | 34 | 48 | 640 |
| Vietnam | 1.70 | 3.90* | 11.44* | 9 | 33 | 517 |
| Isle of Man | 1.91 | 10.57* | 7.88* | 3 | 16 | 98 |
| Curaçao | 0.58 | 12.67* | 7.64* | 2 | 20 | 10 |
| Singapore | 1.25* | 0.60 | 7.29* | 93 | 19 | 788 |
| Bangladesh | 2.86* | 1.31 | 6.48* | 5 | 9 | 454 |
| Switzerland | 4.32* | 5.53* | 5.74* | 176 | 277 | 684 |
| Liechtenstein | 3.30 | 6.60 | 5.60* | 3 | 5 | 11 |
| Luxembourg | 8.35* | 6.04* | 5.22* | 17 | 26 | 41 |
| Rwanda | 3.82 | 5.09* | 4.96* | 2 | 19 | 237 |
| Cambodia | 2.24 | 6.97* | 4.85* | 3 | 26 | 73 |
| Estonia | 2.11* | 8.01* | 4.33* | 21 | 77 | 88 |
| Hungary | 2.96* | 1.38 | 4.16* | 42 | 26 | 166 |
| Austria | 11.77* | 4.48* | 3.95* | 165 | 151 | 323 |

*Indicates that the odds ratio value is statistically significant to control for small sample sizes.

are a group of central and eastern European countries (e.g., Slovenia, Estonia, Hungary, Austria) with varying specializations in technology and finance. Perhaps most intriguing is a set of low- to lower-middle-income countries with increasing levels of discourse over time (e.g., Vietnam, Bangladesh, Rwanda, Cambodia). This last group of countries also scores high on Transparency International's Corruption Perception Index (indicating high levels of perceived corruption), as do the 16th and 17th ranked countries, Nigeria and Venezuela. This suggests a possible link between discourse about Bitcoin and corruption and/or attempts by actors to bypass state institutions. To be sure, these categories are speculative, as are our hypotheses, but this exercise aptly demonstrates how mapping discourse can provide useful direction for further research.

## Geographies of infrastructure

The underlying infrastructure enabling blockchains is the system of miners/validators (i.e., algorithms running on computers) which approve new entries in the shared ledger. Focusing again on the original application of blockchain, Bitcoin pioneered the use of incentives (i.e., new units of currency) to ensure that its distributed record of ownership and transactions was properly maintained. These incentives are distributed to the first miner that solves a randomly generated cryptographic proof (i.e., Proof of Work protocol). The original vision of this design was to ensure that an online community, acting in concert, could maintain a decentralized system of record-keeping beyond the scope of any centralized actor. While this section focuses on Bitcoin (given its predominance in blockchain mining activity), one might do a similar exercise for other cryptocurrencies (and non-permissioned blockchains) that require an infrastructure of miners.

Given it is possible to connect to the Bitcoin system as a miner from anywhere with an internet connection, electricity is a key driver of Bitcoin's mining operations. The costs of electricity are mostly based on source (hydroelectric energy is cheapest), as well as the ability to draw on state-subsidized energy or even stolen electricity (Jolly 2021). In some cases, state subsidies are done directly, such as the country of Georgia offering discounts on energy and tax-free zones (Alderman 2019), while in other cases subsidies are carried out more surreptitiously as seen in the northwest US (Lally et al. 2019). Given the tight interconnection between electricity and subsidies, state-level actors are often key, either profiting from the activity directly or seeking to shut down mining operations, as in the case of Venezuela (see Tomaselli 2020). While very profitable, Bitcoin mining draws significant amounts of electricity from national infrastructures and stresses electric grids not designed for the power draw of cryptocurrency mining operations (Samford and Lovely-Francis 2019). At the global scale, the amount of electricity dedicated to Bitcoin mining is immense. As of May 2021, the Cambridge Bitcoin Electricity Consumption Index (CBECI 2021) estimates that mining represents approximately 0.5% of the world's electricity consumption, on par with the Netherlands.

Measuring the geography of mining operations is difficult given the nature of available metrics. For example, while it is relatively easy to identify miner nodes in the Bitcoin system and locate them (via geolocating IP addresses), it is much more challenging to measure the amount of computational power associated with a node or location, that is, to determine whether it is a single computer or an entire server farm. This challenge is further intensified by the efforts of mining operations to mask their size for competitive and regulation-avoidance reasons. In an attempt to estimate the distribution of Bitcoin mining we gathered the forward-facing IP address of Bitcoin miners in 2018 and 2019 (available via the Bitcoin blockchain) and geolocated them to produce the data in Table 3. This summary is interesting in both what it reveals, large and sustained operations in North America and Europe, and what it obscures, the level of Bitcoin mining in China. The seeming decrease in activity almost certainly does not reflect actual operations as we did not attempt to estimate computational power or adjust for efforts of operators to obfuscate their location. Fortunately, reliable secondary sources are available for these data (Kaiser et al. 2018; CBECI 2021).

**Table 3**
Bitcoin miners by country

| | 2018 | | 2019 | |
|---|---|---|---|---|
| **Country** | **Nodes** | **Share** | **Nodes** | **Share** |
| United States | 2766 | 23.8% | 2307 | 7.9% |
| Germany | 2029 | 17.5% | 1910 | 6.6% |
| China | 1391 | 12.0% | 333 | 1.1% |
| France | 736 | 6.3% | 601 | 2.1% |
| Netherlands | 517 | 4.4% | 491 | 1.7% |
| Canada | 414 | 3.6% | 302 | 1.0% |
| United Kingdom | 377 | 3.2% | 291 | 1.0% |
| Russia | 399 | 3.4% | 243 | 0.8% |
| Singapore | 232 | 2.0% | 316 | 1.1% |
| Japan | 220 | 1.9% | 194 | 0.7% |
| Rest | 2546 | 21.9% | 22098 | 76.0% |

CBECI (2021) relies upon a group of participant mining operations (representing approximately 35% of Bitcoin mining) to estimate global distribution. Their analysis estimates that China contained approximately 75% of Bitcoin mining during the third quarter of 2019 and 65% during the second quarter of 2020. Similar levels were reported by Kaiser et al. (2018), albeit for earlier time periods. Paradoxically, the concentration of Bitcoin mining in China contrasts with other aspects of blockchain operations (detailed below) due to prohibitions on cryptocurrency trading platforms and initial coin offerings (Zhang 2018). While it is beyond the scope of this article to explore why these differences exist, one intriguing hypothesis we raise is the differences between firms and people using blockchain (in that they potentially make state-level regulation more difficult), versus the simple acquisition of value/capital that comes from mining. Recent actions by the Chinese state also indicate potential shifts in mining operations. For example, the province of Inner Mongolia (estimated as the site for 8% of global Bitcoin mining due to its low energy prices) announced in 2021 that it is shutting down Bitcoin operations (Sanson and Lovely-Francis 2019; Kharpal 2021). As a result, operators of Bitcoin miners are seeking new energy sources, including the US and Canada, as states with energy resources such as Kentucky incentivize relocation (Shih 2021).

## Geographies of groupings

The category of groupings is broad by intent, to reflect the wide array of social structures that might be enrolled in the digital. Given the applications of blockchain within finance and business, we focus on commercial activities for this part of our review. Blockchain-focused commercial groups (or firms) are experimenting with a wide range of applications to leverage aspects of the technology—i.e., distributed record keeping, smart contracts, and/or cryptocurrencies—in ways that generate new business models. Given that the firms' foci are broader than the original blockchain-based application of Bitcoin (which we used for discourse and infrastructure), this also highlights how the DIGO framework can be adapted to reflect the specifics of a digital phenomenon.

Given the newness of blockchain, one way of identifying groupings is by leveraging existing visibility on platforms designed to provide data and analytics for a given sector (for non-commercial phenomena we might instead turn to a directory of interest groups or meetups). To capture these groupings, we built another database drawn from Crunchbase, one of the leading business information platforms for startup firms and the tech sector. Again, this broadens our target beyond Bitcoin but given that relevant groupings for blockchain are firms and entrepreneurs, this captures a key current practice for this digital phenomenon. Using search terms "Blockchain," "Distributed Ledger," "Crypto," "Coin," and "Token," we identified 11,209 firms. Given that Crunchbase only includes data for city, state, and country, rather than regional categorization, we constructed regional definitions (e.g., San Francisco Bay Region or Zug-Zurich) for cities with more than two firms to better reflect regional economies. Reviewing the resulting geography of blockchain firms (see Figure 1 and Table 4) suggests that three relations—fintech, labour, and regulation—are good initial frames for probing the locational geography of blockchain firms.

A general question about the blockchain sector is the extent to which firm concentrations mirror existing activity in global financial centres. Figure 1 and Table 4 suggest that some existing financial hubs such as London, New York, and Singapore have emerged as blockchain clusters, while other financial centres such as Shanghai or Tokyo lack a comparable concentration of firms (at least as captured by Crunchbase).

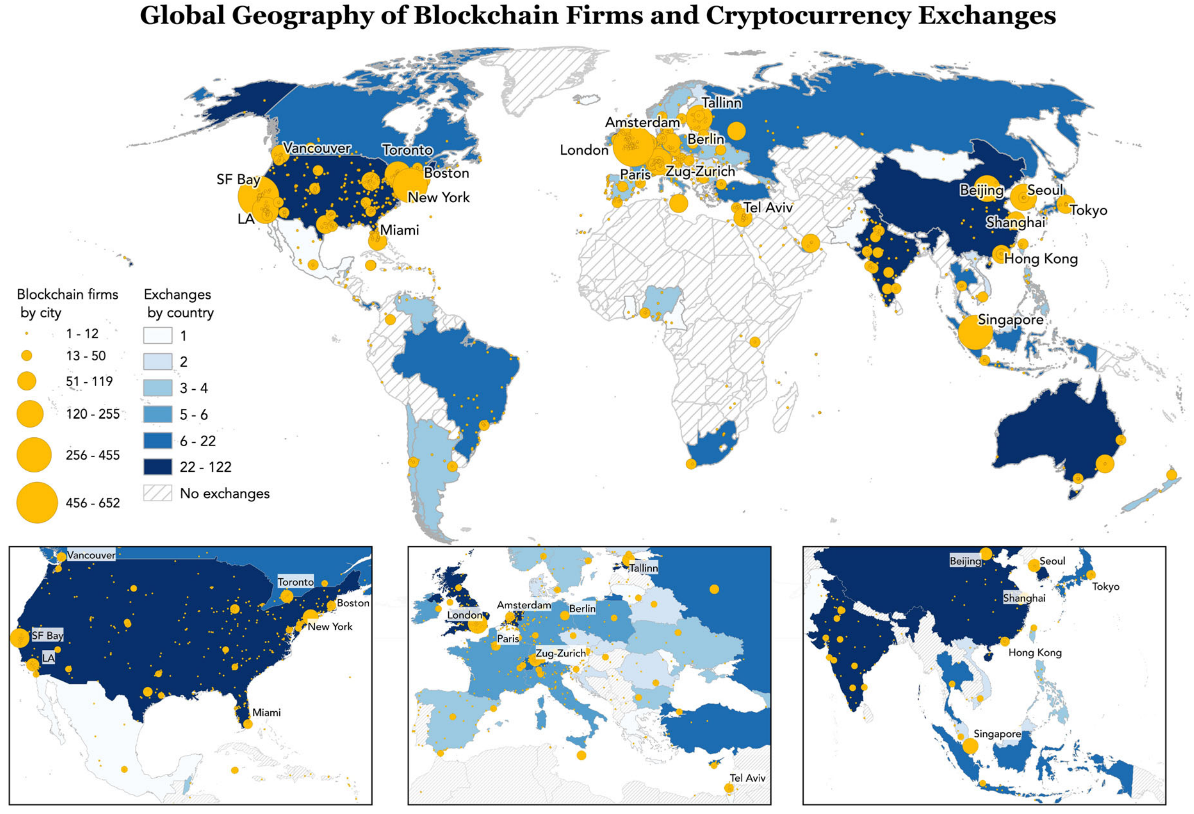


**Figure 1**
Cryptocurrency exchanges from Blockspot.
SOURCE: Authors' curation of Crunchbase data.

**Table 4**
Top 15 global regions for blockchain firms

| City-Region | Firms | Regional Sub-divisions (for cities within commuting distance AND 2+ companies listed) |
|---|---|---|
| London | 653 | — |
| San Francisco Bay Region | 643 | San Francisco (394), Palo Alto (65), San Jose (33), Mountain View (25), Santa Clara (25), San Mateo (23), Sunnyvale (22), Menlo Park (17), Berkeley (11), Redwood City (11), Fremont (7), Oakland (5), Pleasanton (5), Burlingame (3) |
| New York City | 455 | New York (397), Brooklyn (46), Manhattan (12) |
| Singapore | 455 | — |
| Los Angeles Region | 255 | Los Angeles (120), Santa Monica (31), Irvine (22), Newport Beach (12), Beverly Hills (10), West Hollywood (10), Manhattan Beach (9), Venice (9), Pasadena (7), Walnut (6), Marina Del Rey (5), Orange (4), Burbank (4), Costa Mesa, (3), El Segundo (3) |
| Zug-Zurich | 198 | Zug (141), Zurich (57) |
| Toronto | 175 | Toronto (169), Mississauga (6) |
| Tallinn | 156 | — |
| Seoul | 152 | Seoul (94), Yeoksamdong (48), Yeongdeungpo (10) |
| Beijing | 142 | Beijing (126), Haidian (16) |
| Tel Aviv | 119 | Tel Aviv (81), Tel Aviv-yafo (11), Herzliya (10), Ramat Gan (9), Giv'atayim (5), Holon (3) |
| Hong Kong | 114 | Note: Shenzhen (37) and Guangzhou (8) are not included in Hong Kong |
| Tokyo | 114 | Tokyo (108), Roppongi (4), Akasaka (2) |
| Berlin | 108 | — |
| Paris | 100 | Paris (94), Boulogne-Billancourt (3), Neuilly-sur-seine (3) |
| Miami-Fort Lauderdale | 91 | Miami (50), Boca Raton (13), Miami Beach (8), West Palm Beach (8), Fort Lauderdale (4), Palm Beach (4), Coral Gables (2), Coral Springs (2) |
| Vancouver | 85 | Vancouver (77), Surrey (2), Victoria (2) |
| Amsterdam | 75 | Amsterdam (70), Haarlem (3), Hoofddorp (2) |
| Boston | 72 | Boston (51), Cambridge (15), Burlington (2), Wellesley (2), Wakefield (2) |
| Chicago | 71 | — |
| Shanghai | 71 | Shanghai (65), Xuhui (2), Huangpu (4) |
| Other | 5114 | — |

SOURCE: Authors' curation of Crunchbase data.

These differentiated geographies of blockchain firms (relative to existing financial networks) leads us to the framing of fintech. Contextualized within the growing interconnection between financial and technology capital (Knight and Wójcik 2020; Lai and Samers 2020), many of the top regions shown in Table 4—Singapore, London, and Zug-Zurich—consistently appear at the top of global fintech rankings (Ankenbrand et al. 2020) and have collectively seen over $16 billion in venture capital investment between 2012 and 2020 (Hays et al. 2021). In this way, blockchain firms appear to overlap with financial centres specializing in finance-oriented technology provision, suggesting that blockchain groupings may be tied to a combination of infrastructure and clientele clustered in fintech financial centres.

Relatedly, regions with strong technology sectors, particularly related to cybersecurity, have emerged as sites with large concentrations of blockchain firms. This leads us to labour as a frame for understanding the sector. Regions such as the San Francisco Bay, Toronto, and Tel Aviv all have extensive technology infrastructures and associated labour forces. While Tallinn, Estonia's high ranking may seem somewhat surprising, it is partially tied to the country's long-standing work to integrate blockchain within public record-keeping (Leetaru 2017), which has created clusters of developers specialized in cryptography. In short, skilled developers are vital to setting up and managing commercial applications for any digital technology, and blockchain is no different. As a result, blockchain firms appear to originate in (or seek out) regions with labour markets that can meet the demand for skilled developers capable of working with the technical nuances of blockchain.

A third framing is the decisive role of regulation in shaping blockchain firm location. Returning to the high ranking of Tallinn, in 2017 the Estonian state created a set of rules for cryptocurrency companies designed to gain more insight on their activities (Aaspõllu 2021). Given the relative ease with which one could establish a blockchain company in Estonia, these rules became a beacon for entrepreneurs (including those tied to illegal activity), particularly as it provided a toehold in the European Union (Soom 2021). On the other side of the globe, we might ask about the role of regulation in shaping the relative underrepresentation of Chinese technology and financial centres. Beijing, Hong Kong, and Shanghai have extensive financial infrastructure coupled with highly skilled science and technology workforces, but appear lower on the list than these infrastructures might suggest. Aggressive action by Chinese regulators to delist cryptocurrency exchanges and limit connections to formal financial infrastructure have drastically reduced the number of blockchain applications focusing on the exchange of digital assets within China (Zhang 2018).

Shifting from all blockchain firms, we now examine cryptocurrency exchanges. These exchanges focus on developing, trading, and assetizing various cryptocurrencies, as well as "decentralizing finance" or enabling cross-border transactions outside the control of regulatory agencies. To examine these geographies more closely, we scraped two industry aggregator websites—Coinmarket and Blockspot. Both datasets show broadly similar geographies; however, we selected Blockspot as this list was larger, although only available at the country level of specificity (see Table 5).

The geography of cryptocurrency exchanges roughly mirrors the clustering patterns found in blockchain firms (see Figure 1 and Table 4) with many of the top countries highly ranked in both tables. One intriguing difference, however, is that unlike firms, the first and third largest concentrations of exchanges are categorized as "unknown" or "worldwide/decentralized." While the discourse, infrastructure, and labour associated with these exchanges most certainly have material manifestations, the inclusion by Blockspot of these categories highlights how exchanges seek to position themselves. That is to say, certain exchanges view themselves as groupings beyond the control of centralized state regulatory institutions.

Notably, the explicit masking of location through "decentralized/worldwide" or "unknown" aligns with clusters in offshore finance locations. Concentrations in offshore financial hubs such as the Seychelles, Malta, the Netherlands, and the Cayman Islands suggest a connection between cryptocurrency exchanges and financial apparatuses developed in the 20$^{th}$ century to mask flows of global capital (see also the relative concentration of discourses in offshore financial centres shown in Table 2). Interestingly, these clusters of exchanges suggest a grafting of the project of decentralized finance onto existing financial infrastructures firmly embedded within the mainstream of global financial networks. This is not surprising given the observed trend we see of blockchain firms clustering in locations with ties to fintech and available labour pools. Of course, the avoidance of traditional financial networks is easier said than done. Exchanges located in existing financial centres can benefit from regulatory stability and access to global capital as evidenced by the substantial number of exchanges clustered in the US, Singapore, and the UK.

**Table 5**
Cryptocurrency exchanges by country

| Country | Count | Country | Count |
|---|---|---|---|
| Unknown/Not disclosed | 130 | South Korea | 28 |
| United States | 122 | Malta | 27 |
| Worldwide (Decentralized) | 77 | Australia | 26 |
| United Kingdom | 71 | India | 23 |
| Singapore | 59 | Switzerland | 22 |
| Estonia | 44 | Canada | 22 |
| Hong Kong | 43 | Brazil | 22 |
| China | 43 | Japan | 16 |
| Seychelles | 36 | Cayman Islands | 16 |
| Netherlands | 33 | Other | 255 |

SOURCE: Blockspot.

## Geographies of outcomes

Turning to the fourth and final category in our DIGO framework, we focus on arguably the most impactful outcome of blockchain, namely the surge in financial gains and speculative investment associated with the technology. While much of this relates to Bitcoin's meteoric rise in value, a related practice are Initial Coin Offerings (ICOs) used by blockchain-related firms to raise startup capital (Zook and Grote 2020). The phenomenon of ICOs has fostered a boom in digital assets and firms over the past decade and represents an important artifact in blockchain's development.

To measure the outcome of ICOs, we used a similar method as Huang et al. (2020) and reviewed ICO aggregation websites for available data. Ultimately we selected ICOBench data because we judged it to be the most comprehensive available, a judgement shared by Huang et al. (2020). A methodological challenge with this particular dataset is that in early 2021, the ICOBench website was no longer regularly maintained, a not uncommon occurrence with fast evolving digital phenomenon. To address this, we turned to an archived version of the website available at the Internet Archive and were able to gather the data shown in Table 6 from an embedded graphic.

The geography of ICOs mirrors the patterns for blockchain firms and exchanges. However, unlike the relative concentrations of firms and exchanges, the vast majority of ICO offerings (68%) and funds raised (80%) were concentrated within the top 20 countries, perhaps reflecting the higher barriers to holding an ICO versus founding a firm. The US, Singapore, and the UK remain near the top of both "ICO counts" and "Funds raised from ICOs," a trend likely tied to the three relations—fintech, labour, and regulation—discussed in the Groupings section. It also demonstrates that ICOs are largely integrated within traditional circuits of capital, rather than decentralized as some proponents' rhetoric suggests.

That said, there remains a substantial portion of ICOs which reflect offshore financial activity, again mirroring the clusters seen with exchanges. This includes the tax havens of the Cayman and British Virgin Islands (ranked 4$^{th}$ and 3$^{rd}$ respectively in the world in terms of total funds raised) and to a lesser extent Cyprus. Also relevant are countries that act as conduits to off-shore finance, including Switzerland, the Netherlands, the UK, and Singapore (Garcia-Bernardo et al. 2017). This suggests firms holding ICOs seek both favourable regulatory environments and functional ties to exchanges where the coins/tokens from ICOs can be listed for trading (see Table 5).

The regulatory aspect is likely associated with the high ranking for Estonia—see discussion above and Soom (2021)—and perhaps for Russia as well, which did not appear in the top-ranked locations for firms or exchanges. This poses questions about the levels of speculation on ICO offerings, and highlights the openness of certain forms of blockchain-based decentralized finance (including cryptocurrencies) to new types of fraud (Casey et al. 2018). Russia's high ranking for ICOs might also tie to supplies of developer labour (emerging from earlier historical practice), as well as to current high levels of interest in blockchain (Huang et al. 2020).

If applications of blockchain technology are normalized within traditional business pathways as fintech adoption of the technology increases, we may see shifts towards traditional sites of startup and venture financing such as London, New York, or Singapore. However, if ICO-like practices continue to be a key method for financing the blockchain sector, we might expect to see continued financial activity in places such

**Table 6**
ICO offerings by count and funds raised

| Country | ICO Count | Raised Funds (in millions $) | Country | ICO Count | Raised Funds (in millions $) |
|---|---|---|---|---|---|
| United States | 717 | 7,345.9 | France | 79 | 169.2 |
| Singapore | 587 | 2,500.0 | British Virgin islands | 69 | 2,400.0 |
| United Kingdom | 514 | 1,536.1 | United Arab Emirates | 68 | 289.8 |
| Russia | 328 | 667.0 | China | 64 | 283.8 |
| Estonia | 300 | 946.4 | India | 62 | 174.8 |
| Switzerland | 265 | 1,778.5 | South Korea | 58 | 48.5 |
| Hong Kong | 185 | 650.0 | Indonesia | 53 | 49.2 |
| Germany | 122 | 341.7 | Cyprus | 48 | 178.3 |
| Cayman Islands | 120 | 1,340.0 | Japan | 48 | 274.7 |
| Canada | 110 | 490.5 | Other | 1,821 | 5,384.9 |
| Netherlands | 109 | 150.7 | TOTAL | 5,727 | 27,000.0 |

SOURCE: ICOBench.

as the Cayman Islands, British Virgin Islands, or Cyprus.

## Conclusion

Our goal in this article is to document the messiness of digital phenomena and their inseparability from material manifestations. Blockchain is much more than a decentralized digital database. It is the discussion and touting of cryptocurrencies online; the libertarian ideology that undergirds it; the servers and electricity necessary to keep it running; the people, firms, and governments seeking to promote, create, and regulate it; and the new and amended practices enabled through its emergent networks and geographies. The DIGO framework we propose for studying such complexity uses four broad categories—discourses, infrastructures, groupings, and outcomes—that provide insight on how digital phenomena unfold across space and scale. We acknowledge that this framework is partial and subject to critique for the selection of categories and metrics used to demonstrate them in this article. For example, this analysis does not include the geography of the labour that goes into making blockchain. While these kinds of data are almost certainly missing from census sources, they are likely obtainable from measuring profiles on professional networking websites such as LinkedIn or GitHub.

To be sure, the DIGO approach focuses on locational and geographical questions almost exclusively. While we did this intentionally, we acknowledge that it shortchanges other important dimensions such as the social and political complexities that constitute these practices. We do, however, see ways our DIGO approach might complement work attending to the social and political complexities of digital phenomena. For example, Richardson's (2020, 623) work on the food delivery app Deliveroo highlights the importance of focusing on the "complex networks of actors'" involved in a digital phenomenon, be it blockchain or delivery, to better "understand how these networks operate and are articulated." We might incorporate the social arrangements Richardson stresses into our category of infrastructure by focusing on how platform food delivery is supported. Richardson includes the code behind the app, the kitchens in which food is prepared, and the contingent labour conditions of workers who contract to deliver that food. In short, in the case of the digital phenomenon of Deliveroo, infrastructure is much more than the slick facade of the app, also including the flat tires and the interstitial moments where workers negotiate the final metres between a street address and the point of customer pickup (Richardson 2020).

Relatedly, the data-driven specificity of this approach also means that it misses larger structural practices less amenable to direct measurement. A case in point is El Salvador's adoption of Bitcoin as a legal currency in the summer of 2021. Supported by President Bukele through populist discourses to "bank the unbanked" and help with remittances, the adoption of Bitcoin as a legal tender is also a political strategy for dealing with domestic challenges facing Bukele, as well as ongoing negotiations with the IMF (Arnold and Strohecker 2021). Within this broader framework, we can also see some of the ways newly minted Bitcoin millionaires seek to remake El Salvador in their vision. This includes the creation of a "Bitcoin village" test case maintained by outside subsidies (Aleman 2021), as well as the creation of advantageous regulatory spaces (see also Crandall 2019). In short, the DIGO approach must also be complemented with attention to the larger political economy not directly captured in these metrics.

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