Uneven development, crypto-regionalism, and the (un-)tethering of nature in Quebec

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Abstract

Since emerging in 2009, cryptocurrencies, such as bitcoin, have captured the imaginations of many investors and users in accumulating private wealth detached from government control and oversight. This article examines how the rise of bitcoin has particular geographies and trajectories of uneven development across the globe. The generation (or 'mining') of cryptocurrencies is computationally-intensive, requiring computer hardware, cool air and cheap energy. Adopting the case study of Quebec, Canada, we show how these variables interact to produce a relationship between digital currencies, economic imaginaries and space in the regions where cryptomining is clustered. We argue that these new geographies of cryptocurrency 'mining' leave residual marks on the regions where they are located but remain highly mobile – moving from location to location in search of the cheap energy that supports private accumulation. Adopting an illustrative case study of Quebec, Canada, we work to render visible the materiality of cryptocurrencies, such as bitcoin. Far from existing both nowhere and everywhere, the generation of bitcoin is foregrounded in local contexts and regional economic imaginaries with both spatial and social implications for the cities and towns where cryptomining takes place. We conclude with a call for further research into this emergent 'crypto-regionalism' and its consequences.

Keywords: Bitcoin; Uneven development; Political economy; Quebec; Cryptocurrencies; Economic imaginaries; Energy demand

1 Introduction

Bitcoin, the most well-known cryptocurrency, first appeared in the wake of the 2008 Financial Crisis when global banking systems, buoyed by years of easy access to Wall Street speculative capital and the deregulated derivatives markets, plunged into disarray. In the time since, the number of digital currencies has ballooned (there are now over 2000 different currencies in circulation). These cryptocurrencies are observed by proponents as a viable alternative to 'out-of-date' and casually destructive financial institutions, providing flexibility, transparency and speed and at a significant distance from government monopoly and the other transaction "fees" associated with standard currency.

Cryptocurrencies are presented as digital, disruptive, and immaterial. They are seemingly produced, spent and transferred from user to user without ever taking material form. The intangibility of cryptocurrencies creates important questions for regulation and accountancy, but it also obscures the material costs associated with the computing infrastructure that underpins this financial technology (Rella, 2020). In this article, we build on and move beyond recent scholarship that examines the geography of internet infrastructures and their interaction with economic, political, social and historical contexts (Starosielski, 2015), to put cryptocurrencies forward as an example of the materiality and spatiality of contemporary internet infrastructure. Whilst metaphors of the 'cloud' might persist, the internet is stitched together by a series of connected material objects, such as fiberoptic cables and data centers (Zook et al., 2004; Kinsley, 2013). Cryptocurrencies are no different – hitting the ground and finding materiality at the sites where the servers that process them are found (Rella, 2020).

We explore the materiality of bitcoin and other cryptocurrencies by focusing on the process which validates bitcoin transactions and, in doing so, produces new coins. Unlike other forms of electronic payment, which require the verification of a third party, cryptocurrency transactions allow two parties to have a direct transaction without the need of a "trusted third-party" (Nakamoto, 2008). This is because users of the currency network perform the validation of transactions through the computationally intensive process of solving a mathematical problem based upon a cryptographic hash algorithm every 10 min (in bitcoin). Solving a problem creates a new 'block' (a digital record of a series of transactions, about 500 in bitcoin) and, once that block gets enough confirmations, the transactions contained in that block are valid. A 'blockchain' is a sequence of blocks, verified in this manner, that provides an open, distributed public ledger of cryptocurrency transactions. The race to solve the math problem first is known as 'cryptomining'. It is the process through which new "coins" are produced (the miner that successfully solves the problem receives a reward in bitcoin) and value is generated.[1] The process of 'cryptomining' represents the key moment – and site – at which cryptocurrencies become material – with this new tangibility found in the location of the servers that provide proof work and the intense computing power required to complete these tasks.

The whirring of computer servers to solve equations requires energy – both to run the computers themselves and to cool them. Whilst disputed, the energy demand associated with cryptocurrency mining has been estimated as 87.1 Q4 terawatt-hours (TWh) – or allegedly half of the total energy demand of data centers globally (De Vries, 2019). This demand of cryptocurrency mines results in energy becoming a key component of decisions of where mines are sited – with cheap, consistent (and consistently cheap) energy causing cryptocurrency interests to cluster in particular regions.

This article focuses on the geographical clustering of cryptocurrency mines to explore the paradox of how a virtual currency, effectively untethered from governmental monopoly, financial regulation and geopolitical borders, must nonetheless reckon with the hard constraints that emerge from its material relationships with nature in the process of its (re)production. Indeed the high energy demand of cryptocurrency mines is a key component in decision making surrounding mining site selection– with cheap, consistent and plentiful energy causing cryptocurrency interests to cluster in particular regions.

We focus on the case of Quebec, Canada – where a concerted appeal from regional actors to entice digital technology interests (such as server farms) to the region resulted in the unexpected arrival of cryptocurrency companies – and vast energy demands from 2018 onwards. Upon their arrival in the region, cryptominers became new actors in preexisting historico-geographical energy relations of economic imaginaries, uneven development and 'surplus' energy. In exploring the case of Quebec, we highlight the complex nature of the material side of cryptocurrencies. Drawing on secondary materials (newspaper articles, policy documents, etc.), we detail how the energy demands of the internet infrastructure represent a key conduit in its interactions with the region, its community, and respective discourses of economic growth.

We draw on existing geographical ideas related to economic imaginaries and uneven development to explore how cryptocurrencies (and their mining) – considered as new material and spatial actors – interact with broader political and economic geographies. Whilst recent work by others has sought to explore the localized nuances and impacts of cryptocurrency mining (Greenberg & Bugden, 2019; Lally et al., 2019), we take a regional view – exploring how the entrance of cryptocurrencies into a region represents a new stage in regional imaginaries and visions of economic development. We seek to add to the geographical literature on cryptocurrency which up to this point remains scant, particularly in terms of the evolving material relationship between cryptomining, regionalism and nature (Maurer et al., 2013; Howson, 2019; Lally et al., 2019 are notable exceptions).

This article charts how this digital process "mints" a new actor in the regional politics of energy, development and economic imaginaries. In the following section, we map contemporary geographies of cryptocurrencies – discussing the economies of scale and energy demand linked to cryptomining. We then turn to a discussion of what we term as 'crypto-regionalism' in mining and its spatial and social implications. We discuss the economic discourses and imaginaries that are produced to justify investment and mobilize resources for cryptomining and we explore the implications these practices have for the cities and towns where it takes place. We then provide empirical detail to this conceptual work with an illustrative case study of cryptomining in Quebec. We conclude with a way forward for geographers and others to examine new production systems in the contemporary period.

2 Geographies of cryptocurrencies I: Monopolies and energy demand

In 2017, bitcoin's total market value was over $28 billion – more than transnational giants like carmaker Renault (Chapron, 2017).[2] In theory, cryptomining has a low barrier to entry: anyone with a computer, electricity and an internet connection can join the race to solve the next problem. However, due to its profitability, cryptomining has transformed from a hobby pursued by individuals on their personal computers to a capital-intensive industry that is reliant upon specialist equipment (such as multi-graphics card systems) dominated by a narrow set of interests (Vranken, 2017). Increased competition to solve new blocks, has increased capital expenditure and raised barriers for new actors looking to access the market. Others have dropped out. Many more have joined 'pools' where miners act collectively. Far from the original decentralized system intended by bitcoin's developers and advocates (Nakamoto, 2009), the industry of cryptomining has come to hold oligopolistic tendencies (Vranken 2017). The rapid growth of mining operations has allowed the centralization of computing power, 'proof of work' calculations, and the wealth derived from this process. Over the course of 2019, seven mining pools controlled over 75 percent of hashing power on the network.[3] The top four mining pools controlled just shy of 50 percent and six of the top seven pools are based in China.

The economics of mining have not just favored the centralization of pools but also their vertical integration: the leading ASIC hardware manufacturer BT Main also owns the top two mining pools (BTC.com and ANT Pool). The incentive structure favors companies that manufacture their own hardware and rigorously guard their IP, thereby increasing the start-up costs for new arrivals (Ekblaw et al., 2016). The oligopolistic tendencies of the mining network also point to an "invisible politics" (De Filippi and Loveluck, 2016) situated at the intersection of the assumptions embedded in the technology and the increasingly centralized and undemocratic process of mining. For example, mining pools change the way that voting functions in the bitcoin system. Essentially, when software updates or protocol upgrades are proposed, miners cast a "yes" or "no" vote over a polling period (Hsieh et al., 2019). These "votes" are important because they determine which upgrades will appear in new versions of bitcoin and hence affect the direction of travel for the technology. Voting power is linked to how much computing power one contributes to the network, but because the votes are embedded in mined blocks and pool managers are in charge of embedding all the blocks mined by the collective, the pool's choice is effectively decided by managers (Ekblaw et al., 2016).

Far from the popular understanding of an informal, decentralized arrangement of individual miners, the process of Bitcoin mining involves vast effort and expenditure—with millions of machines operating across the globe to create and trade cryptocurrency. The face of bitcoin-mining is not the artisan miner working from home but is, instead, an industrial operation involving hundreds of machines across an organized, regimented warehouse floor. The centralization of mining power has had an important by-product, the geographical clustering of these warehouses in certain regions.

Cryptomining is computationally intensive because the difficulty of the problem to solve is directly proportional to the combined computing power of all users. To maintain the rate of new 'coins' entering the market, Satoshi Nakamoto designed the mining process to become more difficult—and thus more energy-intensive—as the overall computational power available increased. As the value of bitcoin increased, the demand, computational power and volume of mining increased as well—as did the complexity of the equations to be solved. Although bitcoin was originally designed with regular computer users in mind (Volastro, 2014), cryptomining has become more and more specialized with users employing higher-end computing hardware to gain an advantage. Today, most mining for bitcoin poses high entry costs simply to overcome the computational hurdle: it requires specifically tailored computer hardware known as ASICs (Advanced Specific Integrated Circuits) – usually used for gaming. The problem is not just that ASICs are prohibitively expensive (they retail between $1000 and $3000 USD per unit and professional miners typically purchase multiple units) but also that the available inventory struggles to keep up with demand. For example, two premier retailers of mining ASICs (Bitmain and Halong Mining) have both sold out of all their ASIC products and have long waitlists for future batches. Moreover, the lifespan of these units is remarkably short – raising additional questions of electronic waste. Moore's law predicts that microprocessors double in computational power every 18 months, but in the case of

ASIC's demand has driven a brisker pace of every 6 months. This has meant not only that new prohibitively expensive mining "rigs" become obsolete within months but also that increased computational power is required to mine coins.

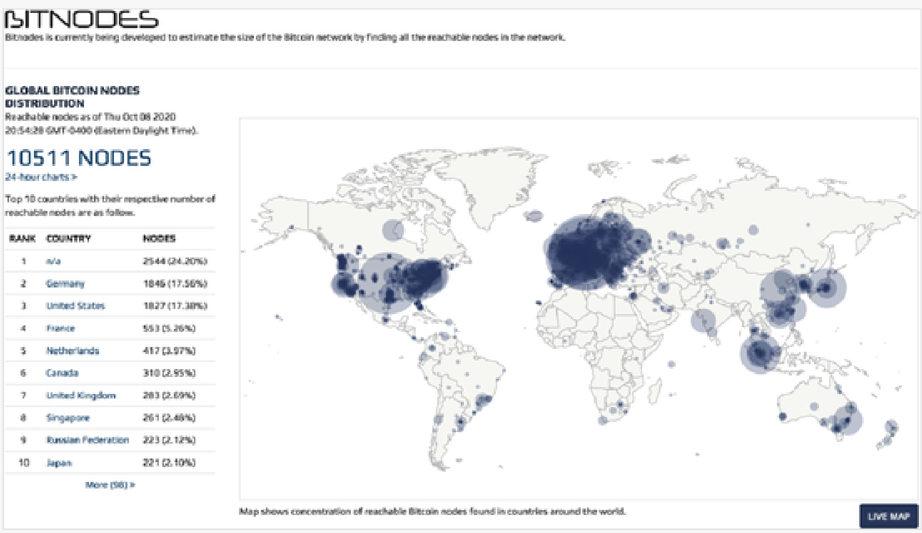
Besides hardware, electricity is the single largest cost for cryptomining and high levels of energy consumption are inherent within the system. Mining requires the combined processing power of countless computers operating 24 h a day. This produces excessive amounts of heat and places strain on local and regional electricity grids. For example, according to one Bitcoin energy consumption index, the mining of Bitcoin consumes approximately 69.37 terawatt-hours (TWh) of energy per year—a figure similar to the consumption rate of a country like Colombia (Digiconomist, 2020). Others have estimated that the energy used to mine a single Bitcoin is equal to the monthly electricity demands of the average British home (Truby, 2018). Finally, the energy use involved in mining one US dollars' worth of cryptocurrencies (as a whole sector) has been estimated to be more than that used to mine the same value of platinum, copper or gold (Krause and Tolaymat, 2018).

What estimates are available paint a dramatic picture (Li et al., 2018)[4] and the energy consumption of these emergent technologies poses the question of where this energy comes from and what its potential role may be in the emission of greenhouse gasses. For example, Chinese miners represent 70% of global mining capacity and even though many are located in areas with abundant hydroelectric power, a significant proportion of this activity is completed using energy generated by coal (Bram, 2019).[5] The mining of Monero (another cryptocurrency) is estimated to have emitted up to 19.42 thousand tons of carbon into the atmosphere between April and December 2018—equivalent to the emissions associated with 4034 passenger vehicles driven for one year (Li et al. 2019). Given the energy demands of cryptomining, some have estimated that Bitcoin alone could push global warming over two degrees Celsius in a few decades (Mora et al., 2018). Concerns over the environmental impact of cryptocurrency have only grown since the technology's emergence a decade ago (Giungato et al., 2017; Vranken, 2017; Hern, 2018; Li et al., 2018).

Despite the scale of its energy use, there are few reliable estimates of the overall size and distribution of the Bitcoin mining network. It is nearly impossible to create a comprehensive map of where miners and mines are located in part because an unknown number of them operate over anonymous, hidden networks (such as Tor) which make a user's location more difficult to identify. Anonymity is also connected with maintaining a market advantage or evading official scrutiny: a number of miners use different location-masking services, such as virtual private networks (VPNs), to conceal where they are based.

One of the few real-time maps of the Bitcoin Network is available from Bitnodes (Fig. 1) is also incomplete because it does not include network nodes that are running older versions of the Bitcoin protocol (Bitnodes, 2019). In May 2019, prominent Bitcoin Core developer, Luke Dashjr, explained that many estimates, including those from BitNodes, had vastly underreported mining activity. Dashjr explained that many estimates had only captured "listening" (i.e. publicly listed) Bitcoin nodes,[6] but that non-listening nodes were also active in mining operations (Canelis, 2019). Whereas BitNodes reported just under 10,000 active Bitcoin nodes, Dashjr revealed that over 100,000 nodes were in operation in early May 2019 (Canelis, 2019).[7]

Fig. 1



Map of Bitcoin Nodes. Source: https://bitnodes.earn.com/ (8 October 2020).

Whilst cryptomining activities are global in scale, mining companies increasingly cluster their facilities in multiple sites where 'cheap' energy is abundant (Hileman and Rauchs, 2017). The energy demands of cryptocurrencies are often concentrated in regions like Iceland and Northern Scandinavia (Norway and Sweden), George and Armenia and, Sichuan and Yunnan in China. Of these, Sichuan is perhaps the most important – recently home to as much as 50% of global cryptomining activities (Bendiksen and Gibbons, 2019). These regions can be broadly divided into regions largely powered by hydropower and everything else (a mix of fossil, nuclear, solar and wind generation sources) (Bendiksen and Gibbons, 2019) (see Fig. 2).

Fig. 2

Regional Map of Bitcoin Nodes. Source: https://bitnodes.earn.com/ (8 October 2020).

Due to the desire for cheap, consistent energy, cryptocurrency interests are often drawn to regions where there is a surplus of renewable energies, such as hydropower and geothermal. The abundance, availability and cheapness of geothermal energy have resulted in the continued growth of cryptomining activities in Iceland (Baraniuk, 2018). Regions served by hydropower such as Canada, the Columbia River basin of the United States and pockets of Continental and Northern Europe are particularly coveted. A decision to locate in areas served by seemingly abundant energy resources can often allow cryptomining companies to reduce the costs associated with production dramatically. For example, HydroMiner, a mining company based in Austria, announced that the energy provided by nearby hydroelectric projects is 85% cheaper than the average costs in Europe (Ingram, 2018). Although the adoption of green and renewable energy might represent an important step in mitigating the carbon-intensive footprint mining itself generates, it also poses new questions connected with the social sustainability, regulatory frameworks and political pressures associated with the arrival of these operations in regions with renewable energy.

3 Geographies of cryptocurrencies II: Digital Space and Economic Imaginaries

Whilst recent scholarship on cryptocurrency mining has adopted a localized lens of analysis – exploring the place-based externalities of this digital prospecting (Greenberg and Bugden, 2019; Lally et al, 2020), we seek to illuminate the regional dynamics of this digital technology and practice. For all its disciplinary twists and turns, many continue to view the region as a dynamic spatial and scalar concept to understand pressing contemporary issues (Thrift 1999; Peck 2001; Gibson 2001). This has been the case for those steeped in debates around the continued relevance of the region (Thrift 2001; Smith 2001), its retreat (Harvey 2004) and, partial 'renaissance' (Jones and MacLeod 1999; MacLeod and Jones 2001). Many of these debates are far from new, rooted as they are in the global restructuring of labor and manufacturing associated with the shift from Fordist to post-Fordist flexible accumulation in the late 1980s and 1990s (Castree 2001; Agnew 1987; Massey 1984). For many, these developments signaled the death knell of the region, which had seemingly become "obsolete as a production unit" (Webber 1986, 202; as quoted in Smith 1988, 142). In the context of growing economic globalization, epitomized by the signing of the North American Free Trade Agreement (NAFTA) and the erection of special economic zones, such sentiments seemed wholly sensible. A number of economic geographers argued that these trends illustrated the typical pattern of capital navigating crisis by seeking out new spatial and social 'fixes' in the form of cheap labor, access to natural resources and lax environmental regulation (Harvey 2005; Scott 2007). At the same time though, new manufacturing regions in Brazil, Russia, India and China (BRIC), as well as in the Asian 'Tigers' emerged on the global stage and rapidly displaced Ohio's steel mills, Detroit's auto towns, and Liverpool's textile mills. This was indeed a period best captured in Neil Smith's epigram: '*The region is dead! Long live the region*!' (1988). Global investment flows arriving in one region represented their departure from another.

National boundaries grew increasingly porous to economic intercourse and specific segments of industrial production shifted to an emerging group of industrializing countries thereby challenging traditional assumptions about the international division of labor. This transformation in the geography of capitalism (Harris, 1987; Soja, 1987) affected once thriving areas of economic activity and growth in the United States, where pockets of urban blight, crime, unemployment and memories of a forgotten time proliferated. The literature is steeped in vivid descriptions of industrial spaces left behind and the 'rust belt' relicts of a post-war boom era. Yet it also charts the emergence of 'new industrial spaces' and 'new localisms' (Smith 1988), and local 'ensembles of production' (Scott and Storper, 1987), as well as the constructive 'enframing' of new regional hubs based on creativity, knowledge and technology (Christophers 2007; Storper and Scott 2009; Harvey et al. 2007).

The contemporary 'geography of capitalism' provides a unique vantage point from which to explore the region's role in the contemporary geographies of digital infrastructure, such as data centers and cryptominers. In exploring how the energy demands of cryptomining interact with regional political economies, this article follows scholarship exploring the ways in which the infrastructure that underpins the internet takes material form. This infrastructure – dubbed 'cloudfrastructure' by Furlong (2020) – includes the data centers and fiberoptic cables that store, collect and transport our data across global networks. Whilst the internet is often described as spaceless, placeless and in 'the cloud', it is at these sites that it takes material form. This materiality is understood as both in the infrastructure's physical properties and its spatial relations to other systems (be they social, political, economic, atmospheric, or thermodynamic) (Starosielski, 2015). Whilst this infrastructure may be designed to blend in, the geographies of the 'cloud' are unevenly concentrated– they are localized in environments conducive to the whirring of servers (Furlong, 2020). Much like fiberoptic cables run parallel to historic trainlines (Burrington, 2015), Data centers are drawn to the provision of cheap energy, infrastructural connectivity and the assumption of security of the data stored on their servers. As a result, these infrastructures are located in particular spaces and have particular place-based externalities that interact with localized contexts of energy use, power dynamics and historical patterns of (often uneven) economic development (Pickren, 2018; Lally et al, 2019; Vonderau, 2019). For Pickren (2018: 226), computing infrastructure represents a "palimpsest, a layering of different historico-geographical moments that is unfolding in contingent ways." When this is taken into account, cloudfrastructure should be understood as a new industrial actor – similar to more-traditional heavy manufacturing industries, such as the automotive sector (Carruth, 2014). Geographical scholarship must explore this cloudfrastructure to understand how it interacts with historic patterns of uneven development – as well as representing the manifestation of new spatialities and 'regionalisms'.

Digital infrastructure is drawn to areas for a number of reasons – including cheap energy, accommodating business environments and the ability to hide in plain sight. However, they also follow historic patterns of economic boom and bust. Just as fiberoptic cables run parallel to historic train lines (Burrington, 2015), this infrastructure often follows historical patterns of economic development. Data centers are often drawn to post-industrial regions due to the presence of abundant yet surplus energy, a legacy of deindustrialization (Pickren, 2018). For example, data centers have previously been drawn to Chicago, Illinois – a city that has a history that makes it a prime location for data infrastructure – evident in the presence of fixed capital, connectivity, energy infrastructure and vacant lots (Pickren, 2016). In Chicago, cloudfrastructure has taken over old printers and bakeries (Pickren, 2017). In Lenoir, South Carolina, Google's servers have taken over a former furniture factory. Elsewhere, they can be found in abandoned military air bases (Iceland) and former nuclear bunkers (UK).

The occupation of relics of post-industrialization alludes to a wider economic imaginary associated with the location of digital infrastructure within once industrially dominant regions now on the peripheries of economic flows. Regions have often turned to digital infrastructure as a means to provide themselves with a new form of economic branding. As

Nathan et al (2019) have explored in the case of East London, this 'place branding' represents a form of 'economic imaginary', where the arrival of digital interests go hand-in-hand with the economic rejuvenation of a region. Within these visions, cloudfrastructure becomes 'imagined' as a driver of change – in social, economic and material terms (Pickren, 2016). Thus the rise of networked technology and the economies of production, communication and consumption it has engendered provide the backdrop for regional imaginaries that aspire to replicate the sort of high-tech production centers that dominate Silicon Valley (e.g., Googleplex in Mountain View, and Facebook in Menlo Park, California). The latter are sites of technological and knowledge-based creative industries where new disruptive technologies create spaces for 'new localisms' to develop (Scott and Storper, 1987). However, they also lead to the development of 'new regionalisms', or visions of regional economic rejuvenation that promise to relocate a particular region from the economic periphery to center stage.

Across the globe, local authorities in regions that are home to both cheap, surplus energy and cool climates are actively-seeking to entice digital technology interests, such as cryptocurrencies, to secure increased tax revenues and revitalize post-industrial landscapes (Bennetton et al., 2019). The entrance of new digital-industrial infrastructure into a region can become a key part of state-making and identity-building agendas. On the Reykjanes Peninsula (Iceland), the siting of a data center at a former military base was deemed as transformative for the region, representing the arrival of 21st-century economic relations and promising an new era of growth after the 2008 financial crash (Johnson, 2019). Vonderau (2019), exploring the case of Facebook's data center in Luleå (Sweden) describes a process of 'clouding', in which the digital cloud functions to create new, dynamic scales and geographies, based within wider political and/or corporate programs. Luleå's data centers – located in northern Sweden – became a symbol for the technological, innovative future of the city and wider region – with the international brand of Facebook adopted by local government actors to rebrand and redefine the city itself, seeking to reverse the city's position on the periphery of Sweden's economy (Vonderau, 2019).

These economic imaginaries play a constitutive role in identifying and fixing economic relations, privileging certain visions as legitimate and certain sectors as worthy of intervention (Jessop, 2013). According to Christophers (2009, 44) and others (Jessop 2002; Mitchell 2002), these imaginaries, in as much as they are also 'mapping' exercises identifying and constituting 'potential' regional sectors, also produce novel governance arrangements that make their targets "'available to power' through a process of enframing: rendering them separable, visible, discrete, and calculable." In a similar vein, Sum and Jessop (2013, 166) note that economic imaginaries create, privilege and stabilize "selectively defined" segments of the economy through narrative constructions that set them in opposition with the "actually existing economy." The former's coherent, calculable and quantifiable subset of activities are strategically framed against the chaos of the latter (which is often represented as a smorgasbord of freewheeling economic activity) and serves to limit the traction that "contrary or agnostic imaginaries" might gain (Jessop, 2013, 167).

Like other imaginaries, visions of a regional digital future, anchored in discourses of regional and local economic development, work to create a novel spatial, scalar and temporal alignment of capital (Mitchell 2002). Indeed according to Mitchell (2002: 281) such imaginaries lay the "metrological" groundwork (i.e., the instruments, calculations, and measurements) that allow markets to be *made* real. In this sense, the discourses that surround and frame cryptomining are an example of the type of cultural, ideational "work" routinely performed in opening new spaces up for capital accumulation (Harvey 2005). That work creates the space for the clustering of cloudfrastructures in regions to consolidate and flourish, to the detriment of those living in them. On the Reykjanes Peninsula, the population of the region enjoyed limited interaction with the new infrastructure. Just as with previous military infrastructure, the data center symbolizes and consolidates the peripheral role of the peninsula in the global economy (Johnson, 2019). The community living near data centers function as 'go-betweens', intermediary points in the collection, storage, and delivery of data (Johnson, 2019). In Quincy, Washington, the local community has challenged the presence of a Microsoft Data Center based on air pollution complaints (on-site generators consume half the town's total energy consumption) (Glanz, 2020). In many regions, despite the dream of a new digital future, local communities that have welcomed data centers remain on the economic periphery (Johnson, 2019; Vonderau, 2019) and the economic imaginaries associated with this infrastructure remain an illusion.

Cryptocurrencies are no different and it is important to render visible both the material geographies and economic imaginaries of this digital technology – as well as its material demands. These geographies emerge through the energy used and demanded by the servers that process cryptocurrencies. This is what we turn to in the next section – where we advance the illustrative case study of Quebec.

4 Quebec, Surplus Energy and Cryptomining

In 2016, the government of Quebec, in partnership with provincial energy utility Hydro-Quebec, announced a series of policy packages designed to attract the server farms and data centers of Silicon Valley to the area (Miles, 2018; Patriquin, 2019). The plans promised cheap hydroelectric energy (reportedly as low as 4 cents per kWh), 25 million square feet of operations space and additional technological support (Patriquin, 2019). The proposals successfully attracted interest from the technology sector, but they also generated an influx of cryptocurrency miners armed with a glut of proposals for locating their operations—and the energy infrastructures required for such activities—in the region. Between the autumn of 2017 and May 2018, Hydro-Quebec received three-hundred proposals from cryptomining and blockchain companies for up to 18,000 megawatts of electricity (Patriquin, 2019). Demand quickly overwhelmed projected capacity and the regulator called a moratorium on such proposals in May 2018. Taken together, these new cryptocurrency mining operations requested 18,000 MW of energy ─ 220 times the amount used by the 46 data centers in the province (Nadeau & Barlow, 2019).

Hydropower represents more than the mere provision of electricity in Quebec. Since the 'Quiet Revolution' in the 1960′s, the expansion of hydroelectric infrastructure has taken on an important economic and social symbolism – representing the development of Quebecois autonomy from the rule of 'English' Canada. As a result, hydropower came to represent a historic economic imaginary - with successive provincial premiers of Quebec seeing hydroelectricity as a route to economic development through enticing big industry into the region and providing jobs (Froschauer, 1999). From the 1960s to the 1990s, the was an expansive process of hydropower development in Quebec. Between 1963 and 1978, Hydro-Quebec expanded its capacity fourfold through the development of new infrastructure and the purchasing of pre-existing facilities (Froschauer, 1999). The construction of hydropower represented the development of new political geographies which harnessed hydrological resources within new visions of economic growth, industrialization, and autonomy.

This occurred through a reorganization of the region's spatial division of labor: the lands north of Quebec were flooded and harnessed to provide energy to the south where industrial demand was clustered (Desbiens, 2004). The hydropower sector also carries neo-colonial symbolism in Quebec. Schemes like the James Bay projects (built in the 1970s) flooded the land and dislocated First Nation communities as well as the geographical imaginaries and cultural experience they were linked to (Desbiens, 2004). The James Bay project, in particular, came to represent a new production of space – in which extensive environmental damage and the loss of First Nations cultural sites and livelihoods was justified by an ideology of economic development and surplus energy (Desbiens, 2014). The project also illustrated how power flowed through the province –dominant ideologies and authority coursed north, while the energy produced by James Bay swept south to the sites of industry (Desbiens, 2014). Provincial hydropower utilities became "powerful agents" for regional autonomy and industrial development in Canada (Froschauer, 1999: 12).

Hydropower was deemed as the cornerstone of a new, Quebecois economy – that was designed to increase the provinces' economic and political autonomy. Yet, the expansion of hydropower during this process involved the production of surplus energy – damming rivers to increase the availability of energy for industry or exporting what remained south to the United States of America. The presence of surplus hydroelectricity in Quebec was produced by the economic imaginary that pursued the expansion of hydropower infrastructure as a core element of industrialization and growth agendas (Froschauer, 1999). The energy surplus was produced by the overbuilding of hydroelectric schemes, with many projects built before they were needed by the grid. For example, the increased energy generative capacity provided by the development of the James Bay projects was redundant by the mid-1980s, rendered surplus by deindustrialization (Froschauer, 1999). In the summer months in the 1980 s, the total capacity of James Bay (10,287 MW) was well above Quebec's requirements (Froschauer, 1999).

The presence of this 'surplus' energy was extended by deindustrialization in the region from the 1980s onwards. The past decade has witnessed Hydro-Quebec in transition, seeking to develop new markets and services. Data centers were central to the utility's vision of increasing local energy demands as a means to increase the sale of surplus energy resources (Nadeau and Barlow, 2019). To develop new internal markets of energy demand, Hydro Quebec sought to entice technology firms to the region – promising cheap energy to power servers. As of 2019, there were 46 data centers sited in the province – including those owned by tech giants, Amazon Web Services, Alphabet and Microsoft.

In several parts of Quebec, the arrival and presence of cryptocurrency mines became entwined with economic imaginaries of rejuvenation – with one local mayor claiming these new interests would reduce the region's dependency on heavy industry (Nadeau & Barlow, 2019). Many cities in Quebec own and manage their electricity network and the arrival of cryptomining presents a unique solution to an otherwise intractable problem: these companies want to buy surplus energy that would otherwise remain unused. Indeed, the *trope of surplus* (electricity, labor power, industrial space and post-industrial infrastructure, etc.) frames the narrative around which the relationship between cryptomining farms and regional hydroelectricity providers solidifies. In neighboring jurisdictions, local officials like Steven O' Shaughnessy (the Town Supervisor of Massena in New York state, USA) discussed their community's relationship with mining interests in terms of a mutually beneficial arrangement:

> They need lots of power, and they need to be able to count on it... and we can provide that... We have employable trainable people here that had worked at some of the smelters and at GM's foundry. And we have the capacity to bring the power in, so it's perfect (Sommerstein, 2018)

Bahador Zabihayan, the Director of Public and Government Relations at Bitfarms, echoes Shaughnessy's argument: "Bitfarms can help Hydro-Quebec to reduce the surplus, which will benefit all Quebecers. In Sherbrooke, for example, we only consume electricity surplus. It will bring around $40 million dollars to Hydro-Sherbrooke every year" (Clay, 2018). Indeed, the 2018 deal the firm signed with the City of Sherbrooke provides Bitfarms with 98 megawatts of electricity (previously deemed surplus by the energy supplier) but stipulates that in times of peak demand, Bitfarms must reduce its energy consumption (CBC News, 2018).

Nonetheless, the energy demands of cryptomining are not tension free, local communities and regulators increasingly view the long-term impact of mining with apprehension. In 2018, the City Council of Magog (Quebec) voiced concerns that the electricity-consumption of Bitfarms and BitLinksys placed too much pressure on the energy grid and called for a moratorium on the entry of new mining operations in the area (Rudin, 2018). More generally, the prospect of new cryptomining operations relocating to the Quebec area raised concerns about its ecological and cultural impact but also about whether the region's energy supply could support this new demand, especially during winter (Miles, 2018; Stanley, 2018). In response, Hydro-Quebec quickly recalibrated by introducing a tariff rate for cryptomining that was 3.96 cents per kilowatt-hour above what it initially offered (Miles, 2018; Stanley, 2018). Hydro-Quebec's policy change was driven by the desire to avoid being caught up in what increasingly resembled the boom and bust cycles of a traditional gold rush. Jonathan Côté, a spokesperson for Hydro-Quebec, explained the situation in similar terms:

> Though we have certain energy surpluses, we simply can't connect every would-be Bitcoin farmer who knocks on our door... If we were sure these demands were going to be here in five or 10 years, we might be able to up capacity. But that certainly isn't the case (Patriquin, 2019)

Quebec's overtures to Silicon Valley where part of a broader effort to prompt the development of a regional knowledge economy that could generate long-term economic growth (see: Moser, Fauveaud and Cutts, 2019). Yet the cryptomining interests that have settled in the region have, rather than seeking new, creative space, sought out the relics of past industries to house operations. For example, in Quebec, Bitfarms has installed its 16,500 individual computing systems in a former metal plant in Magog, a one-time Tupperware factory in Cowansville, a vacant carpet factory in Farnham and a former storage facility for cocoa in St-Hyacinthe (Valiante, 2019). In Sherbrooke, it is currently working to convert a vacant hockey stick factory into another mining operation (Valiante, 2019). These locations, all located within a 90 min drive from one another, cumulatively mined 13,638 units of cryptocurrency (generating a revenue of $33.8 million USD) in 2018 (Business Wire, 2018).

Cryptocurrency operations have been understood to cluster in post-industrial regions with unoccupied industrial and commercial facilities (Roberts, 2018). These regions are rich in the sort of surpluses (abandoned industrial infrastructures, skilled pools of reserve labor, dreams of miraculous economic renewal) left in the wake of corporate and industrial flight. They have ready access to the industrial energy connections required to mine cryptocurrencies and have local authorities long accustomed to thinking of economic development and regeneration through the prism of industrial and corporate partnerships. Steve Lussier, the Mayor of Sherbrooke, illustrates just how supportive municipal governments can be of the cryptomining industry:

> "The entire population will benefit from this innovative, growing tech company because of its positive economic impact on Sherbrooke. I would like to thank the company's management team for their confidence and assure them of our collaboration in their success" (Clay, 2018)

Cryptomining activities are often framed as a mutually beneficial enterprise that will offset the economic landslide generated by the retreat of manufacturing and industrial jobs and facilities in these communities (Sommerstein, 2018). The support of local community members and local politicians often hinges on the real or imagined prospect of job growth and local reinvestment. Vicki-May Hamm, the Mayor of Magog (Quebec) has promised to reinvest the local profits made from Bitfarms and BitLinksys into regional infrastructure (Patriquin, 2019). Similarly, in May 2018, José Fortin, the director of a local entrepreneurial group, voiced his strong support for Bitfarms because it "answers several of the needs of [a] changing Sherbrooke economy" (Patriquin, 2019). In Baie-Comeau, Mayor Yves Montigny argued that cryptomining provided the most-effective route for the city away from dependency on heavy industry (Nadeau and Barlow, 2019: 159).

Yet in other communities in Quebec, the number of cryptomining operations and their energy demands have generated alarm. For example, in March 2018, the regional government of Brome-Missisquoi (Quebec) was sufficiently concerned about the socioeconomic and environmental impact of cryptomining in the area that it announced a moratorium on new partnership (Clay, 2018). As Robert Desmarais, Director-General of the Brome-Missisquoi MRC Council put it:

> "These centers occupy quite large spaces, create few jobs, have an extremely high demand for electricity and cause noise pollution because it takes extremely strong fans to remove the heat that is generated by the computers in the warehouses." (Clay, 2018)

As we have already noted, despite claims of economic regeneration and job creation, cryptomining (unlike the local relationships forged by industrial capitalism) is a largely extractive process. It does not generate scores of new jobs because it does not require them. Much of the core activity of this business is automated and most of the jobs it generates are not particularly specialized. In 2018, Bahador Zabihiyan (International Public Relations Director at Bitfarms) announced that the arrival of the company in Sherbrooke would result in the creation of:

> ...nearly 200 permanent, full-time, well-paying jobs will be created, including positions such as engineers, technicians, electricians, systems administrators, security managers and security staff. Approximately 50 of these employees will be hired immediately to upgrade and develop the different sites where Bitfarms plans to do business. (Globe Newswire, 2018)

As of July 2019, Bitfarms employs 65 people across its five Quebec sites (Bloomberg, 2019). Similarly, Coinmint pledged to invest close to $700 million in Massena by creating 150 jobs over 2018 and 2019 (Rooney, 2018). Yet Coinmint operations in Plattsburgh have hired only six people - "a security guard... and a guy who comes when something breaks" according to Colin Read, the Mayor of Plattsburgh (Holder, 2018). Read compared Coinmint to other local businesses, as well as the sort of industrial players cryptomining operations often purport to rival in terms of benefits for local communities: "The restaurant across the street employs more people than the Bitcoin mines... They're not generating the 480 workers an industrial plant might employ using even less power, so that's difficult for us" (Oberhaus, 2018). Finally, a 2018 report by KPMG commissioned by Hydro-Quebec found that cryptocurrency operations in the region generate an average of 1.2 jobs per megawatt of electricity used. This figure should be understood in light of an average 25 jobs per megawatt for data centers and 27 for physical, extractive mining operations (KPMG, 2018)

There is a fundamental disconnect between the discourses that surround cryptocurrencies—which emphasize the disruptive potential of its frictionless highways of transaction—and the deep infrastructural "work" taking place in the background which binds these global data flows to local materiality. As our brief, illustrative survey of these local entanglements suggests, the situation that characterizes the interactions between cryptominers, local communities, and energy grids is fraught with tension and anxiety. The arrival of cryptocurrency miners into places like Quebec, Canada has been accompanied by discourses of job-creation and economic rejuvenation, promises of breathing 'life' back into the region. However, the type of server farms that underpin global cryptomining do not require large workforces or previous industries. They run near-independently, hiring freelance workers to fix machines or install air conditioning units when more cool air is required. Indeed, the average cryptomining firm employs 20 people (Hileman and Rauchs, 2017) − far from the 150 promised to residents of Massena, New York. Mutually-beneficial exchanges of the kind outlined by Sherbrooke Mayor, Steve Lussier in 2018 are difficult to detect.

Finally, and perhaps more importantly, promises of job creation and economic development masks the *impermanent* and *transient* nature of cryptomining. Miners do not necessarily create jobs for local residents or invest in the city itself. Instead, they can arrive and depart in a matter of days—siphoning off extensive amounts of energy in the process. The high electricity prices they leave in their wake underscores the point that while the cost (in terms of high energy demand and more expensive utility bills) is universally distributed, the wealth generated by cryptocurrency is monopolized by private interests. In this sense, crypto currency represents yet another realm where energy is extracted from landscapes and communities, with limited sharing of benefits reaped or regulation of the costs locally incurred. As Philippe Couillard, Quebec's Premier, put it in 2018:

> If you want to come [and] settle here, plug in your servers and do bitcoin mining, we're not really interested...[T]here needs to be added value for our society; just having servers to do transaction mining and acquire new bitcoins, I don't see the added value. (Wilmoth, 2018)

However, further work is needed to explore the tensions that exist within the crypto-regionalism evident in the Quebec case studied. Whilst the provincial government of Quebec was a central actor in the enticing of cryptominers to the region, its economic imaginaries of a high-tech regional future was not shared by all. Local communities and governments across the region opposed the arrival of these actors. From the 2018 moratorium called in Brome-Missisquoi to Couillard's public concerns about the value that crypto-miners add to the regional economy, the location of new digital infrastructure in the province has exposed different visions of the regional economy. Far from representing the conflict between progression and obduracy in regional imaginaries (Hodson, 2008), this tension affirms how, in the era of the smart city and digital imaginaries, regional economic development continues to mean different things to different communities − and one high-tech economic actors to one policymaker may well represent an unwanted energy-gluttonous neighbor to a local resident. If cryptomining represents a new frontier in contemporary processes of mineral extractivism (Zimmer, 2017), the social and economic questions that this private accumulation of wealth (thus far side stepped) are all the more immanent. As Couillard intimates, what is the cumulative impact of these changes for individuals and communities across the globe who - like the population of Sherbrooke - may never see the benefits that their cheap energy has given to private interests?

5 Conclusion: on crypto-regionalism

This article explores the contradictions between cryptocurrencies as a global financial tool, seemingly existing within the digital sphere and the material realities of uneven development at its local level 'mining' sites. In this final section, we reflect on our overarching aims − set out at the beginning of this article, namely to chart how this digital process comes to represent a new actor in a regional politics of energy, development and economic imagination. Whilst the 'virtual' character of cryptocurrencies persists in popular and policy discourse, it remains geographically contingent on regions that offer permissive regulation and cheap energy. In previous sections, we detailed how the entrance of cryptomining activities into a region represents more than the arrival of a new financial actor. Instead, it patently signifies the social and economic production of a new form of space, interacting with the materiality of the region's energy grids and local populations.

We understand this as representative of a 'crypto-region' − or the production of a regional, politico-economic imaginary in which digital/financial technology interests enter a region to the fanfare of renewed investment and job-creation (Christophers 2007; Storper and Scott 2009). Broadly, cryptomining in Quebec illuminates the intricate relationship between energy deemed 'surplus', community tensions and challenges to existing energy regulation regimes. Such tensions are not exclusive to Quebec, with other researchers exploring similar episodes in the Columbia River basin in the Pacific Northwest of the United States (Greenberg and Bugden, 2019; Lally, Kay and Thatcher, 2019). Lally et al (2019) label the process of cryptomining "parasitic" and Greenberg and Bugden (2019) compare the process to that of 'fracking' (or hydraulic fracturing for natural gas). We believe that the use of the term 'mining' to describe the generation and monitoring of cryptocurrencies is particularly pertinent— demonstrating the deep connection between the extraction of the abstract asset using regional material resources (in terms of energy) to provide financial benefits for others.

Following work on the geographies of 'cloudfrastructure' (Pickren, 2018; Furlong, 2020), we understand crypto-regions, much like other spatial imaginaries, as actively produced even if the product strays far from the economic possibilities envisioned and promoted by its architects. In this sense, the crypto-region is co-constructed through powerful discourses of economic, social and technological investment and growth. Whilst popular discourse surrounding them presents them as ethereal and existing exclusively in the virtual realm, the decentralized computing of cryptocurrencies has local and material consequences. The energy use that underpins them is not placeless. The material impacts of cryptocurrencies are highly-centralized in local regions and host communities, becoming intertwined with wider questions of infrastructure and political economy (Howson, 2019; Lally et al., 2019). 'Miners' cluster in areas where cost-savings can be made. As Jingyang Zhang, one of the first bitcoin-investors in China, told Wired in 2019, cryptomining has, in the past, become clustered in areas of China where miners have "easy access to machines, you have cheap labor to maintain them and build the mining facilities, and crucially you have excess power here, which needs to be sold off for something, so it might as well be used for mining" (Bram, 2019). Yet, this does not only represent the savviness of these actors but also the powerful role that emergent digital technology interests can play in the economic ''rejuvenation' of a region.

The presence of cheap, surplus and renewable energy underpins the operations of cryptomining across the globe – from the geothermal energy of Iceland to the hydroelectricity of Quebec. The economies of scale sought by cryptominers are often in the form of energy bills. The price volatility of bitcoin can, at times, challenge the profitability of its mining. In 2019, JPMorgan reported that the average global cash cost to mine one bitcoin stood at around US$4060 (Lam, 2019). As a result, if the price of bitcoin plummets below such a figure, mining activities across the globe may be challenged. In response to such precarity of profit/loss, mining interests seek efficiency savings in a number of facets of their operations – including the purchasing of ASICs (increasing computational power) and the sourcing of cheap, abundant energy. However, they are not spatially fixed and, in the face of increasing energy tariffs of declining value of cryptocurrencies, may swiftly leave on crypto-region for another.

Many of these crypto-regions retain the material infrastructures and collective memories of an economic past. The comparative advantages they provide over other areas are not just surplus electricity, generated by renewable and cheap energy, but also the blight of deindustrialization which in the context of years of capital retreat and global restructuring, has become functional. Crypto-regionalism, therefore, involves a 21st century sleight of hand. It relies on the expectations and imaginaries of one-time industry towns, which understand their relationship with capital though their decades long experience with industrial capitalism, and thereby miss the point that cryptocurrency represents a new configuration of older, more ruthless patterns of resource extraction reminiscent of the robber-baron era. Unlike the industrial capitalism of the post-war period which built manufacturing and social infrastructure in tandem with the state, propped up regional economies and attracted workers from across the US to industry boomtowns (Zuboff 2019), cryptomining does not require on-site workers and builds relatively little new infrastructure. Indeed, a core attraction of working in the 'rust-belt' is that it already has existing factory infrastructure (heavy electrical grids, shelled out warehouses) that can be retrofitted for cryptomining purposes. It also does not generate the local supply networks, service industries, housing, and broader regional infrastructure that one typically associates with an on-site labor force, while consuming vast quantities of local energy and resources. Indeed, the industrial and material footprint of such ventures is small and designed with a view towards mobility and impermanence. Rather than the bespoke offices and new centers local politicians might have envisioned when they courted these industries, the 'jobless growth' they actually receive involves row upon row of shipping containers filled with high-speed computer processers that feed off the local electricity grid and require a handful of guards for security (Bennetton et al., 2019). Rather than entering into a symbiotic relationship with the places where they set up shop, these ventures are described by Lally et al. as (2019, 2), "parasitic" '...feed[ing] off of existing circulatory systems of energy and capital, disrupting the very conditions that make it a desirable place...while providing little in return.

This is evident in the case of Quebec, in which the provincial government made appeals to digital and financial technology actors – promising cheap energy and business rates, light-touch regulation and additional support. As of February 2018, Quebec was home to over 40 data centers – owned by various interests, including both Amazon Web Services and Alphabet (parent company of Google) – that used an estimate 350 MW of electricity annually (Tomesco, 2018). It is anticipated that the entrance of more server farms – including those involved in cryptomining – into the region may result in such demand tripling (Tomesco, 2018). The regional energy utility, Hydro-Quebec, has perceived digital technology actors as a viable route to soak up the surplus energy generated by the hydroelectric dams of the region and, in doing so, to indirectly fund renewed investment in the transmission network (Loh and Tomesco, 2018). The case study of Quebec discussed in this article is based on secondary materials and, whilst we have made efforts to triangulate all claims made, further empirical work is required to explore both the crypto-regionalism discussed and how it operates in Quebec. Whilst the term 'boomtown' is often used to describe the entrance of an energy *producer*, the development of a 'boomtown' based on the entrance of an energy *consumer* represents the generation of a distinct set of tensions we argue are in need of further study. Greenberg and Bugden's (2019) comparisons to contemporary 'fracking boomtowns,' has resonance in terms how energy end-users alter the socioeconomic and energy fabric of the locality. The "deep, material marks" (Lally et al., 2019: 1) left by such activities include high energy prices in Oregon (US), rolling blackouts in Venezuela, and declining wages in coal-intensive cities in China (Bennetton et al., 2019). Recent work has highlighted the links between cryptocurrency networks and historic processes of accumulation and extraction (Zimmer, 2015). In exploring the role of both economies of scale and regional economic imaginaries, we seek to raise significant questions of how the material resources are being consumed in one location to provide financial impacts enjoyed in others (Lally et al., 2019).

At the start of this article, we raised a paradox – of how a virtual currency, that is untethered from state control, regulation, and territory, relies upon the localized materiality of nature and energy in its production. The material realities of bitcoin mining do not just affect the "prospecting" imaginaries of crypto-currency mining but also bring into relief the fundamental tensions inscribed in the bitcoin project more generally. On the one hand as we have seen the "proof of work", that is necessary to validate blocks and thus mine new coins has become increasingly centralized and with more intense mining activity taking place in specific crypto-regions. Moving forward, analysis of this paradox is ripe for new discussion and debate, particularly in the relation to the ways that it might prompt a rethink of both cryptocurrencies and the wider role of regions (and regionalism) in contemporary geographies of digital currencies and their infrastructure. Further in-depth, empirical and qualitative analysis is needed to understand the effect of this trend in the longer term following the flows of global capital beyond traditional north–south flows, but digital flows of capital which may reverse such trends and which are much more difficult to follow and quantify.

While many are developing critical perspectives of the material implications of cryptocurrencies (Greenberg & Bugden, 2019; Lally et al., 2019; Rella, 2020), this materiality is intricately tied to broader emerging themes, including the emancipatory potential of cryptocurrencies and cognate technologies, such as blockchain (Howson, 2019); empty shop floors and hidden digital labour (Calvão, 2019), as well as tracing larger life cycles of waste and energy consumption (Atkins, 2020). We hope that this work only adds to the gaps of knowledge about cryptomining and its geographical embeddedness and relationship to local level dynamics. Far from existing as an ethereal presence, cryptocurrencies have material impacts that require study and interrogation.

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Footnotes

Text Footnotes

[1] The more problems one solves the more value that the coin carries since the total number of coins that will ever be issued is fixed (21 million) and the reward for solving the problem becomes smaller the closer one gets to this final number (estimated to be in 2021). In other words, there is a finite number of coins available and the race is on to accumulate as many as one can to cash in on the ever-volatile cryptocurrency market.

[2] Yet, the value of cryptocurrency is notably volatile. In January 2019, one bitcoin was worth £2,778. One the same day in 2018, it would have been valued at £6,135.

[3] The "hashrate" or "hash power" is the unit of measurement for the computational power the network requires to continue functioning (i.e., keep validating new blocks at a target rate of ten minutes and issuing new coins).

[4] The energy requirements of the network can be as unpredictable as the price of bitcoin, with localised weather events and efficiencies of machines leading to fluctuations (Mora et al., 2018; Dittmar and Praktiknjo, 2019; Houy, 2019; Howson, 2019; Masanet et al., 2019).

[5] Recent reports of an impending ban on crypto mining in China only further complicate the situation as many crypto mining operations look to relocate their facilities to countries like Canada, the US or Northern Europe (Huang, 2019).

[6]

Nodes represent systems running bitcoin software. Nodes can be used for two complementary purposes: mining and validation of mining activities.

[7] To complicate matters, the re-emergence of 'cryptojacking' which allows cyber criminals to offset their mining costs by illegally, covertly, and temporarily making use of a victim's bandwidth, computational capacities, and energy, making it even more difficult to map the mining network.

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