Money's Infrastructures: Blockchain Technologies and the Ecologies of the Memory Bank

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Material Abstract

Money's Infrastructures

Blockchain Technologies and the Ecologies of the Memory Bank

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This thesis takes the emergence of blockchain technologies and cryptocurrencies for monetary payments as a provocation to investigate infrastructures as the irreducible materiality of money. Increasingly obscured and taken for granted in everyday digitalised interactions, infrastructures are held to be the material condition of possibility for money. Departing from approaches to the social theory of money that privilege either monetary objects or the abstractions of money of account, the thesis demonstrates how infrastructures provide an analytical site where social studies of money and finance and science and technology studies can be fruitfully combined. In particular, the thesis establishes an ecological ontology of money's infrastructures of memory to capture active forms and dispositions of money infrastructures, and the co-evolution of money infrastructures with their associated *milieux.* Focused specifically on cross-border payments, the thesis utilises the blockchain and interoperability firm Ripple as a "revelatory case" for investigating the entanglements of matter, meaning, space, desire, and power that pervade all of money's infrastructures. Analysis is extended in three main directions. First, with reference to recent developments in cross-border payments, money's infrastructures are shown to produce and inhabit spatialities and chrono-topologies that take four main typological forms – pyramids, rhizomes, platforms, stacks. Second, with reference to the libidinal political economy of the cryptoasset bubble that has built up around applications of blockchain technologies in payments, the materiality of infrastructural ecologies of money is shown to be shaped significantly by enchantment and desires. Third, with reference to remittances as cross-border payments where informal circuits of value transfer are presently being formalised as market opportunities to free hitherto idle assets, money's infrastructures are shown to be replete with political-economic tensions between interoperability and platformisation and frictionless flows and rent extraction.

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List of Abbreviations

AML-CFT	Anti-Money Laundering – Combating of the Financing of Terrorism
BIS	Bank for International Settlements
BTC	Bitcoin, used for units of the cryptocurrency
B2B	Business-to-Business
CBDC	Central Bank Digital Currency
CLS	Continuous Linked Settlement (Bank)
CPMI	BIS's Committee on Payments and Market Infrastructures, previously CPSS
CPSS	BIS's Committee on Payments and Settlement Systems
dApp	Decentralised App
DAO	Decentralised Autonomous Organisation
DLT	Distributed Ledger Technologies
DNS	Deferred Net Settlement
DoS	Denial of Service Attack
ETH	Ether, used for units of the cryptocurrency
FCA	UK's Financial Conduct Authority
FinCEN	Financial Crime Enforcement Network
FSB	Financial Stability Board
ICO	Initial Coin Offering
IEO	Initial Exchange Offering
IGO	Inter-Governmental Organisation
ILP	Interledger Protocol
IMF	International Monetary Fund
IOSCO	International Organisation of Securities Commissions
ISO	International Organisation for Standardisation
KYC	Know Your Customer
MTO	Money Transfer Operator
NBFI	Non-Bank Financial Intermediary
P2P	Person-to-Person
PoS	Proof of Stake
PoW	Proof of Work
RSP	Remittance Service Providers
RTGS	Real-Time Gross Settlement
SegWit	Segregated Witness
SEC	USA's Securities Exchange Commission
STP	Straight-Through Processing
SWIFT	Society for Worldwide Interbank Financial Telecommunication
TPS	Transactions Per Second
UNL	Unique Node List
UTXO	Unspent Transaction Outputs
W3C	Worldwide Web Consortium
XLM	Stellar lumens, used for units of the cryptocurrency
XRP	Ripple, used for units of the cryptocurrency

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Statement of Copyright

Introduction

This thesis is situated in the context of three tendencies that are currently traversing digital money: first, an increase in the internal complexity, scalar reach, and material and energetic footprint of payment infrastructures; second, a proliferation of discrete payment infrastructures based upon specific platform businesses; third, a receding of such infrastructures into the background of the routine and everyday operations of money. This thesis observes these processes of proliferation, expansion, and invisibility of digital money from the vantage point of taken-for-granted infrastructures and seeks to reveal how this infrastructural materiality shapes and is shaped by the geographies, cultures, enchantments, desires, and political economies of contemporary money. Not only, then, does money require material and technical infrastructures, but this thesis will show that money itself *is* an infrastructure because it is predicated upon the existence of accounting and payment infrastructures of memory for its very existence. These infrastructures are also money in themselves.

The tendencies that are presently shaping digital money would seem to be at odds with each other. In fact, an expansion in the materiality of infrastructures often evokes widespread and assured connectivity, rather than splintering proliferation of non-communicating platforms and networks. Yet, literature on platform capitalism (Langley & Leyshon, 2016, 2020) and the explosion of cryptocurrencies (Campbell-Verduyn & Goguen, 2018; Zook & Blankenship, 2018) both point towards the monopoly- and rent-seeking tendencies in current developments in payments. Expansion in complexity and proliferation in the number of infrastructures seems at odds with the receding of these large technical systems into the background. Yet, we know very little of the standards, devices, and trajectories of value circulation as we pay for our coffee, for example through a contactless NFC chip incorporated into our phone which, through a mobile banking app, mimics and synchronises with a VISA debit card (Maurer, 2015b). This lack of visibility is all the more apparent as money crosses that mysterious line that partitions monetary spaces into territorialised sovereign currency areas.

More broadly, digitalisation is often understood as an outright disappearance of materiality (Kinsley, 2014). When it comes to money, this process of dematerialisation is often inscribed in the progressive affirmation of a self-referential, virtual, and immaterial form of money that Rotman terms “xenomoney”, “floating and inconvertible to anything outside itself, [that] signifies itself” (Rotman, 1987, p. 92). The “anchor” of gold that for so long provided the referent point for money is replaced with "a complex web of conversions, in which any 'bit' of capital, anywhere and with any time profile, can be measured against any other 'bit' of capital" (Bryan & Rafferty, 2006, p. 275). The fluctuation of prices and values derive no longer from the distance between markets and "fundamentals", but from the recursive computation based on contingency (Parisi, 2017) operating on and against the "incomputability of exchange" (Lotti, 2018; Parisi, 2013).

Indeed, gold itself is not immune to this process of digitalisation: Figure 1 shows a 1 kg bar of gold, property of the Royal Mint, that was circulated during a blockchain expo in 2017. The case in point was to show how gold itself was the biggest hindrance to the ease of trade in the gold commodity market, which in turn was the reason why the Royal Mint was planning to launch the cryptoasset RMG, later cancelled (Hobson, 2018).

Figure 1: A bar of gold is circulated at a blockchain expo on the 31st of October 2017 to illustrate the RMG tokenised gold exchange by the Royal Mint.

However, equating digitalisation of money with its dematerialisation produces empirical and conceptual aporias: insofar as money as object tends to recede, money retains its own materiality in terms of the proliferating infrastructures that are necessary for its circulation (Coeckelbergh, 2015; Rambure & Nacamuli, 2008). In order to circulate as "electronic blips" (Gilbert, 2005, p. 372), money requires a planetary infrastructure of servers, data centres, cables, and devices. Money always holds within itself the very tension between abstractness and materiality which is often depicted as unique to the digital. In fact, as Horst and Miller (2012, p. 5) say, money precedes and, largely, anticipates digitalisation as a widespread turn to quantification and abstraction, rather than being revolutionised through the digitalisation *of* money: "Just like the digital, money represented a new phase in human abstraction where, for the first time, practically anything could be reduced to the same common element". At the same time, even in a world where the speed of light and the Earth's curvature are the last obstacles to the simultaneity of transactions (Pardo-Guerra, 2019), materiality imposes onto infrastructures specific topographies and topologies (Leander, 2015; D. MacKenzie, 2017a).

Counter to the idea that digitalised money knows no border, these infrastructures are also more and more at the centre of geopolitical competition, turf wars and rivalry (Chazan, 2018; Ostroukh, 2019). While digital money is often represented as purely privatised through bank-led issuance and private payment infrastructures, the state still retains large swathes of authority over the material networks that permit value to flow. For example, Real Time Gross Settlement (RTGS) systems are often operated directly by a central bank, they settle in central bank liabilities, and they are almost universally considered critical infrastructures by homeland security agencies (Dunn Cavelty & Kristensen, 2014; Lewis, 2020, pp. 349-370).

This thesis, then, will draw on the "infrastructural turn" across the social sciences to recover the "technological unconscious" (Thrift, 2004) of digital money, i.e., its "substrate of guaranteed correlations, assured encounters, and therefore unconsidered anticipations" (Ibid, p. 177). The term "technological unconscious" is here used in two ways. First, it stands for that which is not immediately visible and graspable about digital money, that which is not consciously apprehended but rather is the material and infrastructural condition of possibility for consciousness (Clough, 2000). Second, money infrastructures are the unconscious of money because they also bear the marks of flows of desire and libidinal investments that "coexist, but not necessarily coincide" with the materiality of such infrastructures (Deleuze & Guattari, 1983, p. 104), and with the rational expectations associated with their use (Chun, 2008a; Harvey & Knox, 2012; Larkin, 2013).

As such, this thesis aims to re-materialise "virtual" money (Kinsley, 2014; Pickren, 2018; Furlong, 2020), in a way that does not see materiality as an "anchor" and a "grounding" for money, like gold ostensibly did before the 1970s. Rather, as Anderson and Wylie have, it, the infrastructural materiality of money is

> never apprehensible in just one state, nor is it static or inert. Materiality is not glue, binding and holding other, less material, things together [...] materiality is always already scored across states and elements. As such, as variously turbulent, interrogative, and excessive, materiality is perpetually beyond itself (Anderson & Wylie, 2009, p. 332).

This thesis traces the infrastructural materiality of both money *and* digital technologies back to Stiegler's concept of "tertiary retention", i.e., a process of externalisation of memory outside the body and into technical artifacts (Hui, 2016; Stiegler, 2010). Core to how the thesis retrieves infrastructures as the "irreducible materiality" of money (Keane, 2001; Maurer, 2017b) is recognition of money's capacity to act as a "memory bank" for the society that uses it (Hart, 2000; O'Dwyer, 2019b). Tertiary retention is none other than the recording of the countless credit and debt relations of money that people enter into, as well as the recording of the acts of value transfer that the same people do across time and space.

Analytically, this thesis will contend that digitalisation entails a change in the internal articulation of the infrastructural materiality of money. Furthermore, the infrastructural materiality of money increases in internal complexity. In finance and technoscience, money and payments are depicted as entering a phase of "Cambrian Explosion" (Nelms et al., 2018) and "Cambrian Moment" (The Economist, 2014), borrowing from paleobiology's term for the explosion in biodiversity that happened around 500 million years ago. This explosion is made of three phenomena: first, the creation of new technologies operating on existing "rails" of circulation. Second, the creation of wholly new payment channels. Third, the proliferation of platforms (Nelms et al., 2018). More in the background, and operating at a slower pace, there is a fourth phenomenon, which is the explosion in value, volume, scale, and membership of "legacy" payment infrastructures, and the industry-wide effort to update the wires and plumbing of money (Pardo-Guerra, 2019; Rambure & Nacamuli, 2008). The Cambrian Explosion, then, will be interpreted in this thesis as an instance of what Stiegler (2010, p. 9) would call a process of grammatisation, whereby the infrastructural materiality of money-as-memory, or what Stiegler calls “mnemotechnical retentional layer”, is “transformed, increased in both complexity and density” (Ibid).

This interpretation of contemporary developments in digital money is underpinned throughout the thesis by an approach which retrieves the roles that infrastructural materiality, cultures, enchantments, and desires have in producing ecological processes of co-evolution within the space of digital infrastructures of value transfers. Indeed, the thesis reconstructs the libidinal and political economies (Gammon & Palan, 2006; Gammon & Wigan, 2013; Lyotard, 1993; Yuran, 2017) that these co-evolutionary dynamics produce, and the forms of inclusion, exclusion, and capitalisation they engender. To this end, this thesis will deploy the analytical strategy called “infrastructural inversion”, that is,

> a struggle against the tendency of infrastructure to disappear (except when breaking down). It means learning to look closely at technologies and arrangements that, by design and by habit, tend to fade into the woodwork (sometimes literally!). Infrastructural inversion means recognising the depths of interdependence of technical networks and standards, on the one hand, and the real work of politics and knowledge production on the other. It foregrounds these normally invisible Lilliputian threads and furthermore gives them causal prominence in many areas usually attributed to heroic actors, social movements, or cultural mores (Bowker & Star, 2000, p. 34).

While rendering visible the internal components of an infrastructure can be an essential part of a strategy to make infrastructures politically actionable, as Chapter 3 will argue, infrastructural inversion does not amount to “opening of the black box” (Winner, 1993). The materialities of the infrastructures are not simply “out there” waiting to be discovered, unpacked, and showed, and the opacities and resistances to access are just as much part of an infrastructure as are its more transparent technical components. More accurately, infrastructural inversion entails, as we shall see in Chapter 5, a process of “unfolding”, not a reverse of folding or an ironing out of folds, but a following from fold to fold. Infrastructural inversion is a conceptual method that resonates with Bernards and Campbell-Verduyn’s (2019) claim that infrastructures can contribute to a critical political economy agenda that is more attuned to political and performative materialities, topological spatialities, and complex power relations. This, in turn, enables the kind of post-Cartesian demystification of technological fetishism that Hornborg (2014) argues for. As a way to capture the widest spectrum of contemporary money infrastructure dynamics, this thesis’ analytical focus will be the intersection between the proliferation of blockchain technologies, Distributed Ledger Technologies, and cryptoassets, on one side, and cross-border payments, on the other.

Blockchain technologies, or Distributed Ledger Technologies (DLT) are here defined as distributed, time-stamped, append-only ledgers of data connected with addresses, simultaneously kept on all the nodes within a decentralised network, following a set of rules, instructions, and procedures called consensus algorithm or consensus mechanism. Blockchain technologies result from the creative assemblage of peer-to-peer networking with cryptographic functions such as public key – asymmetric – encryption, hashing, and proof-of-work (Narayanan & Clark, 2017)[1].

Blockchain technologies serve here as a “paradigmatic case” (Pavlich, 2010, p. 645) of infrastructures as the irreducible materiality of money (Keane, 2001; Maurer, 2017b), i.e., “a singular event that involves placing an exemplar alongside a phenomenon; by virtue of so placing, it shows or reveals key elements of that phenomenon” (Pavlich, 2010, p. 645). This is because, in cryptoassets, their underpinning infrastructures are their sole form of material existence. In fact, blockchains and cryptoassets exist only as infrastructures of records, accounting, and payment: cryptoassets do not have a “cash” form, and they are most of the times non-redeemable into other real-world assets (Garrod, 2019; Ishmaev, 2017). In Swartz’s words, “While Bitcoins operate like nuggets of digital gold, they are only able to do so because they are ‘records’ in the blockchain” (Swartz, 2018, p. 632). Hence blockchain uncovers “the subject’s encounter with the (im)materialism of digital objects; big data and the digital unconscious” (Herian, 2018b, p. 170).

This existence of Bitcoins as records on the blockchain does not imply that they are *passive* records, simply stored and waiting to be moved. Rather, they are

> powerful signs that act and cause transformations. An accounting inscription […] can therefore be conceived of as an action […] accounting and performance measurement reports are not worth so much because of the content they contain, but rather due to the actions they enable and make more concrete (Busco & Quattrone, 2018, pp. 3 and 13).

Just as infrastructures plug into and layer on top of other infrastructures (Furlong, 2020; Star, 1999), blockchain technologies are harbouring and enabling new infrastructures and platforms. In fact, at present most of Bitcoins are stored and moved “off-chain”, on the

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[1] See also Appendix A.

books of crypto exchanges (D. H. Neilson, 2021). The emergence of these “off-chain” layers, like the Layer 2 and 3 technologies in Chapter 5, illustrates that cryptoassets are not categorically different from other forms of digital money (Cf. Çalışkan, 2020). Rather, they are a specific articulation of the infrastructural materiality of money.

Blockchain technologies emerged between 2008 and 2009 with Bitcoin. After a couple of years as a niche technology that primarily caught the attention of cryptographers, cyberanarchists, hacktivists and some software engineers (Brekke, 2020; Brunton, 2019), Bitcoin surged to the world’s stage in 2011, following its adoption as funding method by Wikileaks (Greenberg, 2011), and, for a short while, becoming a quasi-refuge currency for Cypriots after the Financial Crisis wrecked their domestic banking system (Cox, 2013). From 2011, Bitcoin saw steady increments in its popular visibility, following, and price, despite downturns such as the cracking on the illicit online marketplace Silk Road (Barratt, 2012; Brito, 2013) and the bankruptcy of the then largest exchange, Mt. Gox (Schumpeter, 2014). Simultaneously, the malleability of Bitcoin’s open source code captivated the attention of software engineers, resulting in the proliferation of cryptocurrencies and cryptoassets experimenting with algorithmic monetary policies, different forms of consensus mechanisms, and different internal topologies. At the time of writing, there are 9,148 cryptoassets, with a total market capitalisation of US$ 1,892 billion (Coinmarketcap, 2021).

Blockchain technologies emerged at the fringe of formalised capitalism, and often in opposition to it (Brunton, 2019). However, blockchain technologies are undergoing co-optation by market actors, de-politicisation of their design, and increased competition between business implementation, a dynamic labelled as “co-opetition” (Leal, 2014). Some examples are the UBS-led Utility Settlement Coin (Kaminska, 2017b), R3 Corda (2018), the experiments by SWIFT (2018), and CLS (Allison, 2018) for distributed messaging, clearing, and settlement, and the newly launched “JPM Coin” by J.P. Morgan (2019). Furthermore, cryptocurrencies are striving to achieve the status of a new asset class (Burniske & Tatar, 2018) to enable different ways of capitalising on payments, in addition to transaction fees and data monetisation. In June 2019, Facebook, together with a consortium of partners, announced its cryptocurrency Libra, to be launched in 2020, which focuses on financial inclusion and remittances (Libra, 2020).

The focus of this thesis on cross-border payments provides particular insight into the reworking of money’s spatialities and temporalities by digital payment infrastructures themselves. Foreign exchange markets have skyrocketed in value ever since the end of

Bretton Woods and of the fixed exchange rate regime in the early 1970s. The cross-border financial messaging colossus SWIFT went from 239 members in 1979 to 9,281 members in 2009, and to more than 11,000 members in 2020. Its network presently handles more than 8 billion messages every year, and up to 36.7 million messages on peak days (SWIFT, 2020). If in the 1960s the Federal Reserve's Fedwire, was handling payments worth 4.5 times the US GDP, in 2012 this ratio has grown to 90-100 times US GDP (Kahn et al., 2016, p. 564). In the same period, China's share of payments has grown from twenty times its GDP to thirty-four times (Ibid). USA, UK, EU, Canada, and Singapore are all working on updates of their domestic payment rails and experimenting with cross-border synchronisation. The EU and the UK, through open banking, the two Payment Systems directives, and with the UK access to BoE reserves for non-banks, have created an infrastructural condition of possibility for the aforementioned proliferation of platforms to gain further momentum.

A historical study of cross-border payments shows that many characteristics that are considered anomalies of these value transfers – correspondent accounts, problems in synchronisation and data enrichment – are actually the original traits of money as it appears in accounting books. Showing the problems and frictions that money encounters as it crosses borders provides new insights into how those borders came into being and how they are kept in place. Rather than being considered as a line, the monetary border is here acknowledged as a space in its own rights, an "analytical borderland" (Sassen, 2008, p. 379). Furthermore, payments and cross-border remittances have been a crucial application of blockchain technologies since their inception. As shown in Chapters 4 and 7 corporate co-optation of blockchain technologies leads to ambiguous dynamics in the payment space, caught in between interoperability and enclosure, disintermediation and re-intermediation, disruption, and rent extraction (O'Dwyer, 2012, 2015a).

The empirical and analytical contribution of this thesis builds upon on a particular kind of case-based research. As Chapter 2 will further detail, Ripple will be retrieved as a "revelatory case" (Fletcher & Plakoyiannaki, 2010) in this thesis, in that it uncovers and sheds light into the material performativity of design, the ecological co-evolutive dynamics, the complex monetary topologies that infrastructures engender, the libidinal investments that traverse these spaces, and the political economy resulting from the tension between platformisation and interoperability. Ripple was a multi-currency payment system initially designed in 2004 without relying on a distributed ledger (Fugger, 2004). In 2013, the company OpenCoin – subsequently Ripple Lab and Ripple – acquired this project and turned it into the Ripple Consensus Ledger – subsequently XRP Ledger, and started applying this technology to multi-currency payments, both cross-border and between cryptoassets. At the time of writing, XRP is the fourth largest cryptoasset by market capitalisation, with a market price of $1.32 per XRP and a total market capitalisation of $60 billion (CoinMarketCap, 2021). In 2015, Ripple developed a platform-agnostic payment interoperability standard, the Interledger Protocol, subsequently adopted by the World Wide Web Consortium (W3C). As a leading company utilising DLT for cross-border payments, Ripple presently serves a network of more than 300 institutions in more than 40 jurisdictions (Ripple, n.d.).

1. Money and the Infrastructural Turn

This thesis is inscribed in a broader "infrastructural turn" across the social sciences that has directed attention to the material and technological conditions of possibilities for multiple social, economic, and cultural formations. Infrastructures are "extended material assemblages that generate effects and structure social relations, either through engineered (i.e., planned and purposefully crafted) or non-engineered (i.e., unplanned and emergent) activities" (Harvey et al., 2017, p. 5).

Hence, the typical focus for this literature is the large technical systems of the past and present (Bijker et al., 1993; Elster, 1983; Hughes, 1983; Mayntz & Hughes, 1988/2019), including electric grids (Bakke, 2016; Hughes, 1983), water (Nikhil Anand, 2017; Björkman, 2015), sewage, and oil pipelines (Barry, 2013), waste (Gordillo, 2014; Nicky Gregson et al., 2010), internet cables (Blum, 2012; Farman, 2018; Starosielski, 2015) and satellites (Graham, 2016), telegraph (Müller, 2016; Standage, 2009), railways (Schivelbusch, 1977/2014), roads (Harvey & Knox, 2015; Moran, 2010), and logistics (Nicky Gregson et al., 2017; Klose, 2009; Levinson, 2008). A related set of concerns has also been the heterogeneous groups of large technical systems that are deemed, by one sovereign state or another, to be "critical infrastructures" (Aradau, 2010; Cowen, 2010; S. Roberts et al., 2012).

At the same time, the term infrastructure has undergone semiotic, semantic, and conceptual slippage that turned it into a broader analytical strategy to apprehend the obscured role of bodies (Andueza et al., 2020), people (Simone, 2004), language (Frith, 2020), commons (Berlant, 2016; Elyachar, 2012), borders (Grondin, 2020; Kanai, 2016), international organisations (Opitz & Tellmann, 2015), and the state (Lemanski, 2019; J. C. Scott, 1998; Von Schnitzler, 2016). This renewed flexibility of the term "infrastructure" certainly derives from the "doubly relational" nature of infrastructures "due to their simultaneous internal multiplicity and their connective capacities *outwards*" (Harvey et al., 2017, p. 5 emphasis in the original).

Human geographers have been at the forefront of the infrastructural turn (Amin, 2014, p. 137). Digital Geographies (Ash et al., 2018, 2018b) attend to the "global assemblage of digital flow" (Pickren, 2018) always already underpinning ostensibly "virtual" spaces, places, and practices (Kinsley, 2014). Geographical investigations of infrastructures have foregrounded the malleability and situatedness of infrastructures, hence complicating scalar concepts of local and global (Furlong, 2011, 2019, 2020). Infrastructures are also foregrounded as political economies, whereby changes in both material components and "immaterial" property and ownership relations can deeply alter the social fabric (Graham & Marvin, 2001; Longley, 2003). Smart city infrastructures have been shown to produce specific metabolisms (Doshi, 2017; Heynen et al., 2006) and to afford a degree of sentience to the urban tissue (Amin & Thrift, 2016; Luque-Ayala & Marvin, 2020; McFarlane & Rutherford, 2008; Thrift, 2014). Infrastructure is constantly reassembled and reproduced "from below" in informal settings (Graham & McFarlane, 2015; McFarlane & Silver, 2017).

Finally, economic geography has foregrounded the role that finance plays in the funding, defunding, valuing, devaluing, becoming, and falling apart of infrastructures (Knuth, 2020; Knuth et al., 2019; Langley, 2018). A focus on the built environment has animated economic geography ever since Harvey's concepts of "spatial fix" and "capital switching", wherein urban, material, and social infrastructures become the focus for investment returns that cannot be realised from the circuits of capitalist commodity production (Castree & Christophers, 2015; Furlong, 2019). This literature foregrounds infrastructure as a site of financialised extraction, accumulation, and rent (J. Allen & Pryke, 2013). It is only recently, however, that finance has been understood as itself made of and made possible by multiple material and immaterial infrastructures (Hall, 2011). With the growth of planetary networks for the exchange of financial messages and funds (Dörry et al., 2018), and with the switching of core institutions from marketplaces to infrastructure providers (Petry, 2020), financial geographers are now increasingly looking at the plumbing and railways of money and finance.

When it comes to money, literature on accounting, long before and alongside the infrastructural turn, has provided an investigation of the material basis of accounting practices, the generative capacity of accounting itself to produce materialisations of their representations, as well as the incompleteness and the *lacune* inherent in either, which in turn further propel accounting's generative capacity (B. G. Carruthers & Espeland, 1991; Ezzamel et al., 2001, 2004; Fourcade & Healy, 2013; Kornberger et al., 2017; P. Miller & Rose, 1990). In fact, as Busco and Quattrone (2018, p. 13) frame it, accounting is "a maieutic process through which meaning and knowledge are constructed through a process that proceeds from what is calculable, known, and visible […] to questioning the elements that may be difficult to account for, unknown and invisible".

Just as Stiegler (1998) argued that forms of retention operate retroactively – how I record my memory in artifacts changes how I memorise things individually, which in turn affects the structures through which I frame my immediate experience – so accounting is not just a passive storage of memory, but, as Carruthers (2003, 2008) argues, organisation of memory and organisation of thinking morphed together throughout the history of Western thought. Quattrone (2009) adds to this the role that visualisations have played in the simultaneous production of recording things on accounting ledgers and of remembering.

> Viewing the book as an object implies that the attention is turned towards inscriptions; their form; their organisation within the space of a book; their manufacturing processes; and, in broader terms, their role as media and mediators – rather than towards their ability to convey some content knowledge (Quattrone, 2009, p. 89)

In the last decade, STS-inflected social studies of finance foregrounded the material and socio-technical devices and standards that provide micro-structures and theoretical equipment to market agents (M. Callon et al., 2007; D. MacKenzie, 2009; Pinch & Swedberg, 2008). This literature contributed to social theorisations of money that otherwise have often refused analytical import to monetary media or "money stuff" (Maurer & Swartz, 2017). For example, despite Ingham (2004, p. 3) defining money as "one of our essential social technologies", he also categorically refused to give payment infrastructures the slightest relevance in the definition of money itself: "Fundamentally, then, the question of new monetary space based on ICT is not technological, or even economic: it is political" (Ibid, p. 182).

Maurer (2012a, 2012c, 2017b) elaborated further on the relationship between money, materiality, and memory, identifying payment infrastructures as the "irreducible materiality" (Keane, 2001) of money in both its cash and cashless forms. Swartz (2020) has studied the participatory cultures inhabiting the sprawling platforms and infrastructures of digital money. Rachel O'Dwyer (2015b, 2015a, 2019b) has unearthed the political economy of "walled gardens", enclosure and privatisation in the payments space, and she reconstructed a genealogy and history of different materialisations of money and memory, which in turn afford different opportunities for value extraction as well as new possible sites and tools of resistance. Guyer (2016) studied how monetary spaces are made of circuits where different special-purpose monies circulate, interlocking through tropic points where money forms are made exchangeable with one another.

What differentiates literature on accounting from the approach adopted in this dissertation, then, is that, while literature on accounting takes the diagram as its starting point, this dissertation takes an intermediate position that takes seriously both the diagrammatic and the already-material sides of money infrastructures. In Chapter 3, hence, the political ontology of active forms and dispositions will move beyond accounting techniques as generative of material formations, and instead produce a detailed yet not only descriptive taxonomy of material formations and their capacity to influence both other material formations and accounting techniques.

Situated at the intersection of the Cambrian Explosion in monetary payments (The Economist, 2014), and the infrastructural turn in the social sciences and social theory of money (Dodson, 2017), this thesis draws on this growing literature on the infrastructural materiality of money to perform an "infrastructural inversion" on the materialities, ecologies, topologies, as well as on the libidinal and political economies that are made possible by and that inhabit money infrastructures. In so doing, it wants to go beyond metaphorical uses of the term "infrastructure" as it is currently applied to money: As Anand et al (2015) would put it, "What happens when infrastructure is no longer a metaphor? What happens to theory making and ethnographic practice when roads, water pipes, bridges, and fibre-optic cables themselves are our objects of engagement?".

2. Empirical and Analytical Contributions

This thesis's primary empirical and analytical contribution, then, is a study of the material politics, topologies, libidinal and political economies of infrastructures in the making. As Star summarised, "People commonly envision infrastructure as a system of substrate [...] by definition invisible, part of the background". However, "the image becomes more complicated when one begins to investigate large-scale technical systems in the making, or to examine the situation of those that are *not* served by a particular infrastructure" (Star, 1999, p. 380). Hence, a study of "new" infrastructures in the making – such as blockchain technologies – provides analytical purchase into dynamics that tend to be buried beneath the surface once the infrastructure is established and deployed.

However, this thesis underscores that studying new infrastructures does not mean that the theoretical insight gained is historically unprecedented or unique. Rather, new infrastructures can reveal previously existing yet unobserved or unobservable dynamics. For example, Çalışkan (2020, p. 558) argued that

> data money's materiality is historically and categorically different from paper or metal money, or their digital representations. […] in the sense that they do not need the authority of a bank, state, or corporation in accounting, minting, or controlling currencies.

This thesis concurs with Çalışkan that blockchains are *historically* different from other money form because they propose a money infrastructure made of components that, albeit pre-existing (Narayanan & Clark, 2017), had not hitherto been combined together. This thesis, however, does not share the idea that they are *categorically* different from other forms of money. In fact, money has existed in a networked form that does away with public institutions in other moments in time: the bill of exchange, the *Hawalas-Hundis* and Local Exchange Trading Systems show that money existed in decentralised arrangements. Furthermore, blockchain technologies, albeit touting decentralisation, do not entail a categorical disintermediation of money: as Çalışkan (2020, p. 553) argues, "Blockchains do not disintermediate, but reintermediate". The emergence of intermediaries like exchanges, custodians, lenders, and asset managers in the crypto space further challenges this claim of categorical uniqueness.

Blockchain are highly representative of the current transformations in digital money, due to their near-general purpose technology status (Hacker et al., 2019a) and, at the same time, for their widespread use in payments (D. Mills et al., 2016). Rather than being radically new, cryptocurrencies remind us that every money form requires an underpinning material and technological infrastructure to function. Beyond an illustration of the infrastructural materiality of money in general, blockchain technologies also illustrate the specific material components and their individual and combined effects on the spaces and political economies created by money circulation. At the same time, these technologies are relatively new, and it is highly beneficial to expand our empirical knowledge of "actually existing" blockchain technologies: in fact, as Çalışkan (2020, p. 542) notices, "existing social science literature rarely draws on empirical social analysis; it interprets blockchains and cryptocurrencies either by drawing on anecdotal experience, or on the theoretical premises of the very empirical developments they aim to understand".

As Chapter 3 will elucidate, blockchain technologies emerged with an often overtly political design (Brunton, 2019; Eich, 2019; Golumbia, 2016; Karlstrøm, 2014), and the proliferation of different consensus algorithms and other technical components illustrates how different "active forms" can combine together to engender highly heterogeneous propensities of "dispositions" (Easterling, 2014). Blockchain technologies also help to apprehend active forms and dispositions in their flexibility and dynamism, and to observe standardisation as a deeply political act. Since they are a technology still in their infancy, they occupy a liminal space fraught with "framing struggles" (Hacker et al., 2019b, p. 14) over terminology, status, and regulation.

Furthermore, rather than looking at blockchain technologies in isolation, this thesis approaches them as caught in processes of ecological co-evolution with existent and incumbent infrastructures, institutions, and power structures, in particular in the handling of cross-border payments. This, in turn, allows for a more open-ended and less deterministic understanding of what active forms are and the disposition they engender. In fact, for all the innovations and particularities that blockchain technologies have, which sometimes make people refer to them as singularities, this thesis strives to avoid presentism, technological fetishism and determinism, and solutionism as a way to frame technologies as unproblematically self-fulfilling prophecies (Hütten, 2019).

Among financial applications, cross-border payments are a particularly important field for blockchain experimentation (D. Mills et al., 2016) to improve an infrastructure for multi-currency and cross-border value transfer that is often considered slower and outdated (Amery, 2020; McKinsey, 2015; Rambure & Nacamuli, 2008). Cross-border payments are taken as an analytical focus for the problematisation of bounded monetary spaces they entail, and blockchain applications to cross-border payments shed light on the hybrid topologies and spatialities of money. Money infrastructures, then, proliferate borders rather than merely connecting and bridging them. As the so-called "SWIFT affair" during the War on Terror shows, infrastructures not only challenge borders and interconnect across them, but also actively produce and reproduce borders, and function as bordering devices (de Goede, 2012; Romaniello, 2013).

Being simultaneously a new infrastructural technology for value transfer and a powerful vector for speculative investments, blockchain technologies are also analytically important for the connection they reveal between the material and the semiotic, the technical and the cultural and affective components of any technologies. An infrastructural approach to blockchain technologies, then, illustrates powerfully that infrastructures are not only material constructs, but active sites where libidinal and political economies are created and sustained trough enchantments, desires, and imaginaries (Müller, 2016; Schivelbusch, 1977/2014; Standage, 2009). In particular, blockchain technologies are caught in a "compound desire bubble" (Cf. Blyth, 2008) made of self-reinforcing flows of desire and sources of enchantment deriving from cryptoassets themselves, from the intermediations that blockchain technologies afford of old and new platform economies, or for the generalised interoperability.

Lastly, particularly when inscribed in more formalised circuits of value (Rodima-Taylor & Grimes, 2019), blockchain technologies help us elucidate the tension between blockchain-based interoperability and digital feudalism of blockchain platforms (Arvidsson, 2020; van Lier, 2017), and between disintermediation and reintermediation (Glaser, 2017; Schneider, 2019). In fact, as Tasca and Piselli (2019) show, interoperability for blockchain technologies is not only smooth interconnection between "siloed" network, but a smoothening of political difference in vast machines that try at once to co-ordinate across a community and to determine the very forms of sociality that happen within that community.

The strategy adopts a "revelatory case" selection strategy that makes possible "to observe and analyse a phenomenon previously inaccessible to investigation" (Fletcher & Plakoyiannaki, 2010, p. 838). Ripple uncovered interrelations between materiality, politics, and cultures and imaginaries, on one side, and between public, private, and grassroot actors, on the other, that would not have otherwise been visible. Ripple is a provocation to investigate the complex link between analytical dimensions in the infrastructural nature of money in multiple sites and across time, rather than just maximising the knowledge about the case at hand.

The complex materiality of Ripple shows how different active forms, alone and in combination, can engender very different dispositions in the whole space determined by these infrastructures. Ripple's materiality, internal governance, and value proposition changed dramatically over time, showing how multiple tangible and intangible materialities influence infrastructures' disposition. Çalışkan (2021a, p. 129) calls "intangible materialities" those elements that "draw on observable orders. These orders are produced and maintained, in part or entirely, by representational tools such as data or algorithms produce.” The thesis expands on this concept to include cultures, stories, and imaginaries, but also affects, enchantments, and desire as part of a broader libidinal political economy that make infrastructures possible.

Ripple folded and unfolded onto and through multiple monetary topologies, illuminating how the space of monetary circulation can be shaped in very different ways. Ripple was caught in multiple flows of desire that triggered the whole cryptoasset market to grow in just over a decade from a quirky niche to almost a trillion dollar in market capitalisation, and Ripple got under the spotlight of the early wave of venture capital investment into “disruptive” blockchain platforms. Ripple has been a powerful driver of the use of blockchain technologies as a tool to mainstream and formalise this “informal” value transfer network. In so doing, however, Ripple largely formalised itself and turned it into a software infrastructure provider for incumbent financial institutions, rather than an alternative monetary space.

Ripple also provided important insights into cross-border payments, in particular remittances, because it is the only DLT that focuses on the infrastructural level of cross-border value transfers, i.e., correspondent banking, rather than the “point of sale” or user-centred apps. The first use case of blockchain technologies in remittances, in fact, has been BitPesa. Born in 2013 and inspired by the success of the Kenyan payment system M-Pesa (Omwansa & Sullivan, 2012), BitPesa manages payments between two fiat currencies by matching them with payments from the originating currency to Bitcoin, and from Bitcoin to the currency of the country of destination (McKay, 2014; B. Scott, 2016). BitPesa has since expanded in geographical reach by serving eight countries across Africa, and it changed focus, from person-to-person (P2P) remittances to business-to-business (B2B) operations, hence losing the original emphasis on remittances *per se* (DuPont, 2019, p. 19).

The second example, Abra, was mentioned by The World Bank as a system to manage “instant peer-to-peer money transfers with no transaction fees […] combining cryptocurrency with physical bank tellers” (World Bank, 2018, p. 29). Currently, however, Abra seems to have focused on providing cryptocurrency wallets, as well as investing and trading services, rather than cross-border payments (Cf. Cotton, 2018, p. 116). Stellar, which was born by branching out from Ripple‘s source code in 2015 (Mazières, 2016), is undergoing a similar path through the implementation, with IBM, of World Wire, that aims to compete with both Ripple and SWIFT (IBM, 2019a; Wolfson, 2019). Ripple, which is the case this thesis will mainly focus on, made of cross-border interbank payments its primary market, with the specific aim of replacing correspondent banking (Rosner & Kang, 2015).

3. Theoretical Contributions

The second set of contributions made by this thesis are theoretical. These contributions stem from a reappraisal of commodity and claim theories of money to retrieve infrastructures as the real *loci* of money's materiality, on the one hand, and the development of a fruitful combination between science and technology studies and cultural and political economies of infrastructure, on the other. This thesis argues that what is missed by both commodity and claim theories of money is the irreducible materiality of the infrastructures that allow the recording of credits and debts and that, in turn, allow for a society to identify monetary objects as money. Even if we consider digital money as a collection of digital objects, then, we are confronted with the need to acknowledge the interobjective materiality that makes those digital objects possible, i.e., the materialisation of both internal and external relations of objects and the creation, by materialised interobjectivities, of their own milieux (Hui, 2016, p. 160).

Hart's conceptualisation of money as a "memory bank" (Hart, 2000) profoundly resonates with Stiegler's concept of "tertiary retention" (Stiegler, 2010) as a process of crystallisation of memory into technical artefacts. It is from the point of view of this infrastructural interobjectivity that money, as Desan argues, has an "internal design":

> Societies produce [money] by structuring claims of value in ways that make those claims commensurable, transferable, and available for certain private as well as public uses. That architecture, in all its intricacy, determines the way money works in the world (Desan, 2017, p. 111).

Reading social theories of money and science and technology studies and cultural and political economies of infrastructure through each other, then, makes it possible for this thesis to apprehend money infrastructures as political by design (Winner, 1980): the materiality of infrastructure bears the marks of present and past imperial formations (Aouragh & Chakravartty, 2016; Kooy & Bakker, 2008; Parks & Starosielski, 2015; Starosielski, 2015), gender relations (Elyachar, 2010; Siemiatycki et al., 2020), racial relations (R. Benjamin, 2019), political economies (Rossiter, 2016; Winseck, 2017), and even geologies (Parikka, 2015). The onto-epistemologies of new materialism shed light on the "material performativity" (Barad, 2003) of infrastructures, i.e., the simultaneous production of meaning through matter and inscription of meaning in matter.

An infrastructural approach to money, then, constitutes that "fluid ontology" that Velasco (2017, p. 720) calls for to investigate blockchain technologies, in that they are

> as much a digital financial token, an infrastructure, a digital object, and […] an entity that is both human-made and computer-made. A fluid ontology suits an object that is heavily material when is produced with the tangible electric and electronic needs of the mining industry; embodies a deeply symbolic value on market exchanges; is a formal abstraction of an alphanumeric series at a textual level; and is the infrastructure where it unfolds itself (Velasco, 2017, p. 720)

New materialism is rife with ways of conceptualising the agential capacities of matter itself, from mattering (Barad, 2007), to thing-power (Bennett, 2010), to onto-politics (Chandler, 2018) just to make some examples (Coole & Frost, 2010; Dolphijn & Tuin, 2012).

In Chapter 3, this thesis retrieves in Keller Easterling's (2014) vocabulary of active forms and dispositions the most apt conceptual lexicon to apprehend money's infrastructural materialities in their specificity, to retrieve what affordances and resistances each component provides, and which effects and tendencies they produce when assembled. Disposition is a "relationship between potentials. It describes a tendency, activity, faculty, or property in either beings or objects-a propensity within a context […] that results from the circulation of […] active forms within it" (Easterling, 2014, pp. 71-72). Active forms, in turn, are "markers of disposition, and disposition is the character of an organisation that results from the circulation of these active forms within it" (Ibid, p. 72). What differentiates this lexicon from other new materialist vocabularies is the level of detail that is used to flesh out the different affordances and resistances that each active form provides.

While the concept of infrastructure foregrounds the material field of possibilities where multiple forms of interactions take place, the concept of ecology illustrate the nature of those interactions as fluid, seamless[2], and highly power-fraught (Nardi & O'Day, 2000; Star, 1995a). Ecology, then, is not on the same analytical level as infrastructure, but it is a second-level concept that illustrates the specific kind of relationality engendered by and

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[2] Seamless here does not mean without friction, but rather without voids and operating continuously rather than discretely. When interacting with an infrastructure, we are in a situation more similar to being immersed in a fluid and interacting with the fluid osmotically rather than being "plugged in" to a more or less complex web.

underpinning infrastructures. Infrastructures are here conceptualised as “deeply relational techno-human ecologies” (Coeckelbergh, 2013; Nardi & O’Day, 2000; Star, 1995b). The concept of ecology also rejects biological or functionalist metaphors of harmonic balance and orderly internal competition, associated with the concept of “ecosystem” (Holmes, 2009; Hörl & Burton, 2017).

The concept of ecology allows for a radically flat ontology not to result in a “flat politics” in which agency and, hence, accountability become untraceable. It also enables an analysis of elements of money infrastructures that are not immediately material, such as cultures, imaginaries and practices that imbue an infrastructure with meaning and that exert often powerful influence on its overall disposition. The concept of ecology will also question the ubiquitous corporate discourse that depicts FinTech and blockchain technologies as a more or less orderly, albeit complex, *ecosystem* (Adner & Kapoor, 2010; Adomavicius et al., 2007; R. P. Dos Santos, 2017; Winner, 1984). The concept of ecology, lastly, highlights the interplay between materialities and cultures (Beer, 2009, 2013; Beer & Burrows, 2007, 2013; Punathambekar & Mohan, 2019), practices, imaginaries, mystics, and affects (Sjørslev, 2017; Wilson, 2016) in determining an infrastructure’s disposition.

Just like, methodologically, the first step of infrastructural inversion is to allow for the often obscured materiality of infrastructures to come to the fore, the first theoretical step then must be that of developing a onto-epistemological vocabulary to apprehend the different categories of material forms and their effects on the world. Chapter 3 takes both these steps at once, by simultaneously opening up the “engine” of Ripple’s distributed ledger, and to then generalise the insights thus gained into a full-fledged political ontology of blockchain infrastructures. This ontology draws on existing taxonomies of blockchain materialities, and it reads them through Keller Easterling’s vocabulary of active forms and dispositions.

After having established the ontological coordinates of an infrastructural theory of money, this thesis will explore three analytical dimensions in further depth: topology, desires, and formalisation. First, as Dourish and Bell (2007, p. 418) show, infrastructures are themselves spaces and spatial diagrams, i.e., “infrastructures [are] fundamental elements of the ways in which we encounter spaces – infrastructures of naming, infrastructures of mobility, infrastructures of separation, infrastructures of interaction, and so on”. The promise of time-space compression deriving from infrastructures is not taken as a given or as unproblematic effect, but as a promise underpinning and inspiring a spatiotemporal project. Infrastructures frame, script, and produce space not only through their material presence in the topography and landscape, but for the complex topologies and connections the enable and disable in material as well as imaginary ways (Harvey, 2012; Hönke & Cuesta-Fernandez, 2017).

This thesis shows how money has a layered, stacked internal topology made of the accumulation of claims over time (O'Dwyer, 2019b). This thesis relies on Martin and Secor's (2014) post-mathematical approach to develop a new materialist topology that does not need necessarily to be loyal to the mathematical principles of topological models, but close enough to the material configuration of relations and distribution of resources embodies in infrastructures. Rather than using topology metaphorically for a re-theorisation of space as such (John Allen, 2016), this thesis uses topology metonymically (Straube, 2016) to describe the material conditions of possibility that material configurations create and destroy, open up and obscure. Topology, rather than being a purely theoretical construct, is the materialisation of a spatial diagram, of a "spatial disposition" inscribed in infrastructures' active forms and deeply connected with their disposition.

The topological diagram of an infrastructure acts as an "abstract machine" (Deleuze & Guattari, 1987; Raunig, 2010) and different infrastructures perform different abstract machines, each of which with their centralising or decentralising tendencies, forces of territorialisation and deterritorialisation, and internal hierarchies. Furthermore, this thesis shows how money's topologies are always chrono-topologies (Lotti, 2018), because of the rhythms of creation and settlement of obligation they entail. This thesis will develop the pyramid, the rhizome, the platform, and the stack as four distinct topological abstract machines informing, respectively, domestic payment systems, mutual credit networks, blockchain payment platforms, and interoperability technologies. Each of these diagrams crystallise materially the abstract machines of overcoding, consistency, stratification, and axiomatics mentioned by Deleuze and Guattari (1987).

Second, this thesis pries open the desires and enchantments that shape, maintain in place or disrupt infrastructures, to see how infrastructures are not inert objects but sites of affective and libidinal, as well as economic, investment. Infrastructures, in fact, always embody and crystallise promises (Larkin, 2013) and enchantments (Harvey & Knox, 2012). As Bowker et al (2019, p. 5) have it, infrastructure "can articulate aspirations, it can envision new realities, it can make and mobilise new desires". As Larkin (2013, p. 329) puts it,

> Infrastructures also exist as forms separate from their purely technical functioning, and they need to be analysed as concrete semiotic and aesthetic vehicles oriented to addressees. They emerge out of and store within them forms of desire and fantasy and can take on fetish-like aspects that sometimes can be wholly autonomous from their technical function.

This thesis, by focusing on the enchantments and ostensibly irrational investments traversing infrastructural speculation, contributes to a "libidinal" understanding of political economy (Lyotard, 1993). For Lyotard, "every political economy is libidinal" because "*There is as much libidinal intensity in capitalist exchange as in the alleged 'symbolic' exchange*" (Lyotard, 1993, p. 109, emphasis in the original). For Deleuze and Guattari (1983, p. 104), "desire is part of the infrastructure" of any social formation because "There is an unconscious libidinal investment of the social field that coexists, but does not necessarily coincide, with the preconscious investments, or with what the preconscious investments 'ought to be.'" Noam Yuran, in turn, expanded on how money itself is an "object of desire" (Yuran, 2014, p. 2), where desire is understood as pre-subjective and social from the start, i.e., it is not individualised and kept private, but rather it invests the entire political economy and, through the materialisation into objects, it can "confront the subject as an alien drive" (Ibid, p. 8).

This thesis unpacks the ways in which desire is channelled through economic investments and materialised in specific infrastructural configuration and, conversely, how specific materialities can harbour and foster specific desires. The libidinal and the political economies surrounding infrastructures engender distributional effects, and they afford new opportunities of rent and value extraction. Desire, in short, is shown to be "the very conditions of causality (and hence rationality) that underwrite production (understood very broadly) within the social field" (Gammon & Palan, 2006, p. 99).

Lastly, this thesis deploys the concept of formalisation, borrowed from Timothy Mitchell, to understand the peculiar political economy inherent to interoperability. STS in infrastructures has already shown the importance of interoperability in networking technologies and protocols (Adamson, 2002; T. Gillespie, 2006; Guston, 1999; Houston et al., 2019; Musiani, 2015), in healthcare and bioscience (Hester, 2020; Hoeyer, 2019; Hogle, 2019; Leonelli, 2012; Lezaun, 2006; Mackenzie et al., 2013; Ribes & Polk, 2015), and in climate and ecological data (Freidberg, 2020; Schinkel, 2016; Sovacool et al., 2020). Through the concept of formalisation, this thesis contributes to this body of knowledge by adding a political economy perspective to the trends towards interoperability in payments, to ask "what is at stake in interoperability?".

Far from being a neutral technology to reduce frictions and transaction costs (Pesch & Ishmaev, 2019), then, interoperability is the condition of possibility for the rent extraction inherent to platform capitalism. This resonates Bowker et al.'s (2019, p. 4) observation that infrastructures are "always valuation regimes that constitute orders of worth", that entail and enable processed of valuation (Kornberger et al., 2015) and assetisation (Birch & Muniesa, 2020; Muniesa et al., 2017), in addition to being themselves the object of assetisation and valuation. The Cambrian Explosion engenders an internal tension between the "infrastructuration of platforms" (Plantin et al., 2018; Plantin & Punathambekar, 2019) and "platformisation of infrastructures" (Helmond, 2015; Westermeier, 2020) associated with the proliferation of walled gardens and hidden intermediaries (T. Gillespie, 2010, 2018). These tendencies illuminate the political-economic salience of interoperability as condition of possibility for assetisation, capitalisation, and rent extraction. The tensions and conflicts around interoperability also show how standards are inherently political, and how interoperability, decentralisation, and standardisation are always unfinished business (Jensen, 2010a; Pesch & Ishmaev, 2019; Schneider, 2019).

4. Methodological Contributions

The last set of contributions that this thesis brings are methodological. This thesis is based on my 18-months of fieldwork, which encompassed online archival research, ethnography of online meetings, participant and nonparticipant observation of online forums, participant observation of eight industry trade fairs, expos, and conferences; and a total of twenty-seven digitally mediated and traditional in-person, in-depth expert interviews. In particular, this thesis brings together a unique combination of methods, such as temporary ethnography, online interviews, online archival research, and online ethnography. This "methodological toolbox" enables to follow and trace money across space.

Literature in economic geography has long regarded the spatialities of money to be quite elusive, not least because of money's propensity for restless circulation and undifferentiated pooling in large amounts of capital, and to money's ability to script and produce time (Christophers, 2011a, 2011b; Gilbert, 2011). Furthermore, money is peculiarly hard to follow because it is at once personal and impersonal (Hart, 2007), highly localised and highly embedded in the world system (Hart & Ortiz, 2014). Hence, the application of well-established methods for investigating, for example, the spatialities of a commodity is far from straightforward when it comes to money (Cook, 2004; Cook & Harrison, 2007; Nicky Gregson et al., 2010).

By drawing on methodological reflections on hybrid ethnographies of online and offline settings (Preda, 2017), participant and non-participant observation of temporary events (Høyer Leivestad & Nyqvist, 2017; Moeran & Pedersen, 2011b; Sandler & Thedvall, 2017), and "scavenging ethnographies" of experts and elites in finance and technoscience (Seaver, 2014, 2017), this thesis will develop a methodology that takes the "multi-sited imaginary" (Hart & Ortiz, 2014; Marcus, 1995) of networked conceptualisations of the field (Burrell, 2009) and takes them further.

This thesis shows that finance and technoscience contain specific challenges to access, which in turn require different strategies, ethics, and subjectivity. In terms of data collection strategy, the "scavenging ethnographer" uses multiple data sources to "route around" (Seaver, 2017, p. 10) the multiple resistances to knowledge she will encounter in her way. Ethically, the ethnographic impetus towards empowering informants and "giving back" needs to be critically reassessed: taking informants at their word might mean becoming a promotional echo chamber rather than a social researcher. Rather than taking informants' accounts at face value, one should "parse corporate heteroglossia" (Seaver, 2017, p. 8) and disentangle the different, sometimes contradictory voices that inform a PR discourse.

The study of online (forums, exchanges, websites) and offline (trade fairs, conferences) settings where cryptoasset markets were constructed also enables this thesis to contribute to the "taking place" of cultural economies, i.e., on the context-specific spatialities and topologies of cultural and material practices associated with the creation of markets and the use of market devices (M. Callon et al., 2007; Hall, 2011; D. MacKenzie, 2003). An account of the multiple, hybrid, and heterogeneous spatialities of the explosion in blockchain technologies contributes to "place" these technologies and to study them together with their "worlds" (D. MacKenzie, 2003). More broadly, the heterogeneous network that connects together the spatialities of this fieldwork is a contribution towards "an understanding of money that is more attentive to the situation of money in time and space, that is more grounded in material practices" (Gilbert, 2005, p. 360).

In particular, through the study of trade fairs and conferences, this thesis brings methodologically innovative ways to study speculation and investment and, in turn, to study the relationship between technology, finance, and desire. Starting from the point of view that the "nitty gritty" of the logistics of money is just as important as the speculation, myths, enchantments connected with technological innovations, fairs can be seen as "bubbles in controlled form", i.e., materialisation in one space of the crowds that gather around specific markets and assets during speculative frenzies. Trade fairs perform two complementary functions. On one side, they are the "front stage" (Goffman, 1990) of performative practices (C. W. Smith, 2011, pp. 97-99) where tournaments of value take place. On the other side, conferences and trade fairs work as "field configuring events" (N. Anand & Jones, 2008; Garud, 2008; Glynn, 2008; McInerney, 2008; Oliver & Montgomery, 2008).

Lastly, the hybrid online-offline ethnography that informed this research produced important insights, on the one side, on the reciprocal roles of online and offline spaces and, on the other side, on the relationship between fieldwork and time. In terms of the connections between online and offline settings, the material or discursive connections constructed practically and at the level of the imaginary by the informants matter more than the well-defined boundaries of a traditional field site, and the heterogeneous nature of the field is just as much a methodological challenge for the researcher as it is a practical challenge for the informants to inhabit.

In terms of the relationship between fieldwork and time, time figures both as an external as an internal part of fieldwork, acting as a medium, as hype and attention cycle, and as a limit. The mismatch in time and location of online archival research and remote interviews offers a more paced collection-analysis rhythm, but it also does not allow for rapport to be built over time and for interviews to build on each other in the same way as traditional research setting. However, the more paced data collection allows to collect data over longer periods of time, hence allowing one to escape the traps of hype cycles. Especially in fast-moving industries like blockchain technologies, being able to capture longer trends is necessary for research to hope to pass the test of time. A limit, however, needs to be imposed, in order for the multi-sited fieldwork to become the endless fieldwork.

5. Research Questions and Structure of the Thesis

The first group of research questions broadly framing this thesis are *what is money, what is an infrastructure, and how can they both be studied?* These onto-epistemological questions are addressed in the two chapters in Part I. Chapter 1, in particular, takes the infrastructural turn in the social sciences as a tool to pry open and revisit extant conceptualisations of money, in specific for what they say about materiality. The Cambrian Explosion provides an important empirical provocation, although not an unprecedented one (Bátiz-Lazo & Efthymiou, 2016). Chapter 2 devises a methodological toolbox to study money as infrastructure. It will expand on the methodological tools required to study money infrastructures thusly conceptualised. Departing from debates in economic geography on how to best follow and place money in time and place, the next chapter will develop a radically multi-sited methodology to match the ecological approach to infrastructures that this chapter developed (Cf. Burrell, 2009; Marcus, 1995). Chapter 2 will show how "following" of money is enabled by a "scavenging ethnographer" subjectivity (Seaver, 2017) that combines multiple field locales and hybrid online-offline research setting to both "route around" obstacles to access (Seaver, 2014) and to apprehend an object, like money, that is inherently translocal and dispersed (Hart & Ortiz, 2014).

A second set of research questions animate Part II of this thesis: *What are the specific material components that make up money infrastructures, especially blockchain infrastructures; and, what the broader interdependencies between these materialities and cultures, politics, and regulation?* Chapter 3's main contribution, through the fivefold typology of material active forms of multipliers, switches, governors, wiring, and topologies, is to "read" in the immediate politics inscribed in the materiality of money infrastructures. At the same time, this acknowledgement of infrastructures' "thing power" (Bennett, 2010) does not in a fetishisation of technology, but rather in an enrichment of the "deep relationality" (Coeckelbergh, 2013) that characterises it. This allows to lay the groundwork for establishing the "trading zone" between STS and political economy that animates this whole thesis.

Chapter 3, then, fleshes out the specific material components that make up money infrastructures, especially blockchain infrastructures. The case of Ripple provides here the jumping-off point, a revelatory case that unearths the internal diversity of any money infrastructure, its capacity for evolution and change, and the multiple, oftentimes contradictory dispositions that the same combination of active forms can engender. The chapter then reviews the explosion of blockchain infrastructures that followed the invention of this decentralised technology, and it reconstructs a taxonomy of active forms that each blockchain employs.

Chapter 4, conversely, expands on the ecological character of money infrastructures, to retrieve disposition as much more than simply the sum of the active forms internally composing it. The chapter will, then, trace the evolution of Ripple's infrastructure as a revelatory case of much broader interdependencies between materialities, cultures, politics, and regulation. The Chapter will then expand the analysis of blockchain technologies more broadly, to retrieve the core intangible yet material active forms such as stories, imaginaries and cultures that inspire it. Furthermore, it connects the emergence of blockchain technologies to longer lineages of money and finance digitalisation and alternative financial practices that composed the rest of the "Cambrian Explosion" in digital money. Lastly, it apprehends the broader political-economic fault lines traversing these industries, composed of regulatory interventions and public investments that, in multiple forms, have influenced the development and dispositions of multiple money infrastructures.

Part III of this thesis is framed by three distinct research questions that each seek to deepen our understanding of money as infrastructure and the analysis of the application of blockchain technologies in cross-border payments. First, Chapter 5 will address the questions: *Which monetary spaces do money infrastructures produce, maintain, and question? Through which material devices and practices are monetary spaces separated, connected, transformed, and maintained? Which internal and external boundaries and hierarchies do actors, devices, and practices produce?* To this end, Chapter 5 will explicitly extend the infrastructural approach taken by the thesis to connect more directly with geographical literature on topologies, literature across the social sciences on the materialities of digital spaces, and Deleuze and Guattari's conceptualisation of abstract machines of overcoding, consistency, stratification, and axiomatics. Chapter 5 will thereby conceptualise money as always inhabiting and producing stacked topologies. However, not all these stacked topologies are the same and produce the same effects: by changing the articulation of the relations between and across ledgers, four topologies are retrieved. Pyramids are embodied by central-bank operated payment infrastructures, and they entail the centralised determination of settlement rhythms. Rhizomes constantly proliferates horizontal connections of credit and debt based on trust, and they are embodied by informal credit networks such as *hawalas*. Platforms exemplify stratification, embodied by blockchain payment infrastructures. Stack, lastly, are new and emergent topologies of interoperability and axiomatics.

Chapter 6, then, addresses the following questions: *How is the materiality of infrastructure and its disposition influenced by intangible, yet material forces? In particular, how does desire, enchantment, and fascination influence how an infrastructure behaves in the world? How are these libidinal investments converted into economic speculative investments in a way that enables or forecloses specific infrastructural developments?* This chapter reads existing concerns in infrastructure studies literature on enchantments, imaginaries, and desires (Flichy, 2008; Harvey & Knox, 2012; Larkin, 2013, 2018) alongside social studies of finance and historical literatures on speculative bubbles and popular investing (Chancellor, 2000; Preda, 2001; Stäheli, 2013). It retrieves three distinct articulations of the relationship between materiality and enchantment. First, the cryptoasset bubble can be read as a new instance of the Tulip Mania of the 1630s, whereby enchantment and desire is focused on the asset itself and its own almost magical self-appreciation. Second, the cryptoasset bubble can be read as a new Dot Com bubble (Feng et al., 2001; Thrift, 2001; Zook, 2007), based on the promised capacity of blockchains to turn things into assets (Birch & Muniesa, 2020) and intermediate relations through platform business models (Langley & Leyshon, 2016, 2020) through rearticulation and monetisation of the relationship between a platform and its ecosystem. Lastly, the cryptoasset bubble can be read as the Railway Mania of the 1840s, where enchantment is towards the infrastructure itself and the seamless connectivity. Here interoperability, read against tokenisation and platformisation, foregrounds the interdependency of the infrastructure and the platform: the platform allows to monetise on interactions and assets, the infrastructure allows to "cash out" (Westermeier, 2020).

Chapter 7, lastly, delves deeper in the political economy of interoperability – the hallmark of the Railway Mania – and it zooms in on international remittances as one important form of cross-border payments, to see blockchain at work as a technology of representation and formalisation of hitherto informal relations. As such, this chapter addresses the following research questions: *What are the political-economic effects of interoperability and internetworking on the actions, interactions, and relations that are made interoperable? Which opportunities do they open for communication and circulation? What alternative arrangements do they foreclose, obscure, and disable?* The chapter argues that blockchain technologies do not represent a rupture in the tendency toward remittance formalization. Rather, these technologies represent a "frontier" surrounding formalised market relations, one that is constantly incorporated through the deployment of technologies of representation that, by making ownership of assets visible, allow for these assets to be capitalised and monetised upon. Blockchain technologies are both part of the frontiers surrounding market relations, and themselves a set of technologies of representation that make other assets visible and tradeable. This, in particular, allows the mobilisation of hitherto “idle assets” and “dead capital” such as Nostro-Vostro Accounts that banks maintain with each other in the correspondent banking regime (CPMI, 2016a).

To close out this thesis, the Conclusions chapter will summarise core arguments and draw further connections between the contributions made here and wider debates in order to elaborate possible avenues for future research. In particular, an infrastructural perspective of money will be understood as a potentially fruitful way of combining historical materialist and new materialist approaches, thereby bringing together concerns with the demystification of commodity, money, and technology fetishism, on the one hand, and Post-Cartesian understandings of material and more-than human agency and the relationality of technological systems, on the other. This proposed alliance between “old” and “new” materialism can re-politicise technology and reinvigorate debates on which technological developments we want, and which ones we want to reject, subvert, and resist.

The Conclusion will also illustrate potential avenues for future research. First, future research should consider the subjectivities that populate the space of blockchain’s infrastructural technologies and cryptoassets. While a theory of subjectivity is implicit in the neomaterialist theories of technologies, this thesis foregrounded the materialities of infrastructures rather than the actors that engage with them. One type of subjectivity worth studying will be the “token designer”, who shapes the internal functioning and incentive structure of a blockchain platform and a token. Another subjectivity is the day trader summoned through interactive spot trading apps such as Plus500, eToro, Trading 212, and Revolut (Preda, 2017; Swartz, 2020). Lastly, remittance senders and receivers using Ripple’s interoperability solutions might be a fruitful area of study.

A second area for future research expands on the property of monetary spaces as assemblages of enunciation. The thesis uncovers a broader analogy between money and language in the similarity between the act of cross-border payment and translation. Future research needs to expand into the working of cross-border payments and FX markets to uncover similarities and differences with translation platforms. Cross-border transactions between two “exotic” currencies, in fact, are often bridged through more liquid ones like the Pound, the Yen, the Euro or the Dollar. As Chapter 3 showed, Ripple tried to position

XRP as one such bridge asset. An interesting question could be whether automated translation software uses similar kinds of "bridges", for example, by using English to bridge between "illiquid" language pairs (Thornton, 2018).

A third future research area explores the political economy of liquidity as bandwidth, defined as the maximum rate of data transfer across a given path in a network. This apparently niche area of research can provide fruitful contributions to political economic approach to information and digital economies (Castells, 2010), as well as into imaginaries of money circulation in addition to already-studies metaphors (Langley, 2017), such as water (Swade, 1995), mercury (Clark, 2005), blood (Mann, 2010), electricity (Mayhew, 2011), and poison (Peckham, 2013). In fact, the fieldwork unpacked more and more frequent analogies between liquidity and bandwidth in blockchain infrastructures (Interledger, 2018b), which beg the question on how a trivial technical element can have momentous aggregate effects over entire money infrastructures.

Lastly, the methodological and theoretical toolbox provided by this thesis can be put to use to analyse larger, older, or more geopolitically strategic infrastructures of payments. While SWIFT has recently started to gain the attention that it deserves (de Goede, 2012; Dörry et al., 2018; Romaniello, 2013; S. V. Scott & Zachariadis, 2013), CLS remains a little-known institution despite its infrastructural function as clearing house for the largest financial market on the planet, i.e., FX, as Chapters 5 and 7 will expand on. CLS shows how quasi-central bank powers are partially emergent from payment infrastructures, as hinted at in Chapter 5.

PART I

Chapter 1: Towards an Ecology of Money Infrastructures

1. Introduction

This chapter takes money digitalisation and the emergence of blockchain technologies as a provocation to investigate the role that materiality plays in money. Starting from a reappraisal of commodity and claim theories, this chapter develops an infrastructural approach to money. This will enable to theorise money's materiality as exceeding the "thingness" of monetary objects, on one hand, and the ostensible immateriality and abstractness of credit relations, on the other. What is missed by both commodity and claim theories of money is the irreducible materiality of the infrastructures that allow the recording of credits and debts and that, in turn, allow for a society to identify monetary objects as money.

These conceptual realisations do not follow from digitalisation as such, understood as an unprecedented step-change in the history of money. Rather, money itself, both as a mnemonic and as an accounting technology, always holds within itself the very tension between abstraction and materiality which is often depicted as unique to the digital. Digitalisation is often conceptualised as an outright disappearance of materiality (Kinsley, 2014). However, as Ash et al (2018a) argue, "there is no monolithic 'the digital', only a variety of differently materialised objects, subjects, spatialities, effects, and affects that arise from varied practices and processes of digital production, circulation, use, and mediation."

When it comes to money, this process of dematerialisation is often inscribed in the progressive affirmation of a money form that becomes pure means of payment and exchange, depriving it from its substance and intrinsic value (Simmel, 1900/2011). However, equating digitalisation of money with its dematerialisation produces empirical and conceptual aporias: insofar as money as object tends to recede, money retains its irreducible infrastructural materiality that is necessary for its circulation (Coeckelbergh, 2015; Keane, 2001, 2005; Rambure & Nacamuli, 2008). Money, then, requires the materiality of accounting systems and devices that record credits and debts, and allow for value to circulate across time and space: "It should no longer be assumed, even at a residual level, that money and accounting have ever simply 'represented' pre-existing values or transactions" (Ezzamel & Hoskin, 2002, p. 360).

Performing infrastructural inversion on money here means reading long-standing social theoretical debates on the materiality of money through the lenses provided by neomaterialist literature in science and technology studies of infrastructure. This conceptual move is particularly pertinent to cryptocurrencies, in that the sole form of material existence of these digital assets coincides with their underpinning infrastructure of records, accounting, and payment. Rather than being radically new, cryptocurrencies remind us that every money form requires an underpinning material and technological infrastructure to function. Retrieving and specifying this infrastructure theoretically is the aim of this chapter.

Inevitably, however, a conceptual move to engage money's infrastructures through the broad and extensive neomaterialist literature raises significant questions about the very nature of "infrastructures". Running through the chapter's contribution to theorising the specifics of money's infrastructures, therefore, is also a wider contribution to the neomaterialist theorisation of infrastructures. In particular, this chapter will trace back the infrastructural materiality of both money *and* digital technologies to Stiegler's concept of "tertiary retention", i.e., a process of externalisation of memory outside the body and into technical artifacts (Hui, 2016; Stiegler, 2010). Both money and digital computation then emerge as mnemonic technologies that require an "interobjectivity" to exist, understood as the *materialisation* of both internal and external relations of objects and the creation, by materialised interobjectivities, of their own *milieux* (Hui, 2016, p. 160 emphasis in the original).

This chapter will retrieve and stress two core aspects of infrastructures that are often taken for granted: respectively, the immediate performativity and political relevance of the material components of infrastructures, and the deep ecological relationality of infrastructures themselves. Infrastructures are here conceptualised as artifacts that have politics (Winner, 1980) through the active forms populating the infrastructural space, which in turn engender specific dispositions (Easterling, 2014). They are endowed with material performativity whereby matter and meaning are intertwined, and materiality has the immediate capacity to summon specific distributional outcomes (Barad, 2003).

Susan Leigh Star's concept of ecology – and later reiterations and reconceptualisations - allows for a radically flat ontology not to result in a "flat politics" in which agency and, hence, accountability become untraceable. It also enables an analysis of elements of money infrastructures that are not immediately material, such as cultures, imaginaries and practices that imbue an infrastructure with meaning and that exert often powerful influence on its overall disposition.

Developing and departing from this conception of infrastructures as deeply political and relational techno-human ecologies, this chapter then introduces the key analytical dimensions of this dissertation. First, the chapter builds on and expands extant reflections in geography and the social sciences on topology (Lata & Minca, 2016; Lury et al., 2012; L. Martin & Secor, 2014; Mol & Law, 1994) by developing a chrono-topology of money (Lotti, 2018) based on the relationship between money, memory, and space. The chapter illustrates how memory is first instantiated in money as the chronological layering of credit and debt claims, and subsequently it is functionally layered between messaging, clearing and settlement. Furthermore, this layering is always grounded on a material basis but in a way that does not see in the monetary infrastructural "hardware" a final anchor of existence and value. Rather, the hardware is the material site of instantiation of the interobjectivity that makes money possible.

Second, the chapter will claim that infrastructures, in addition to their materiality, always already entail a semiotic, symbolic, cultural, and affective dimension that propels their functioning and that profoundly influences their dispositions. Current literature on infrastructure foregrounds the more or less already discursive and at least partly rational dimensions of cultures and imaginaries in shaping large technical systems and their disposition. This thesis, conversely, wants to expand on the ways in which non-discursive and affective elements ascribe particular meanings to technological systems, and simultaneously how they may create distinct political economies.

Third, and lastly, the chapter combines more closely science and technology studies and critical political economy approaches, to retrieve the patterns of formalisation, value extraction, exclusion, inclusion, and capitalisation that are enabled by the materialities, topologies, and imaginaries of money infrastructures. The chapter leverages the concepts of "formalisation" and "technologies of representation" by Timothy Mitchell (2007) to describe the use of imaginative, theoretical, and material tools to turn "dead capital" and "idle assets" into sources of revenue through the formalisation of property rights.

The chapter, then, retrieves (digital) money infrastructures as caught between to polarly opposite tendencies which are nonetheless mutually necessary: platformisation and interoperability. The former stands for widespread assetisation and tradeability of multiple income and data streams, as well as the struggle to achieve monopoly rents in the intermediation of multi-sided markets. Often considered under the rubric of what Star and Lampland (2009) considered "boring things", interoperability is typically acknowledged as mere standardisation aimed at reducing frictions and transaction costs. However, and with the specific illuminative example of money infrastructures built on blockchain technologies and DLTs, interoperability is far from being a neutral endeavour. As the literature on "walled gardens" shows, the existence of platforms is predicated upon the existence of an underlying interoperable infrastructural layer that allows to "cash out" and to realise investments and trades.

The remainder of the chapter is structured as follows. Section 2 frames the conundrums associated with money and materiality in extant literature on the social theory of money and identifies money's infrastructures as a promising empirical and theoretical *locus* around which the true irreducible materiality of money can be retrieved. Section 3 then defines the neomaterialist approach that the thesis will take to infrastructures, expands on the immediate performative and political capability of material active forms in determining an infrastructure's disposition, and further develops an ecological conception of infrastructure. Sections 4, 5, and 6 expand, respectively on the infrastructural relationships between money, memory, and space; on enchantment and desire in money infrastructures, and on interoperability and platformisation as political-economic drives in infrastructural spaces. The conclusion summarises the chapter.

2. The Matter of "Virtual" Money

Money's materiality represents a conundrum for social theory. Money is understood as either a commodity which stems from the free exchange of barter, or as the social relations of credit and debt denominated in an abstract and immaterial money of account (Schumpeter, 1917/1956). The next sections reconstruct money as conceptualised by, respectively, commodity and claim-credit theories, and it then moves on to add an infrastructural perspective.

2.1. Commodity Theories

Those who argue that money emerges out of barter foreground money's *thingness* and derive money's inherent value from that. This genealogy often traces its origin back to a commodity, like precious metals, used in barter to facilitate exchanges. Money, thus, acquires four functions: unit of account, medium of exchange, means of payment, and store of value (Desan, 2014; Ingham, 2004). For commodity theories, money is "the God of the realm of commodities", in that it brings to the extreme the two functions of any object understood as a commodity: "to be put to use and to be possessed" (Baudrillard, 1968/2005, p. 91). The "use" of the money-commodity corresponds to its means of payment function, while money as property corresponds to its function as store of value. As Yuran (2014, p. 76) succinctly puts it:

> What [money] carries to an extreme is precisely this element of exclusion, of *not yours*, that is essential to private property. Money is the extreme form of ownership because it has no other quality but ownership-it has no sense outside the context of ownership. Yet, precisely as an extreme form of private property, it has nothing truly private in it: it is completely meaningless as a private object.

As Ishmaev (2017) shows, the Hegelian theory of property that Marx develops is that of a public, not private relation: that which is owned is not only owned because someone appropriated it, but because the rest of society recognises that property as *not theirs*. Property has little to do with the might of the actor who appropriates, and everything to do with the collective that recognises its deprivation deriving from the act of appropriation.

Money, then, folds onto itself a problematic relationship between money and memory. Money as a commodity – through the commodity fetish – works by erasing its past and its underpinning social relations, yet the collective nature of property requires collective memory, in that society constantly must remember that something, be it real estate or a sum of money, is *not theirs* (Yuran, 2014; Cf. Hart, 2014). In this sense, money as a commodity slips into money as a "claim upon society", as theorised by Georg Simmel (1900/2011, p. 176).

For commodity theories, the stakes in understanding digital money derive from an apparent contradiction between money's function as store of value and medium of exchange, on one side, and those of unit of account and means of payment, on the other. While the former two functions seem inextricably linked to the inherent value of money's substance and materiality, the latter two seem connected to the progressive dematerialisation of money, a becoming-immaterial that is also becoming-function of money itself (Dodd, 1994, p. xviii). Marx (1867/1982, pp. 222-223) expressed this tension in these terms:

> The fact that the circulation of money itself splits the nominal content of coins away from their real content, dividing their metallic existence from their functional existence, this fact implies the latent possibility of

> replacing metallic money with tokens made of some other material, i.e., symbols which would perform the function of coins.

Georg Simmel, albeit from a rather different standpoint, identifies a similar tendency for money to dematerialise. He called this process "spiritualisation", wherein "only to the extent that the material element recedes does money become real money, that is a real integration and a point of unification of interacting elements of value, which only the mind can accomplish" (Simmel, 1900/2011, p. 198).

2.2. Claim and Credit Theories

As noted above, commodity and historical materialist theories of money contrast with claim, credit, and chartalist theories of money, divided as they are between those who give primacy to private credit networks or to the state in defining the unit of account and in issuing currency (S. Bell, 2001; B. G. Carruthers & Espeland, 1991; Ingham, 2004; Keynes, 2013; Knapp, 1924; Kocherlakota, 1998). As Ezzamel and Hoskin (2002, p. 335) have it, "money's genesis was as money of account, in contrast to traditional approaches which view it as a 'response' to demands for a medium of exchange or store of value". Ingham (2004, p. 12), succinctly, defined money as "a social relation of credit and debt denominated in a money of account".

Claim theories, then, take as their starting point what for commodity theories is a conundrum: money, for claim theorists, is *ab initio* an abstract and immaterial instrument. As Einaudi reconstructs, in the Charlemagne system of pound, shillings, and pence – connected through the ratio 1:20:240 – the pound was never coined (Einaudi, 1953). As Mitchell Innes put it,

> The eye has never seen, nor the hand touched a dollar [...] What *is* a monetary unit? What is a dollar? We do not know [...] what we do know is that the dollar is a measure of the value of all commodities, but is not itself a commodity, nor can it be embodied in any commodity. It is intangible, immaterial, abstract. (Innes, 1914, pp. 155-159)

As Keith Hart said, "the memory bank [...] is money itself" (Hart, 2000, p. 9). More recently, Rachel O'Dwyer (2019b) showed how the link between money and memory is made all the more evident and compelling in light of the emergence of digital transactional technologies such as payment platforms. Minsky (2008) famously defined the act of creating money as a two-sided balance sheet operation. He argued that everyone could create money, the problem then would be to have it accepted. Stephanie Bell (2001), however, rightly pointed out that acceptance is a non-started for a theory of money generation: if money is a *two*-sided balance sheet operation, its creation begins with acceptance, i.e., it begins with someone issuing credit to someone else who, in turn, accepts that credit *as if* it was money.

Money, then, does not start as a point, as an object that becomes money and later enters exchange and circulation. Rather, "The unit of matter, the smallest element of the labyrinth, is the fold, not the point" (Deleuze, 1993, p. 6). The coin is always already a relation of credit and debt: "In the beginning it was not the coin: it was the receipt" (Maurer & Swartz, 2017, p. xvi). Each accounting book is a fold that generates money by recording it as someone's assets and someone else's liabilities. The monetary space, hence, begins and ends with the book. An accounting book could, potentially, grow indefinitely but, at the same time, it can only "see" the relations that invest the bookkeeper. Hence, the first border of money is the border of the book where debts and credits are stored. The need for correspondent accounting is always present as the deterritorialising principle of the book and the territorialising principle of any monetary network. A monetary network can only arise when multiple books are synchronised in the money they use, how they settle their obligations, and how they communicate with one another.

For commodity money to work as money, there needs to be a material system in place that allows all participants to exchange to recognise objects made of or referring to that commodity *as if* they were money. If commodity theories of money, when confronted with digital monetary objects, need to acknowledge the infrastructural interobjective materiality that make these objects money, then claim theories of abstract money need to be reminded of the "irreducible materiality" of any sign, for even if money were a pure sign, it is also true that no sign is fully immaterial. In short,

> we remain heirs of a tradition that treats signs as if they were merely the garb of meaning-meaning that, it would seem, must be stripped bare. As this tradition dematerialises signs, it privileges meaning over actions, consequences, and possibilities. (Keane, 2005, p. 184)

Neither money nor memory nor digital computation can ever fully decouple themselves from materiality. As Yuk Hui (2012, p. 387) illustrates:

> Digital objects appear to human users as colourful and visible beings. At the level of programming, they are text files; further down the operating system they are binary codes; finally, at the level of circuit boards they are nothing but signals generated by the values of voltage and the operation of logic gates. How, then, can we think about the voltage differences as being the substance of a digital object?

> Searching downward we may end up with the mediation of silicon and metal. And finally, we could go into particles and fields. But this kind of reductionism doesn't tell us much about the world.

Digital objects themselves are not only the product of relations between multiple kinds of materialities, but they are the very results of multiple processes of materialisation of those relations:

> A general tendency of technology consists in the materialisation of all sorts of relations by rendering what are otherwise invisible elements or aspects in *visible* and *measurable* forms. [...] The second dimension is that materialised interobjectivities create their own milieux that connect both nature and artifacts. (Hui, 2016, p. 160 emphasis in the original)

As we shall see in section 4, even when money is moved in the form of coins and notes, these artefacts are not the "authentic" materiality of money, but rather a complex and layered mnemonical technology folded onto an object, they are "receipts, accounts, and proto-monetary tokens in one" (O'Dwyer, 2019b, p. 136). In the folds of money, "the line of inflection is actualised in the soul but realised in the matter" (Deleuze, 1993, p. 35), i.e., the abstract functions and properties of money can be folded onto the same object, yet they might remain separate in categorical terms. The digitalisation of money, then, is a process of externalisation of economic memory into more and more complex technological systems, a process defined by Simondon and Stiegler as grammatisation (Simondon, 2016; Stiegler, 2010). Digitalisation, then, results in an expansion rather than a contraction of money's materiality.

As we shall see below, this materialised interobjectivity is a deeply relational infrastructural materiality, where infrastructural does not mean "foundational", but rather as the material substratum channelling and shaping flows and circulation, hence articulating the relationship between socio-technical individuals and their associated milieu (Kaufmann & Jeandesboz, 2017). In fact, in neo-materialist accounts of technogenesis, individuals, being them natural, technical, or digital objects – including humans – are not taken as given, but as the result of processes of individuation that always occur in pairs, at once producing individuals and their milieux (Kinsley, 2014; Simondon, 2006; Stiegler, 1998). Even *if* we assume that money is primarily an object, and even *if* we centre our analysis on digitalised money as a collection of digital objects, the question of materiality would pose itself because digital objects are predicated on relational interobjective materialities (Hui, 2012, 2016).

2.3. More Rail That Train: An Infrastructural Definition Of Money

This thesis does not only inflect an infrastructural imagination on money, but it also argues that money is an infrastructure. This generates a need for categorical specification between money-objects as *quanta* of value and money as infrastructure. In short, I argue that money is more rail than train, i.e., moneyness derives from the complex ensemble of standards, procedures, and material components that enable *quanta* of value to flow, rather than from those *quanta* themselves. This sub-section develops this argument to enable a translation of terms and concepts in the infrastructural literature into debates about money, and vice versa, in the next section.

As we saw earlier, understanding money as an object that travels from sender to receiver, either incorporating or representing value, creates a problem: even when money's value is considered to be inherent to its matter, this happens only because the production of the money commodity obscures the social relations that made it possible. Furthermore, both ostensibly "inherently" valuable objects and purely symbolic monetary objects derive their moneyness not from the signs they bear, but from the infrastructure of accounting that makes them valuable, that makes them recognisable *as* money.

Ezzamel and Hoskin (2019b) understand money of account as a supplement emerging from the combination of token accounting, calculus, and writing. Drawing on Derridean understanding of the supplement, they understand money as a double supplement of both accounting and writing that, by virtue of remaining secondary, supplants the very relations it supplemented. Money, in short, "constructs value by denominating it as something other than, and separate from, either the commodity or its accounting" (Ezzamel & Hoskin, 2002, p. 347). Money, then, emerges as something else, and something deeper than the token used, or the accounting underpinning those tokens. While token accounting was the very foundation of abstract, double-entry bookkeeping, moneyness is produced as a supplement to token accounting, a supplement to values-as-train, that then supplants what it supplements: money-as-rail takes over the material form of the previous material form that value assumed. As argued by Gustav Peebles regarding cash versus digital money, "Cash is the material body that houses the soul qua value; demonetisation is simply the death of a given material body. […] A given material object can only house economic value because *outside others* continually affirm its legitimacy" (Peebles, 2020, pp. 104 and 111).

As we saw in the previous section, money has been defined by Keith Hart as a Memory Bank. He goes on to add that "the origins of the institution in Europe drew a firm association between money and *collective* memory" (Hart, 2000, p. 9, emphasis added). The term collective is key here: even though in Chapters 5 and 7 we shall see how different infrastructural architecture modulate collective memory in different ways, some of which imply the portability of memory and its detachment from the material events that produced it, money is always collective. As Amato and Fantacci (2012, p. 34) have it, money as a clearing system "makes it possible to register (1) a debt owed by someone who is required to make a payment but cannot do so immediately; and (2) the corresponding credit in favour of the party to be paid." This system, however, as Amato and Fantacci (2012, p. 34) have it, is

> from the very outset a trilateral rather than a bilateral relationship: both sums are registered as debit or credit with respect to the system as a whole. […] In this way debit and credit are not individual and fungible positions but acquire their meaning in relation to the entire set of relations constituting the system.

What is fundamental about money is not the monetary object or the accounting relationship, but the collective supplement to any given bilateral accounting relationship with the collective level. The decoupling between money as value "in flight" between sender and receiver and money as the infrastructure that enables to perceive the former as value is further specified by Ingham: "the advantages of money for the individual presuppose the existence of money as an *institution* in which its 'moneyness' is established" (Ingham, 2004, p. 23 emphasis in the original). Unlike Ingham (2002), however, this thesis argues that technological infrastructures, and not only institutions and states, have historically produced, and still produce nowadays specific monetary forms and spaces.

It is from the point of view of infrastructures as the "trilateral" nature of money illustrated by Amato and Fantacci, or the supplement indicated by Ezzamel and Hoskin, that digitalisation provides an important paradigmatic illustration of the infrastructurality of money, while at the same time not representing a categorical shift from previous forms of moneyness. Digitalisation does not change what money is, or it does not make money infrastructural where previously it was not: it simply makes untenable the idea that money was not *ab initio* an infrastructure. Yuk Hui shows how digital objects are material, in that they can be reduced to electrical impulses that run through cables, but these impulses are meaningless without them being encoded by the sending machine and decoded by the receiving one.

The same applies to money: money is interobjectual *both* in its physical-analogic form *and* in its digital form. In fact, as O'Dwyer (2019b) shows, cash money bears onto itself a layering of records and assets that allows it to settle debts *when it moves* as an object. Cash still needs an infrastructure made of a central bank registry that records how many units of notes, bills, and coins are issued and minted, a logistical infrastructure that allows them to move, and very complex cash management procedures that avoid theft and forgery. But that infrastructure is not quintessential to allow *all* units of cash to move *at all times*. If the Royal Mint's presses stopped working today, I could still pay with the cash I already have in hand, and the case of Indian demonetisation shows how hard it is to deliberately stop the circulation of material monetary objects (Srinivasan, 2017).

However, while the value it represents moves across space, digital money does not move *strictu sensu*: there is no object that materially travels across space and that settles debt, but rather a list of instructions that, when executed, are agreed upon to represent the final discharge of obligations. Two instructions encoded in the same number of bytes – i.e., that require the same number of electrical impulses to be sent to destination – can represent wildly different monetary values, and vice versa: the same sum, sent through an MT message, requires on average 500 bytes to be sent, while it requires 3500 bytes if sent through an ISO20022-compliant MX message (SWIFT, n.d.).

In blockchain technologies, a transaction message does not move from sender to receiver, but from the sender node to one of the full nodes in the blockchain consensus network and, through gossip protocols, to one of the validators. Then, each validator packages transactions into blocks including potentially very different transactions, drawn from the pool of unauthorised transactions they accumulated by "listening" to messages relayed by nodes[3]. These transactions are then added to the blockchain once a block is validated, and there is where money "moves". Each sum is only valuable and can only be spent because it is included in the Unspent Transaction Outputs (UTXO) database that miners check when validating transactions. Each UTXO is then destroyed as soon as it is spent, to make it unspendable again. Each sum can be traced back to the UTXOs that have been "destroyed" in past transactions (Antonopoulos, 2017, pp. 119-120). The Bitcoin as an object only exists as reminder of a chronology of records, and it only moves as a message through an

[3] See Chapter 3 and Appendix A for an explanation.

infrastructure, to the actualise its value, again, as a record on a collective accounting system, as we shall see in Chapter 7.

Hence, if the wires are the rails, then messages are the trains. The sums represented in those messages, like the objects contained within trains, can be understood as *value*, or valuable. However, for them to be recognised as money they need to be plugged into an infrastructure that allows to translate messages into accounting changes, hence finally discharging obligations. Hence, this thesis agrees with Kavanagh et al. (2019, p. 519) when they say that money is an information infrastructure because

> Like other infrastructures, it is widespread and pervasive, yet invisible while working. […] In the case of money, the invisible infrastructure includes the legal, tax and banking systems, an elaborate system of regulatory practices, the state control of the police, military and prison systems, and the soft infrastructure of norms and values.

Money understood as an infrastructure stands for the "record of all manner of relationships of credit and debt across time and space […] all the systems for transferring money, recording those transfers, and creating great globally expansive ledgers" (Maurer, 2017b, p. 111). They comprehend Financial Market Infrastructures (FMIs), defined as "a multilateral system among participating institutions, including the operator of the system, used for the purposes of clearing, settling, or recording payments, securities, derivatives, or other financial transactions" (BIS & IOSCO, 2012, p. 7). This definition, in this thesis, is enlarged to include informal and alternative payment and monetary systems.

Claiming that money is infrastructure, however, does not correspond that money is *only*, or even *primarily* infrastructure (Cf. Peebles, 2020, p. 109). As I argued elsewhere (Rella, 2020) the issue is not that of providing yet a new definition of money that can solve the contradictions posed by other definitions of money, but of illustrating how an additional analytical dimension of money can be revealed and made thinkable if we start thinking that money is an infrastructure, while money retains its other natures as a tool for power, an object of regulation, a means to accumulating value, an affective device framing identities and attachments, a rhetorical and moral device, etc.

3. Money as Infrastructure

This thesis argues that payment infrastructures are the *loci* through which money's materiality, abstraction, universality, and cultural specificity play out. Infrastructures, however, remain peculiarly hard to define. "Discussing an infrastructure" Larkin (2013, p.

330) argues, “is a categorical act [that] recognizes that infrastructures operate on differing levels simultaneously […] and that any particular set of intellectual questions will have to select which of these levels to examine”. In particular, it is important to spell out which contours does an infrastructure have both empirically and conceptually.

Star tried to give a list of properties that infrastructure show, made of nine items. First, infrastructures for Star (1999, pp. 381-382) are embedded into other structures, social arrangements, and technologies. Second, they are transparent to use: in Heidegger’s (1996, p. 67) terms, the peculiar characteristic of infrastructures is their *Zuhandenheit*, i.e., they are always ready to hand without having to learn how to use them at every interaction. Third, infrastructure has a trans-local reach. Fourth, the taken-for-grantedness of infrastructures is part of the process of acquiring membership of a community of practice. Fifth, infrastructures shape and are shaped by the conventions of said community of practice. Sixth, infrastructures “plug in” to other infrastructures in a standardised fashion. Seventh, they are not built anew, but they are installed on a pre-existing basis that exerts some degree of inertia and obduracy. Eighth, infrastructures become visible upon breakdown. Ninth, infrastructures are fixed and repaired in modular increments and not all at once or globally.

However, Star’s definition is not meant to be a “test” of what is and is not an infrastructure, but rather the list of features that we might expect when studying the interaction between a technology and the community of its users. In fact, the very epigraph of the section devoted to defining infrastructure in Star’s paper “The Ethnography of Infrastructure” (Star, 1999) is a quote from the cyberneticist Bateson (1978, p. 249): “What can be studied is always a relationship or an infinite regress of relationships, never a thing”. Hence, For Star and Ruhleder (1996, p. 112), the right question is not “*what* is infrastructure?”, but “*when* is infrastructure?” – it is precisely its invisibility and “taken-for-grantedness” that makes infrastructure hard to specify.

One can take a reductive view of infrastructure, that treats them essentially as technical networks, or an expansive one. A reductive view sees infrastructure as “a substrate: something upon which something else ‘runs’ or ‘operates,’ such as a system of railroad tracks upon which rail cars run” (Star & Ruhleder, 1996, p. 112). In a similar fashion, Çalışkan assumes that infrastructures as “matters that allows the movement of other matter” (Larkin, 2013, p. 329 cited in Çalışkan 2020, p. 542). “Infrastructures” Çalışkan (2020, pp. 542-543) adds, “arrange the ways in which architectures, that are built on them, connect and bypass each other. They are meta-structures that make possible the building of architectural designs that harbour and form possible trajectories of action". Infrastructures and architectures, assigned to the category of networks, interact with devices, actors, and representations (Çalışkan, 2021b).

Conversely, an expansive view of infrastructure assumes that "the simple linear relation of foundation to visible object turns out to be recursive and dispersed" (Ibid., pp. 329-30), because, for example, electricity might be the infrastructure for the functioning of the computer, but computers are themselves the infrastructure underpinning the energy grid. As we shall see below and in Chapter 6, Larkin is also the author that stressed, in the strongest terms, the cultural, semiotic, and imaginative forces traversing infrastructures and making them possible (Cf. Harvey & Knox, 2012). Nonetheless, this second, expansive view of infrastructure runs into risks of its own. Çalışkan (2020, p. 542) goes on to argue that

> One has to be careful against reviving sociological structuralism, this time in the form of *infrastructuralism*. It would be problematic to categorically propose that infrastructures are primary frameworks that give birth to secondary social behaviour or 'the action'. Networks can determine or have a larger say in how actors behave, but this is a possibility, not a rule.

While this thesis agrees with the first part of the claim – it is true that foregrounding infrastructure, and the conceptual move of infrastructural inversion, should not amount to a neomaterialist return to structuralism – it does not agree with the second part of the claim: infrastructures are not simply or only networks.

When this thesis adopts an infrastructural perspective, it does not take the material element as a network that then enters into a dynamic interaction with devices, actors, and representation. Rather, it takes the whole infrastructure as an ecology of technical material components such as networks, devices, active forms, and their resulting dispositions, alongside which co-evolve users, user cultures, imaginaries, regulation, and other forms of social, cultural, and political interaction. This thesis argues that this recognition of the agential capacities of infrastructures is an antidote, rather than a symptom of infrastructuralism. It is by recognising the capacities of infrastructures to act and react, affect, and be affected, that we can better retrieve the limits, conditions of possibility, and multiple forms of inertia that prevent infrastructures from having an unproblematically structural and structuring effect on their surroundings. By being actors among others, infrastructures cease to be infra-*structures* and become the material site where their dispositions are activated and inhibited by the presence or absence of other sources of agency and power.

In recognising the agential power of infrastructures, this thesis contributes to overcome "the analytical divide between things and humans" that Çalışkan and Callon (2009, p. 390) illustrated as an obstacle in anthropological studies of economisation. This enables "to drop the hypothesis of an ontological asymmetry between […] subjects/agents and […] things/objects/goods altogether, while integrating the active role of materialities more generally" (Çalışkan & Callon, 2009, p. 393). The expansive notion of infrastructure deployed in this thesis resonates with the notion of *agencements* as "arrangements endowed with the capacity to act in different ways, depending on their configuration […] considered from the point of view of their capacity to act" (Çalışkan & Callon, 2010, p. 9). The idea that infrastructures are not simple media or substrata, that they are do not pertain simply to the realm of networks but that they ecologically co-constitute actors, can be argued through Quattrone's (2009, p. 108) idea that accounting books represent a specific disposition to reading. Accounting books invite a specific *praxis* inherent in the interaction with them, that is differentiated from other media, such as scrolls of parchment.

The agential quality of infrastructure comes to the fore when one thinks of the increasing self-executing capacity that inscriptions within infrastructures have. Smart contracts, for example, can be run in a way that, once initiated, does not require, or even allow human intervention to stop them (De Filippi, 2014). While some degree of human agency in initiating that calculation might be required, in studying interactions, instances of calculation produced within the infrastructure can achieve the role of actor, rather than simply actor-enabling or actor-constraining characteristics of networks.

If infrastructures are not only networks, but it is also true that the boundary between actors and networks can often be blurred or reversed. As shown in urban geography by AbdouMaliq Simone (2004), people and bodies can be infrastructures *in themselves*, i.e., being the preconditions of other forms of action and circulation. This has also been illustrated in the analysis of informal value transfers such as "human ATM" (Maurer, Taylor, et al., 2013) in remittance services, or in studies of *Hawaladars* and other human payment networks such as those illustrated in Chapter 5. The next sub-section will delve more in-depth into the ontological and analytical specification of the role that materiality and its articulations – the active forms – play in defining the overall behaviour – the disposition – of money infrastructures.

3.1. Active Forms and Dispositions

If infrastructural inversion is also – although not only – a form of demystification of infrastructures, then the first step is to produce a vocabulary apt to scrutinise, categorise and illustrate the agency that the materiality of infrastructure is endowed with. Money infrastructures "have politics" (Winner, 1980) in and of themselves because they enable and disable specific types of behaviour, hence they engender specific political economies with their distinct distributional consequences.

More specifically, Keller Easterling deployed the concepts of active forms and dispositions, which provide critical purchase for unpacking the material politics and material political economy (Brekke, 2020; D. MacKenzie, 2017b, 2018b) of money infrastructures. Disposition stands for a "relationship between potentials. It describes a tendency, activity, faculty, or property in either beings or objects-a propensity within a context" (Easterling, 2014, p. 71). In turn, "Active forms are markers of disposition, and disposition is the character of an organisation that results from the circulation of these active forms within it" (Ibid, p. 72). This allows us to go beyond a purely metaphorical appreciation of the materiality of money infrastructures and to apprehend money's internal design in its own terms. Active forms can be the governor of an infrastructure space, they can be the material wiring as well as the less-material internal topology of interconnected networks, and they can be switches and/or multipliers that selectively enable and disable specific interactions, and which might make certain choices laborious or unduly expensive.

Surprisingly, Easterling's disposition can find a direct link to the history of accounting in the concept of *dispositio,* which in 1500s guides to accounting techniques was outlined as the "creative act in which the accounts are aggregated and reshuffled according to the *intentio*, which is always changing, multiple, and formed in networks of religious, political, economic and other matters relating to the governing of the order" (Quattrone, 2009, p. 95). Disposition is then the internal order of accounting systems, but the materiality of these systems allow them to "act" in ways that exceeds the *intentio* of the designers.

Furthermore, infrastructures are the site of a power struggle over design, control, access, and distributional effects of active forms and dispositions: "money is not only 'infrastructural' power, it is also 'despotic' power. In other words, money expands human society's capacity to get things done, but this power can be appropriated by particular interests" (Ingham, 2004, p. 4). The control the state exerts over money infrastructures reverberates with chartalist accounts on the origins of money itself (Knapp, 1924; M.

Hudson, 2004; Randall Wray, 2014; Wray, 2004) as well as on International Political Economy accounts of the role between state, society, and markets (Cohen, 2008; Corbridge et al., 1994; Helleiner, 2003; Strange, 1996).

Contemporary sociological (Dodd, 2014; Zelizer, 1999), political (Cohen, 1999, 2001; Helleiner, 2003, 2017), anthropological (Guyer, 2012) and geographical (Gilbert, 2012, 2015; Mann, 2010) accounts provide a more nuanced way in which this top-down establishment is always resisted, contested, and negotiated in ways that require us to distribute agency across society as a whole rather than centring it in specific institutions and places. Post-colonial scholarship on monetary practices such as remittances and informal economies also advise us to "provincialise" the state and its borders (Datta, 2012; S. Singh, 2013), and to consider the geography of monetary practices beyond the polar opposite of Westphalian v. Westfailure (Strange, 1999).

3.2. Infrastructures as Ecologies

As we saw before, there seems to be an onto-epistemological tension between political economy accounts of money and the intent of this thesis to study money infrastructures from a new materialist viewpoint in science and technology studies. Such tension derives from profound divergences on whether one can understand technology relationally while also acknowledging its direct socio-political import. As hinted at earlier, these differences are not fundamental and irreconcilable, and this sub-section will develop steps towards an ecological understanding of infrastructure which will enable a combination of science and technology studies' concerns with non-human agency with political economic concerns with power structures and distributional outcomes of large technical systems.

Star (1999, p. 380) conceptualises infrastructures as "fundamentally relational […] becoming real infrastructure in relation to organised practices". This relationality assumes the characteristics of an ecology:

> A web is composed of filaments, and a seamless web should be an oxymoronic term. There is no empty space in a seamless web, but our image of network is that it is filaments with space between. For this reason, I prefer ecology. Let us use networks- without-voids for an ecological analysis (Star, 1995b, p. 27).

This conceptualisation of infrastructures as ecologies is echoed by Coeckelbergh's (2013, p. 59) concept of techno-human ecologies, which in also resonates with Kinsley's (2014) use of technicity to understand the co-constitutive nature of the human-technology relations. Techno-human ecologies are, for Coeckelbergh, “deeply relational”:

> This ‘deep relational’ approach to human being implies recognising that we are always already related to technology as we act with things and live with things. Technology is not an external instrument but is part of what we are and what we do. There is mutual pervasion, change, adaptation, and life. (Coeckelbergh, 2013, p. 58)

This conception of ecology has then two dimensions, one analytical and one historical. Historically, ecology or what Hörl (2017) calls the “technoecological condition” stands for the trajectory of grammatisation of technology, of de-naturalisation of the concept of ecology, and, eventually, the removal of an “end” and purpose in techno-human and techno-natural relations. The history and genealogy of the term ecology is deeply intertwined to the development of cybernetics as an integrative approach to socio-technical systems (Golley, 1993), where the label “system” has been applied to information (Nardi & O’Day, 2000; J. Smith & Jenks, 2005) and media (Luhmann, 1989), machines (Hui, 2020) and mind (Bateson, 1978; Guattari, 2005). For Hörl (2017, p. 14),

> What the generalisation of the concept of ecology and the emergence of ecology as our new historical semantics spell out is precisely the great challenge of the politics of concepts and theory of our time: the genesis of the technoecological culture of sense.

The technoecological condition accounts for the “deep time” of relatively new media and for the profound ecological and geological impact that the “ecological materiality of technology” (Parikka, 2017, p. 169) has been exerting over surrounding natural and social systems (Mattern, 2017; Parikka, 2015; Zielinski, 2006; Boehnert, 2018; Peters, 2016). At the same time, by showing the effects that technology has on its surrounding *milieu* (Simondon, 2016) and *Umwelt* (von Uexküll, 2001), technology becomes prone to be analysed as an ecology: the internal interactions or intra-actions (Barad, 2007, p. ix) require a conceptual vocabulary and an imaginary that allows more space for pervasiveness of agency and recursivity and non-linearity of causes and effects (Cf. Anderson et al., 2012b, 2012a).

Star’s concept of ecology refuses social/natural or social/technical dichotomies. The concept of ecology also rejects biological or functionalist metaphors of harmonic balance and orderly internal competition, associated with the concept of “ecosystem” (Holmes, 2009; Hörl & Burton, 2017). Ecology represents a concept that stands for the continuousness of the effect of technologies, compared to the discreteness of the notions of enrolment, connection, mediation, translation. For Parisi (2017, p. 83), ecology is not just an "interaction of parts" but "the capacities of an environment defined in terms of a multiplicity of interlayered milieux or localities, to become generative of emergent forms and patterns".

Ecology, furthermore, foregrounds politics, power, and conflict as instrumental and foundational to any ecology and to any infrastructure. The point is to show

> Why and how some human perspectives win over others in the construction of technologies and truths, why and how some human actors will go along with the will of other actors, and why and how some human actors resist being enrolled (Fujimura, 1991, p. 17).

Ecology, then, allows for an "ecology of separation" (Neyrat, 2017) because "without the capacity to produce a distance within the interior of a socio-economic situation, no real political decision is possible, no technological choice is truly conceivable" (Ibid, p. 101).

4. Analytical Investigations

Having specified the coordinates according to which infrastructures are analysed – the direct and material performativity and politics of infrastructures' design, and their ecological internal and external functioning – the next three subsections indicate three analytical lines of attack to expand the present understanding of money's infrastructures. The next section expands on the theme of space and time through discussions in geography and science and technology studies on topologies and rhythms, to understand how money infrastructures "script" time by producing peculiar chrono-topologies. Section 4.2. expands on cultures, imaginaries, enchantments, and desires as intangible, yet material, active forms (Çalışkan, 2021a, p. 129) driving the expansion of infrastructures and influencing their active forms and dispositions. Section 4.3. delves more directly with the politics of infrastructure by analysing how interoperation and standardisation are far from technical endeavour, but rather specific forms of politics of formalisation that produce new assets and incorporate them in new forms of exchange and value extraction.

4.1. Chrono-Topologies of Money

Whilst infrastructural materiality shapes, distorts, and morphs the social, political, economic, and physical space around it, infrastructures also require to be placed and located in specific points: as Hönke and Cuesta-Fernandez (2017) have argued, infrastructured spaces are topolographical (see also Moriset & Malecki, 2009; Moriset, 2018; Zook, 2018). In their studies of, respectively, the automation of finance and the geography of High-Frequency Trading data centres, Juan-Pablo Pardo-Guerra (2019) and Donald McKenzie (2017a) show that, even in a world where the speed of light and Earth's curvature are the last standing obstacle to the seamlessness of value circulation, there is the need for a particular topography of where physical telecommunication infrastructures need to be placed to optimise costs.

This thesis, then, disentangles the specific spatial formations of money infrastructures. Part of this dissertation's project is to develop a new materialist topology that ought not to be loyal to the mathematical principles of topological models, but close enough to the material configuration of relations and distribution of resources embodies in things, devices, and infrastructures (Coleman, 2011). This thesis argues that at stake is less a conceptualisation of space as such – whether space is topological or topographic – and more the conditions of possibility that material configurations create and destroy, open up and obscure (D. Bell, 2011; Elden, 2011; Paasi, 2011).

Martin and Secor (2014, p. 423) argued that poststructuralist geographers ought to develop a post-mathematical topology which "is less concerned with fidelity to mathematical principles than with articulating a poststructuralist idea of space". This thesis agrees with Martin and Secor's approach to topology vis-à-vis mathematical principles: the issue here is not to apply Euclidean, spherical, or hyperbolic geometry to money and payment system infrastructures (Cf. John Allen, 2011a, 2011b, 2016; Lata & Minca, 2016). Till Straube (2016) recently defined this approach to topology as metonymical rather than metaphorical, i.e., topology needs to be considered as capable to provide analytical tools "that take a real technical model (actually informing system building practices […]) and slightly widens its scope while staying close to the original context" (Straube, 2016, p. 6).

In particular, this thesis argues that money infrastructure always produces a stacked and layered topology deriving from the layered accumulation of credit and debt claims on the one hand, and from the rhythms of clearing and settlement, on the other. In fact, if money is first of all record and memory, then this memory is materially stored, which enacts the present as "the most contracted degree of an entire past, which is itself like a coexisting totality. […] memory contracts a differential level of the whole" (Deleuze, 1994, p. 84). This focus of "differential level" points to a shared material element to memory and computation, one which will be shown here to be shared by money as well. Money, memory, and computation all operate in layered, stacked fashions that at the same time list instructions in chronological order and proceed through differential levels of abstraction from the "physical" to the "abstract", from hardware to software.

First, as Rory Solomon (2013) has shown, the stack is a layering and listing of computational instruction that are then executed one after the other according to the principle "last in, first out", i.e., the most recent instructions are executed first (See Figure 2).

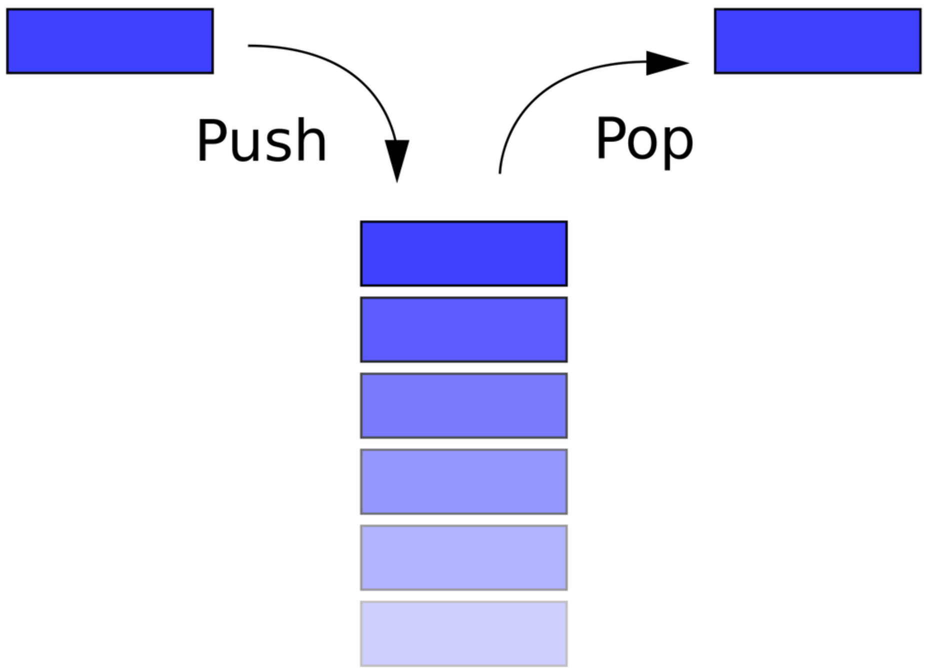

Figure 2: The Computational Stack. Source: Solomon (2013).

In reconstructing the operation of the London Clearing House in the late 19th century, Campbell-Kelly (2010) compared them with the ones of "an algorithm":

> By adding up all the checks on which it owed money, and all those on which it had to pay out, a bank could calculate exactly the total amount it would have to pay out or would receive that day (Campbell-Kelly, 2010, p. 20).

Second, the stack is not only a chronological arrangement of instructions, but also a hierarchical relationship between functions to allow for communications between machines. Stacks organise computational functions modularly so that each layer can operate without knowing how the layer below or above works, but simply by exposing an interface to those layers where data can be decoded and re-encoded (Blanchette, 2011). Straube (2016) illustrates how protocols produce real hierarchies between different levels of abstraction from the physical layer to the application and interface layer.

Benjamin Bratton recently expanded this understanding of the Stack as a model that "allegorises [the multi-layered structure of software protocol stacks in which network technologies operate within a modular and interdependent vertical order] into a general principle of systems" (Bratton, 2016, p. xviii). The chrono-topology that this thesis develops departs from Bratton's totalising stacked topology in that it requires more specification to flesh out the peculiar materialities that the stack of money assumes in legacy payment infrastructures vis-à-vis mutual credit networks, cryptoassets, and interoperable monetary spaces. Furthermore, in Chapters 5 and 7 this thesis criticises Bratton's scalar assumptions: rather than being an "accidental megastructure" (Bratton, 2016, p. 8), the stack is an "infrastructural fractal" (Jensen, 2007) that produces mega-consequences out of repetition of micro-technologies of interoperability.

Rachel O'Dwyer (2019b, p. 135) proposed a taxonomy of money types in light of the array of technologies deployed over time by payment practitioners, that proceeds from first-order money form represented by valuable goods, to second-order monetary records such as promissory notes, third order records such as "ledgers, credit card data, store card data and online transactional data", and finally there are fourth-order records such as "outputs of scoring mechanisms, metrics, and calculations based on the aggregation and analysis of second- and third-order records" (Ibid).

The topology of money that this thesis develops departs from O'Dwyer's four orders of money devices and it combines that with neo-materialist understandings of the stacked topologies of digital infrastructures. Much in the same way as O'Dwyer's orders are based on material money-objects, stacked layering of the third kind always have at its basis the "physical layer" of wires, cables, machines, and plugs and sockets (Blanchette, 2011; Dourish, 2017). Figures 3 and 4 juxtapose the Internet Protocol stack (left) and a layered rearrangement of O'Dwyer's fourfold classification of monetary records (right).

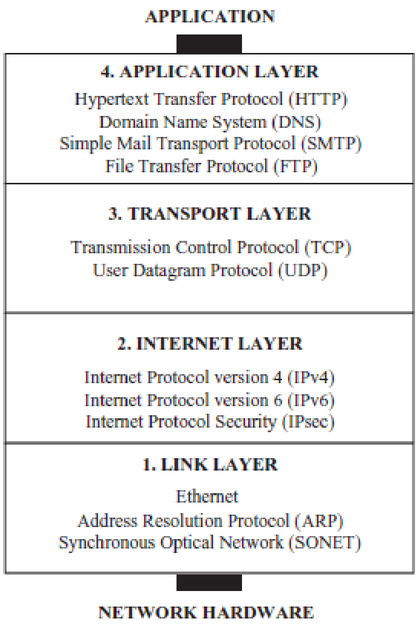

Figure 3: The TCP-IP protocol stack. Source: DeNardis (2009, p. 8).

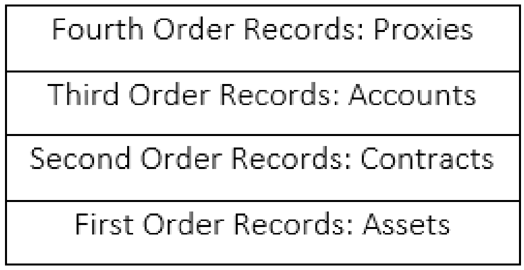

Figure 4: O'Dwyer's (2019b) four orders of money records organised in hierarchical layers. Source: Author's own.

Both stacks in Figures 3 and 4 refer back to a physical layer, a hardware layer where all messages are eventually translated into electric impulses (Kittler, 1995). However, as we saw in section 2 of this chapter, materiality is never the "anchor" of the "true value" of money, i.e., money is never strictly speaking referring back to a fundamental concrete and material layer from which abstraction derives (Cf. Schoenberger, 2010). So, the issue here is not to find an object or a material back to which all value refers, but rather the layer where movement of value entails the final discharging of relations of credit and debt, i.e., settlement. The different shapes and morphologies that the topologies of money assume are derived from the different relationship with settlement they entail.

The result of the combination of this emphasis on the temporalities and rhythms of money is what Lotti (2018) calls a "chrono-topology": money is unique because it scripts the time and temporalities it itself traverses (Christophers, 2011b). Monetary spaces are territorialised by the production of rhythms through which agreed-upon time of monetary circulation is scripted. Payments initiation, reconciliation, netting, clearing, and settlement are the cyclical instructions, the if-then-else passage point of the monetary stack, guarded by intraday liquidity provision, interbank credit, and the like (Lefebvre, 2004). At the same time, infrastructural monetary spaces are disrupted and deterritorialised by speed and lack of synchronism. For Goodchild, "the perpetual displacement of internal limits means that here we are not concerned with a conquest over a smooth, indeterminate space, nor with the self-determination of a representation of value. Instead, we are concerned with a determination of time" (Goodchild, 2010, pp. 33-34). Speed, then, is one of the most powerful vectors of deterritorialisation and displacement of internal limits (Virilio, 2006; Cf. Chun, 2008b).

In a similar way as tangible and intangible components of the Internet Protocol – e.g., address space and packet size – have a profound effect on the topology, speed, and governance of the Internet, different configurations of tangible and intangible materialities of payments produce different topologies. Dourish (2017), Blanchette (2011) and, to a different extent, Galloway (2004) and Galloway and Tucker (2007), showed that ostensibly minor technical specifications in internetworking protocols create entire political economies and trade-offs in terms of energy, computational possibilities, speed, resources, and access. In a similar vein, De Nardis (2014) showed how the specification of internet addresses in IPv4, as well as the governance structures attached to that specification, effectively shaped the spatiality of the Internet in terms of its address space. Lastly, Amoore (2018) showed how cloud computing possesses topological and topographic geographies which do not map out onto the networked cartography of data centres and server racks, but rather they constantly produce and surface new topological visualisations and cartographies through the algorithmic calculations of patterns through big data analytics.

This relationship between design and effects, and materiality and abstraction is rendered through the use of the concept of "abstract machines", defined as

> The map of relations between forces, a map of destiny, or intensity […] the cause of concrete assemblages that execute its relations; and these relations between forces take place 'not above' but within the very tissue of the assemblages they produce (Deleuze, 1988, pp. 36-37).

All spaces, for Deleuze and Guattari (1987, p. 475), are caught between a *de jure*, or abstract, opposition between smooth and striated spaces, i.e., between the deterritorialised space of rhizomes and the striated spaces of State apparatuses. However, all spaces are also always concretely hybrid and mixed between the two. However, this hybridity is determined by the type of articulation between territorialisation and deterritorialisation that each material spatial configuration configures:

> It is the de jure distinction that determines the forms assumed by a given de facto mix and the direction or meaning of the mix (is a smooth space captured, enveloped by a striated space, or does a striated space

> dissolve into a smooth space, allow a smooth space to develop?) (Deleuze & Guattari, 1987, p. 475)

Resonating with Easterling's concept of disposition, the abstract machine is the "spatial disposition" of an infrastructure, i.e., the set of potential properties that the space defined by a material infrastructure will possess. Building on this topological conceptualisation, Chapter 5 will then produce four abstract machines to define the different articulations between territorialisation and deterritorialisation of settlement that they entail.

4.2. Intangible Material Active Forms: Imaginaries, Cultures and Enchantments

In capturing the internal complexity of blockchain infrastructures, Çalışkan (2021a, p. 129) argues that these systems are kept together by two types of materialities: "The first type is a *tangible materiality* associated with infrastructure works and networks of machines [...]. *Intangible materialities* draw on observable orders." While for Çalışkan *intangible materialities* pertain to algorithms and data, this thesis uses this concept to understand cultures, imaginaries, and enchantments that traverse money infrastructures. Infrastructures are always already cultural and symbolic artefacts animated by cultures and promises associated with their use: "stories [...] however immaterial, are powerful enough to buckle concrete or bend steel, and they can maintain an inescapable grip on the disposition of infrastructure space" (Easterling, 2014, p. 137).

Similarly, to Zelizer's and Dodd's conceptualisation of money culture as "a set of interpretative techniques sensitive to how money is perceived [and] to the range of dispositions and expectations which inform how it is used" (Dodd, 1994, p. 58; Zelizer, 1994), infrastructures and money are propelled by more than their internal machinations. Rather, infrastructures and money are always "infrastructures of participation", i.e., arenas of interaction between diverse participatory cultures that shape infrastructures' disposition (Beer, 2009, 2013; Beer & Burrows, 2007).

With reference to debates between commodity and credit theories of money, Bryan, and Rafferty (2016) importantly notice that these theories are not only explanatory devices to make sense of how money works, but they are also "ontological options" that enable different claims to be made on the political economy and the distributive outcomes of specific monetary designs. In a similar vein, Dodd (2014) argues that money becomes perfectly fungible because the idea of its fungibility becomes widely shared. Money as universal equivalent and perfect means of exchange are powerful ideas, and it is the currency that these ideas gain in society through their circulation that produce the effect that they purport to describe. Kavanagh et al (2019) argue, furthermore, that different theories of money's origins and functions resonate with each other within Bitcoin and other cryptoassets, hence producing not one Bitcoin, but many (Dodd, 2018).

Stories also resonate with conceptualisations of imaginaries – or *imaginaire* – and money cultures. As Bátiz-Lazo et al. (2014, p. 105) have it, "the *imaginaire* is an imagined new social order understood as the natural result of adopting an emerging, unproven technology". While stories seem to indicate a somewhat rationalised account of how a technology is meant to act in the world, imaginaries resonate with a pre-representational, oneiric dimension of technology: "all technology is, at certain stages, evidence of a collective dream" (W. Benjamin, 1999, p. 152). In this sense technological constructs are always already, at least partially, cosmograms, i.e., "[objects that contain] a model of the universe and a plan for how to organise life and society accordingly" (Brunton, 2019, p. 10).

The *imaginaire* articulates identities, frames expectations, and distributes resources, power, and influence (Flichy, 2008). Imaginaries are plural, and their interplay distributes resources and power, and shape subjectivities of people interacting with money infrastructures (John Allen & Pryke, 1999). The *imaginaire* is not only a rational expectation: it always entails enchantments and affects (Harvey & Knox, 2012). Money cultures and imaginaries and the materiality of money infrastructure co-determine money's "internal design," and one cannot be fully grasped without the other. This thesis builds on these multiple accounts of money cultures, and it develops an analysis that is centred on the discursive and more or less rational dimension of infrastructural cultures and, more importantly, on the dimension of desire and enchantment.

This thesis, then focuses more on desires and enchantments than on stories and imaginaries because of the relatively less attention that desires and enchantments have received in science and technology studies, especially when infrastructures are analysed in conjunction with the speculative investments that make them possible. While materiality matters to the development of money as infrastructure, this is inseparable from what Harvey and Knox *via* Jane Bennet call the enchantment of infrastructure, i.e., "a mood [...] a surprising encounter, a meeting with something that you did not expect and are not fully prepared to engage" (Bennett, 2001, p. 523). In Harvey and Knox's terms, infrastructures "are thus not just material forms, but are promises towards a future which is uncertain and unclear" (Harvey & Knox, 2012, p. 523). Foregrounding desire allows for an additional step in the aforementioned effort to demystify infrastructures.

Understanding political economy also as a libidinal economy – i.e., as "political economy, that is, capital, carried even into the sphere of passions" (Lyotard, 1993, p. 5) – also allows to avoid casting that between fascination and enchantment, on one side, and materiality and technology, on the other, as a chasm between "hype" and "fundamentals". This chapter avoids the idea that FinTech, blockchain, and cryptocurrency markets represent what McGoun calls a hyper-real economy where

> There are no speculators and investors nor are there speculative-grade securities and investment-grade securities. We can no longer say that speculation trades on psychology and noise and that investment trades on fundamentals and real value. There are no fundamentals or real value for the traders; it is all psychology and noise. There is no distinguishable speculation when everyone is a so-called speculator (McGoun, 1997, p. 111).

Rather, speculation, fascination, and hype are co-constitutive of the materiality of any infrastructure. Desire and enchantments are just as important as materialities in shaping the spatialities of monetary circulation. Furthermore, enchantments co-determine infrastructures' dispositions, i.e., how the infrastructure behaves and who benefits from it. The cultural content of infrastructure is always already political:

> One person's scrap paper can be another's priceless formula; one person's career-building technological breakthrough can be another's means of destruction. Power is about *whose* metaphor brings worlds together and holds them there. […] Metaphors may heal or create, erase, or violate, impose a voice, or embody more than one voice. (Star, 1990, p. 52 emphasis in the original)

The next sub-section will expand on the politics and political economy of infrastructures by zooming in on the theme of interoperability and formalisation.

4.3. Infrastructures and Political Economies: Between Platformisation and Interoperability.

The third analytical concern of this thesis refers to the relationship between different material configurations of money infrastructures and the political economies they are inscribed within. The thesis retrieves two poles between which the political economy of money infrastructures tend to oscillate: that of platformisation and that of interoperability. Within the context of this thesis, the political economy of both platformisation and interoperability is shown as driven towards formalisation operated by capitalist rationality towards the "fringe market" and the frontier capitalism confronts, constituted by hitherto informal or even illicit market practices. Through what Mitchell (2007) calls "technologies of representation" such as "property records, prices, or other systems of reference", market incorporates informal relations in the pricing, trading, and capitalisation of assets hitherto considered "dead capital" (Mader, 2018; Schwittay, 2014; Soederberg, 2013, 2014).

While it is impossible to account for the full scope of the literature on platforms that emerged in the last four decades (Çalışkan, 2021a), this thesis is interested in political-economic debates on platformisation and platform capitalism to capture the capability of blockchain technologies of producing walled gardens that afford new forms of intermediation and capitalisation, despite their original concerns with disintermediation. This literature has foregrounded the winner-takes-all tendency inherent to the network externalities of platforms (Srnicek, 2017a), the importance of users, communities, and programmability of user experience (Van Dijck et al., 2018), the gargantuan growth of Venture Capital funding underpinning new software platforms and apps (Kenney & Zysman, 2016; Langley & Leyshon, 2020), and data mining, extraction, and monetisation (Nieborg & Helmond, 2019). In this literature, platformisation refers to a "distinct mode of capitalist enterprise that aggregates and analyses data and deploys digital infrastructures in order to extract value from intermediation" (Langley & Leyshon, 2020, p. 4).

Platforms, then, operate by combining transactional, locational, and identity data within "closed loops" and "walled gardens" where the platform leverages programmable and plug-and-play infrastructures – such as APIs – to intermediate between the community of users for data mining and fee extraction (Maurer, 2012d, 2014). Unsurprisingly, this tendency towards digital enclosures (Nelms et al., 2018; O'Dwyer, 2015a) and this emphasis around business models based on multiple forms of rent extraction (Langley & Leyshon, 2016; Srnicek, 2017a, 2017b) have caused many scholars of platforms to ascribe to a "neo-medievalist" and "digital feudalist" stance vis-à-vis platformisation (Fairfield, 2017; Rahman & Thelen, 2019). In addition, and nuancing this understanding of blockchains as platforms, Çalışkan (2021a, p. 119) expanded the economisation and marketisation approach to the study of cryptoasset exchange platforms "exceeds marketization relations [...] making it possible for platform actors to move beyond market making in pursuing diverse modes of economization from barter to money-making within a single frame".

Somewhat at the opposite end of the spectrum, interoperability is often understood as smooth and frictionless connectivity. Typical definitions of interoperability are "the ability of heterogeneous IT networks, applications, or components to exchange and use information, that is, to "talk to and understand" each other (Tsilas, 2011, p. 104), "the ability of two or more database or operational computer systems to work together seamlessly with a minimum of format or language conversion and translation" (Harris, 2011, p. 86), and "the ability for two different and independent software applications to exchange information without loss of data, semantics, or metadata" (Sutor, 2011, p. 215).

In fact, as this thesis will show, this rather neutral depiction of interoperability is far from resembling interoperability "on the ground". As Shilton (2018) shows, interoperability is all too often conflated with neutrality, which makes interoperable technological projects particularly hard to investigate to unearth unexpected political economies and power structures (Ribes, 2019, 2017; Shilton, 2013, 2015). In DeNardis's words, "technical standards not only provide technological interoperability but also produce significant political and economic externalities" (DeNardis, 2011, p. viii). In a similar vein, Harris argues that interoperability of data often affords an unquestioned degree of transparency that makes "data" unproblematic and self-evident, a "transparent window on the world" (Harris, 2011, p. 82; Lindsay, 2017).

This vision of interoperability as neutral tool of harmonisation has been shown to trace back to the 1990s (Lévy, 2001), and it was already critically scrutinised by Robins and Webster (2002) in a manner not unlike Winner's fleshing out of the myths informing the then blooming "New Economy" (Winner, 1984). Geopolitically, interoperability has been shown as "[one of] the passwords for reducing vulnerability and anticipating risk, uncertainty, and global threats" (Mattelart, 2010, p. 199) underpinning the emergence of what has been called "Surveillance Capitalism" (Weber & Kämpf, 2020; Zuboff, 2019). Amoore (2018, p. 6), in fact, showed how interoperability was also a driver behind the proliferation of cloud computing in that, in the aftermath of 9/11, there was an increasing fear of the exposures and vulnerabilities deriving from "siloed" data centres.

Platformisation and interoperability are inextricably linked to each other, they imply and require each other and form a co-evolving and compounded political economy. In fact, even looking at the literature on platforms, there is often a difficulty in isolating what makes platforms, and what makes them different from infrastructures (T. Gillespie, 2010). For example, both Van Dijck et al (2018) and Poell et al (2019) use infrastructures and platforms often interchangeably and almost always in combination with each other. Langley and Leyshon (2020) go towards a specification of the “division of labour” between platforms and their enabling infrastructures, although interestingly platforms are also defined as “infrastructural intermediaries” (Langley & Leyshon, 2016, p. 19) of the multi-sided markets they coordinate.

Westermeier (2020) also contributes to the effort to bring much needed conceptual clarity between infrastructure and platform. These two socio-technical systems are, first, distinguished according to their internal morphology: infrastructures are internally heterogeneous and in need for socio-technical intermediaries to function, while platform are programmable with a stable core system (Ibid, p. 4). Second, they are distinguished in terms of temporality: infrastructures are long-lasting, while platforms are based on frequent updates. Third, there is a political-economic difference: infrastructures produce data as a by-product of the interactions they enable, while platforms make of data the core of their business model. However, what looks like a difference in kind is sometimes more a difference in degree, and “there are also some platforms which have infrastructural characteristics as their public implications are undeniable, including Google, Amazon, Facebook, Apple and Microsoft” (Cf. Plantin et al., 2018; Westermeier, 2020, p. 2050). Again, the issue is less to define *what* is an infrastructure, but *when* it achieves infrastructurality.

As noticed by Plantin et al (2018, p. 299), “platforms rise when infrastructures splinter”, i.e., when the smooth texture of an infrastructure falls apart, or when multiple non-interoperable infrastructures emerge and compete for the same market, then platforms promise to introduce smooth interoperability, with the collateral effect of affording capitalisation for those providing this new form of intermediation (Langley & Leyshon, 2020). At the same time, platforms themselves cannot be based on competition because that would inexorably erode their profit margins (Pesch & Ishmaev, 2019), but also the platform business model is predicated on there being one or very few intermediaries for each market (Langley & Leyshon, 2016).

Interoperability is always necessary for the possibility to “cash out” from a given platform. That is why the “appleisation of finance” (Hendrikse et al., 2018) is more a recasting than a disrupting of the role of formal finance vis-à-vis emergent financial technologies: “Instead of replacing existing payment infrastructures, the platform model builds on them and thereby facilitates payments through their services” (Westermeier, 2020, p. 2052).

Interoperability as embodied in infrastructures is the condition of possibility for the development of platforms as more or less isolated cells for value extraction through fees and data monetisation.

At the same time, a plurality of platforms is the precondition for making interoperability palatable from a business point of view because it engenders the need to formalise pools of value that would otherwise be “idle assets” and “dead capital”. As Westermeier (2020, p. 2058) shows, “The regulatory push for interoperability in banking via APIs is inherently a push towards the platformisation of financial services, as this kind of connectivity distinguishes infrastructures from platforms”. The more infrastructures interoperate, the more affordances this new meta-infrastructure provides for platforms and platformisation. The political economy inherent to interoperability could not be more clearly on display than in payment systems.

Lastly, and going back full circle to the relationship between money, technology, and memory, platformisation and interoperability are predicated on different political economies of memories. Platforms aim to produce a localised, yet total representation of the state of the network through the accumulation of records and data generated within the platform. It is this totalisation of memory that blockchain technologies carry to an extreme degree: blockchain technologies are memory machine that store all memory produced within a network, but which cannot see anything that is happening beyond the network. Interoperability, conversely, makes memory portable by disembedding money-as-memory from the material and specific conditions from which it arose, hence making it translatable from payment system to payment system, currency to currency, standard to standard. It is time now to summarise why blockchain technologies and cross-border payments are a fruitful field where to retrieve the politics of materiality, the ecological internal and external co-evolutive dynamics, the topological spatialities, the cultural and affective drivers of enchantment, and the political economy of platformisation and interoperability together.

5. Conclusions

Money is always material, yet money’s thingness is but one aspect of money’s materiality. Money’s materiality is also always already infrastructural, entailing the system of records, accounts, addresses, and logistics, allowing money’s circulation. Both digital objects and money are always already material through the interobjective, infrastructural materiality that makes them possible. Infrastructures are deeply relational techno-human ecologies that are always potentially prone to slippage, dissolution, disassembling, reassembling, and reappropriation, dependence, competition, reinvention, reappropriation, and resistance.

This chapter has also signalled how this thesis will analyse in further depth three analytical dimensions of the ecologies of money infrastructures. First, the chapter expanded on the chrono-topologies that money can assume depending on the materiality and institutional arrangements that subtend money infrastructures. Second, these spaces are held together and kept in dynamic flux through enchantments, cultures and affective forces like desires and libidinal investments: infrastructure spaces are always speculative spaces "in the grip of dreams" (W. Benjamin, 1999, p. 152). Third, interoperability – or lack thereof – between infrastructures engenders specific political economies of connectivity that enable and disable specific forms of value flows and allow specific forms of value capture, extraction, and accumulation. Interoperability is not a neutral endeavour, but rather an essential component and condition of possibility for the dynamics of data and fee mining of platform capitalism.

The different analytical threads that this chapter developed will be expanded in the remainder of this dissertation. In particular, the immediate performativity of infrastructures' materiality, on the one hand, and their deeply relational ecological nature, on the other, will be dealt with in Part II of this thesis, respectively in Chapter 3 and Chapter 4. Part III will expand on the analytical dimensions of the chrono-topologies, libidinal economies, and political economies of money infrastructures. Chapter 5 will develop four articulations of the stacked chrono-topologies of money infrastructures, based on the materiality of different infrastructures and inspired by Deleuze and Guattari's typology of abstract machines of overcoding, consistency, and stratification, to which this dissertation will add axiomatics. Chapter 6 then will develop a libidinal economy of money infrastructure to foreground the desires underpinning speculative investments in the materiality of different infrastructures and platforms. Chapter 7 will deal in further depth into the political economies that money infrastructures harbour and make possible. In particular, it will deal with the tensions between platformisation and interoperability that blockchain technologies entail, with specific reference to the formalisation of remittances.

Chapter 2: Follow the Thing: Infrastructure

1. Introduction

Money, especially in its digital form, is arguably the social relation that is the most embedded in the world system (Hart & Ortiz, 2014). Caught as it is between social relation and material commodity, and circulating through heterogeneous infrastructures, money represents not only a theoretical conundrum, but its study poses unique methodological, epistemological, and practical challenges. As Keith Hart and Horacio Ortiz (2014, p. 466) have it, "We need new methods if we wish to account for how money underpins social identities and relations of conflict, hierarchy, and interdependence in the world we are making today". Technological developments and the emergence of new sociocultural spaces represented by digital media further illustrate how social processes are hybridised between online and offline spaces (Ash et al., 2018, 2018b; Burrell, 2009; Kitchin & Dodge, 2011). This chapter, based on my 18-months of fieldwork, develops an epistemology of money infrastructure and an accompanying methodology to investigate it. The chapter combines methodological, epistemological, and practical reflections to address specific concerns regarding time and temporality of field research, power and access, and space.

Investigating money as an infrastructure provides an analytical framework through which money can be materially situated and followed in time and place (Gilbert, 2005), without the pitfalls connected to following the materiality of the monetary objects in question. In fact, as Christophers (2011b) points out, monetary objects and monetary aggregates are ill-fitted to be followed as physical commodities through space precisely because of money's indistinguishable characteristics, its propensity to aggregate and pool in a way that erases previous histories and trajectories, and in general its social nature and function, which goes beyond the thingness of the monetary artefacts. Emily Gilbert (2011) shows that credit, and not money, is the commodity to be followed, while money itself is more adequately followed by placing in time and space the institutions involved in producing money and managing its circulation, on one side, and the growing apparatus to record and monitor transactions, on the other.

As stated in Chapter 1, the analytical approach followed in this thesis foregrounds money's materiality as inherently infrastructural, encompassing the material assemblage of devices, networks, institutions, hardware, software, and "wetware" that is involved in recording credit and debts, communicating transactions, and allowing for the flow of value (Maurer, 2017b). This analytical framework corresponds to a methodological set of choices necessary to investigate the multiple locales and places where this infrastructure surfaces and can be retrieved: the topology of money and finance can be understood by adopting an analytics of money as infrastructural network (R. Martin & Pollard, 2017).

Ethnography is “an immersive research strategy that seeks to understand how people create and experience their everyday worlds” (A. Kavanagh & Till, 2020, p. 321). As a consequence of the increased mobility of people and things, heightened connectivity and circulation of information, ethnography has been changing (Marcus, 1995). Multi-sited ethnography emerged as a type of social research that is “self-consciously embedded in the world-system […] to examine the circulation of cultural meanings, objects, and identities in diffuse time-space” (Ibid, p. 96). Recently, this “multi-sited imaginary” (Pierides, 2010) has been further developed into a conceptualisation of the “field site as a heterogeneous network” by Jeanna Burrell (2009, p. 182). Such definition goes beyond the idea of “embedding” (Granovetter, 1985; Hess, 2004) the localised, idiosyncratic characteristics of the field site in larger global processes. Rather, one should “imagine the whole” (Marcus, 1989), and follow the instantiation of such a whole by following the people, the things, the metaphors, the plots, the stories, the allegories, the biographies, and the conflicts that traverse and connect field locations (Marcus, 1995).

This chapter will illustrate the process through which I assembled the geographically heterogeneous field site starting from summer 2017 and ending in 2019, and the methodologically heterogeneous fieldwork, on which this thesis is based. In so doing, it offers conceptual contributions to several ongoing debates in online ethnography and digital methods, multi-sited ethnography, and temporary and meeting ethnography. First, it shows how the research questions influenced the case selection strategy and how this, in turn, posed a specific set of challenges in terms of access and creating rapports with informants. A radically multi-sited understanding of the field site of money infrastructures allows to attend to the “texture of access”, where access is less a yes or no answer to a request, but a set of strategies deployed in response to “a resistance to knowledge that is omnipresent and not always the same” (Seaver, 2017, p. 7). This type of access strategy entails a researcher subjectivity defined as the “scavenging ethnographer” (Seaver, 2017) to describe the specific type of positionality that the fieldworker has vis-á-vis the field itself, and which ethical implications this positionality may have. Second, the chapter takes Burrell’s (2009) tripartite conceptualisation of the field as physical, virtual, and imagined spaces seriously as a way to study a peculiar form of logistics (payments) beyond the existence of a specific control room, and how materiality and speculation play just as important roles in defining the contours of the field. In so doing, it attends to the "taking place" of cultural economies, i.e., on the context-specific spatialities and topologies of cultural and material practices associated with the creation of markets and the use of market devices (M. Callon et al., 2007; Hall, 2011; D. MacKenzie, 2003). Third, it interrogates how this spatial heterogeneity defines and impacts on the temporalities of the field, in terms of rhythms of recruitment, data collection, and analysis.

My data collection strategy entailed the use of online archival research, ethnography of online meetings, participant and nonparticipant observation of online forums, participant observation of industry trade fairs, expos, and conferences; and both digitally mediated and traditional in-person, in-depth expert interviews. The fields of Financial Technologies (FinTech), cryptocurrencies, and blockchain technologies are highly "hybrid" in their field configuration: they are the result of "relationship between these assemblages and the wider social, cultural and political spaces in which, and upon which, they act" (Hall, 2011, p. 240). They are socially interconnected, yet geographically dispersed ecologies of applications, devices, material and virtual commodities, and communities. Cryptocurrencies, for example, might be developed online through GitHub by programmers that rarely meet in person and who often work far apart from each other. These cryptocurrencies will then be marketed through online material, discussed, and picked apart by enthusiasts in online forums, presented and pitched in real-world venues such as trade fairs and expos, and then integrated in larger markets. Accessing and exploring these spaces, then, requires a "polymorphous engagement" (Gusterson, 1997, p. 116) with different types of research data.

The chapter will be structured as follows: the next section will introduce the case selection process through which Ripple was chosen as a revelatory case (Fletcher & Plakoyiannaki, 2010) for the specificities of blockchain technologies, cross-border payment systems, and interoperability technologies, on one side, and for the interconnection between private, public, and grassroot actors in blockchain technologies and FinTech, on the other side. In section 3, the chapter will expand on issues of access and power in my fieldwork. Then, in section 4, I will unpack the spatial construction and assembly of a radically multi-sited fieldwork, and how boundaries are and should be drawn and redrawn throughout the research process. The fifth section will expand on time, temporality, and temporal boundaries in such fluid research projects. Lastly, the conclusion will summarise the content of the chapter and its contribution to broader social science methodological literature.

2. Between Particular and Universal: What's in a Case?

Ripple is not only a cryptocurrency: to me, that was the most boring part of it. It actually models the entire financial ecosystem

(Interview 15th May 2018).

The epigraph encapsulates a tension within each case study between the specific and the general, the empirical and the theoretical. Case study research, in fact, stands in tension between the idiosyncratic and unique features of the case and the ambition to produce theory that goes beyond that singularity. "For a case study to succeed, that is, for the specific to stand for more than itself" Galison (2004, p. 382) argues "some form of theory (implicit or explicit) will play a role". In Lauren Berlant's words: "the case represents a problem-event that has animated some kind of judgment. […] the case is always pedagogical, itself an agent […] the case points to something bigger, too, an offering of an account of the event and of the world" (Berlant, 2007, pp. 663 and 665). The case selection process, then, aims "to ask philosophical questions that open up empirical work and to pose critical historical questions about the categories deployed by our philosophy" (Galison, 2004, p. 383). Needless to say, this conceptualisation of the case implies that case selection does not derive from statistical representativeness deriving from random sampling, but rather it is a process of theoretical sampling aimed at producing knowledge generalisable analytically (see below) (Emmel, 2013).

For this thesis, the driving question was to what extent one can apprehend money itself as an infrastructure, and which analytical dimensions need to be addressed in order to make such a conceptual move. My specific research focused on blockchain and interoperability applications to cross-border payment infrastructures, such that the fieldwork challenge is to unpack the infrastructural materiality of money and its associated imaginaries, enchantments, cultural practices, and power conflicts and negotiations. The narrowing down to this set of technologies was motivated by each defining element – blockchain, cross-border, interoperability – to represent "paradigmatic cases" of specific yet mutually co-evolving analytical dimensions of the investigation of money infrastructures. Paradigmatic case is here understood as a case deployed with the intent to "develop a metaphor […] for the domain which the case concerns" (Flyvbjerg, 2001, p. 79).

Blockchain technologies, first, were chosen as a paradigmatic case of the irreducibility of money's materiality (Keane, 2001), and the infrastructural nature of that materiality. Blockchain technologies and cryptocurrencies are paradigmatic in that, while cryptocurrencies do not have a material form in terms of money-object – i.e., there is no such thing as Bitcoin in cash form – the sole form of material existence of cryptocurrencies coincides with their underpinning infrastructure of records, accounting, and payment. Second, cross-border payments were chosen as an extreme case of money's infrastructuration: since they are a comparatively less densely infrastructured space, observing the deployment of infrastructures in cross-border payments allows to be more precise in the detection of active forms and dispositions. Extreme cases are used to describe as an unusual case "which can be especially problematic or especially good in a more closely defined sense" (Flyvbjerg, 2001, p. 79). Cross-border payments are often considered the exception to the smoothly working domestic payments.

However, if one reads the history of money as a means of exchange, one sees that central counterparties arise from previously scattered interbank networks. Seemingly unwieldy systems of synchronisation such as correspondent accounts were the bread and butter of multilateral payment systems in the 16th, and 17th century. These systems have now largely achieved infrastructure status: in fact, most LVPS are now included both as systemically important payment systems by international financial overseers like the Bank for International Settlements (BIS), International Organisation of Securities Commissions (IOSCO) (CPSS, 2001) and as critical infrastructures by national security authorities in multiple states across the world (e.g., Homeland Security & Department of the Treasury, 2007). Hence, cross-border payments represent the diagram of the normal condition of any interbank network before the establishment of central counterparties and central banks.

Cross-border payments and their complementary settlement flows represented by foreign exchange markets have skyrocketed in value ever since the end of Bretton Woods and of the fixed exchange rate regime in the early 1970s. If in the 1960s the Federal Reserve's Large Value Payment System (LVPS), Fedwire, was handling 4.5 times the US' GDP worth of payments, in 2012 this ratio has grown to 90-100 times US' GDP, more than half of which can be imputed to FX transactions settled through Fedwire by actors such as CLS Bank (see also Chapter 7). In the same period, China's share of payments has grown from twenty times its GDP to thirty-four times (Kahn et al., 2016, p. 564).

Cross-border payments are taken as an analytical focus for the problematisation of territorially bounded monetary spaces they entail, and because the act of paying across "borders" entails an action across different levels of the stack of domestic payment systems (see Chapter 5). Between undifferentiated money-capital, bounded money-currency, and networked money-payment and money-credit there are always multiple points of contact, translation, transaction: there are borders not only between sovereign currency spaces, but also between and within networks, standards, accounts. Cross-border payments and transactions, hence, are more than simple moving value across a line. What lies across borders is a space in its own right, an "analytical borderland": "what is commonly represented as a line separating two differences, typically seen as mutually exclusive [ought to be turned] into a conceptual field-a third entity-that requires its own empirical specification and theorisation" (Sassen, 2008, p. 379).

My survey of the current literature evidenced BitPesa, Abra, Ripple, and Stellar as the most cited use cases of the application of blockchain technologies for cross-border remittances and payments (Burniske & Tatar, 2018; DuPont, 2019; Tapscott & Tapscott, 2016; Vigna & Casey, 2015; World Bank, 2017, 2018). Only Ripple and Stellar provide applications of DLTs to correspondent banking infrastructures. Stellar solutions for cross-border correspondent banking are still in their infancy, while Ripple has a reasonably well-documented record of partnerships with banks and MTOs. The difference in consolidation and available empirical material also made it hard to justify a comparative research design between Stellar and Ripple. Hence, Ripple was chosen as the critical case of this research. Ripple is, so to speak, a case within a case within a case or, using Fletcher and Plakoyiannaki's (2010) terminology, a revelatory case.

Ripple is a software company that applies blockchain and interoperability technologies to cross-border payments. Its architecture was first conceived in 2004 as a mutual credit network, and it morphed into a blockchain in 2013 (the XRP Ledger), with the ambition to provide an integration infrastructure between cryptocurrencies, alternative currencies, and traditional interbank payment systems. Ripple is also the name of a company that presently has more than 300 clients throughout the world, mainly banks and payment providers. Ripple was interesting to me because it allowed me to investigate the materialities and spatialities of money in different settings such as cryptocurrencies, banks, public regulators, FinTech companies, and alternative currency schemes. It was then the ideal case to unpack the different imaginaries, materialities, and political economies played out at once.

Furthermore, Ripple has, more than other potential case studies, a direct link to three distinct actor coalitions and constellations that are populating the field of monetary financial technologies: public actors and regulators, private actors like FinTech platforms and incumbent financial institutions, and grassroot actors like alternative and community currencies. Figure 5 maps these coalitions out through some examples and case studies. Ripple and the Interledger Protocol are at the centre of this diagram *not* because Ripple is here taken as the emblematic case of cryptocurrency or FinTech start-up, but because over time it touched upon all sides of this diagram.

Figure 5: Diagram of Cases divided into Public, Private, and Grassroot actors. Source: Author's own.

As encapsulated in the epigraph that opened this section, Ripple's case could stand for more than itself precisely because of its ambition of "modelling the entire financial ecosystem". Ripple, then, rather than being a critical, extreme, or paradigmatic case, is here seen as a *revelatory case*, i.e., one "where there is the opportunity to observe and analyse a phenomenon previously inaccessible to investigation" (Fletcher & Plakoyiannaki, 2010, p. 838). Ripple was taken as the case that touches upon, and in turns offers access to, the largest number of analytical dimensions on the relationship between money and power (e.g., direct power through different material forms, indirect power through standards and regulation), money and space (different topologies of money, and the topological act of paying across borders), and money, cultures, and desires (hype and speculation, alternative currencies).

Ripple uncovered interrelation between materiality, politics, and cultures and imaginaries, on one side, and between public, private, and grassroot actors, on the other, that would not have otherwise been visible. At the same time, once these connections have been shown, the centrality and the irreplaceability of Ripple faded somewhat: Ripple became more a provocation to investigate the complex link between analytical dimensions in the infrastructural nature of money in multiple sites and across time, rather than just maximising the knowledge about the case at hand. The case "assumes the sociality of knowledge, the circulation of discourse as its condition" (Berlant, 2007, p. 668). It is the study of that sociality of knowledge and the circulation of discourse that formed more and more the core of the thesis, with Ripple at its centre not analytically, but as a constant empirical provocation to ask conceptual questions. Hence, the process of case selection followed here a double movement, somewhat an hourglass-shaped pattern, as illustrated in Figure 6.

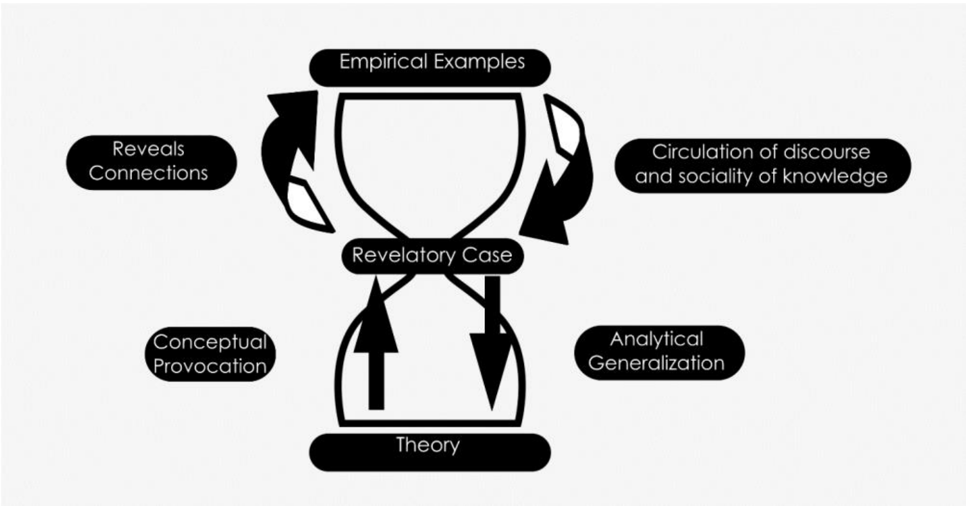

Figure 6: Ripple as a Revelatory Case and its links with empirical materials and theory. Source: Author's own.

The double movement between empirics, case, and theory allowed the case of Ripple to work as "a *system* that resonates with another, larger, system, much like a tuning fork resonates with a (tuned) guitar […] a system that will help us interrogate the larger system" (D. Kavanagh et al., 2019, p. 521). Ripple produced a smaller-scale system that models the larger system represented by cross-border money infrastructures, and the oscillating movement from case – the smaller system – to the empirics – the larger system – and from case to theory allows to produce theory through resonance.

Rather than using case studies to test or disprove new and existing theories, case study research then strives to identify the research units that return "the greatest possible amount of information on a given problem or phenomenon" (Flyvbjerg, 2001, p. 77). The type of generalisability that derives from a well-selected case is not deductive or statistical generalisability, but rather analytical generalisation, i.e., to make a "conceptual claim whereby investigators show how their case study findings bear upon a particular theory, theoretical construct, or theoretical (not just actual) sequence of events" (Yin, 2010, p. 21).

Hence, this thesis "builds theory from the rich descriptions gained during the analysis process" (Treiblmaier, 2019, p. 7) through a radically interpretivist epistemology (Cavaye, 1996). In so doing, one has to be aware that "one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion" (Yin, 2003, p. 18). As we shall see in the next section of this chapter, the heterogeneous network of Ripple's clients, the dynamicity of the space represented by FinTech, blockchain, and interoperability technologies, and the heterogeneity of data in case study research entailed specific challenges in terms of access, recruitment, and positionality, which in turn caused the project to assume a radically multi-sited spatio-temporality.

3. Elite Research from Scavenging Ethnographies to Multi-Sited Field Sites.

If ethnography is about "being there" where a process unfolds, then the "where" to be, and the "how" to get there, are necessarily specific to the research object (Hannerz, 2003; Smets et al., 2014). Jenna Burrell, in defining the field site as a network, departs her analysis of "unconventional" forms and modes of fieldwork by acknowledging that for each process there is a location and a positionality appropriate to it. The field site, then, is defined both "by the movement and dwelling of the fieldworker" and by "the space in which a social phenomenon takes place" (Burrell, 2009, p. 186). Choices about location and time frame shape and, in turn, are shaped by the positionality of the fieldworker. Field, positionality, and location are mutually relationally constituted: as Tunçalp *et al* (2014, p. 60) have it, "the fieldwork is constructed rather than discovered".

The methodological choices that led my field site to be assembled in a geographically disperse and online-offline hybrid fashion were deeply influenced and dependent not only by the research questions and the selected case. This multi-sited methodology derived also from the "polymorphous engagement" consisting of "interacting with informants across a number of dispersed sites, not just in local communities, and sometimes in virtual form; and it means collecting data eclectically from a disparate array of sources in many different ways" (Gusterson, 1997, p. 116).

The process of recruitment made apparent what Dos Santos (2018, p. 103) calls "trial of access". In Seaver's words (2017, p. 7), access "is a protracted, textured practice that never really ends, and no social scene becomes simply available to an ethnographer because she has shown up". It is thus necessary to expand on the issues with access, power, and expertise that I confronted while on fieldwork. In fact, "if fieldwork-based knowledge is always haunted by the limits to what one person can observe in a given time and place", Hart and Hortiz (2014, p. 475) argue, "this is even more the case with the study of money".

The next three subsections will investigate the texture of access of the three main methods I used: trade fair ethnography, interviews, and online archival sources. A multi-sited fieldwork requires a specific type of fieldworker subjectivity that Seaver (2017, p. 6) calls "scavenging ethnographer": "the scavenger replicates the partiality of ordinary conditions of knowing". A scavenging ethnographer collects and analyses data through "chains, paths, threads, conjunctions, or juxtapositions of locations in which the ethnographer establishes some form of literal, physical presence, with an explicit, posited logic of association or connection among sites that in fact defines the argument of the ethnography" (Marcus, 1995, p. 195).

3.1. Getting where? Access in Conferences and Fairs

My initial research project focused on the making and remaking of subjectivities through and by networked technologies and their interfaces (Cf. Greenfield, 2017; Langley et al., 2019). During the first year, the project progressively drifted towards the making and remaking of monetary spaces through digital payment infrastructures, driven by an uncanny similarity between the flow of money and logistics (Rea et al., 2017). Since I wanted to test the extent to which a project on digital money could employ similar methods and concepts as research projects in critical logistics, I asked for feedback to a professor in the department for feedback. I was told that this analogy could hold critical purchase. However, to capture it, I should "get to the control room" where money was actually moved.

Hence, I started attending industry conferences and expos primarily as networking sites, where I could recruit my informants such as bankers, software developers, and marketing specialists. This came with an increased attention towards the specific texture of access that pervades fairs and expos themselves and the "multiple levels of access" (Havens, 2011, p. 154) they entail. The price tag is not the only variable influencing the degree of access and "insidership" they grant, even though it is a powerful one. As Thompson (2011, p. 60) shows in relation to art exhibitions, while all fairs within a field tend to be connected with each other, they are not created equal: there are “must see” events, as opposed to “nice to see” events. For example, in my field, events like SIBOS, organised by SWIFT, or Money 20/20, would have been probably the most important venues to visit to be on the cutting edge of the industry. However, the costs to attend these events are prohibitive, considering that the entrance ticket for Money 20/20 alone would cost more than $2000. An informant at one of the fairs pointed out that, given that the industry is very closely knit, once one gets to know an insider it is normally possible to gain access to free tickets given to sponsors or press (Field Notes 12/06/2019). However, this is another thread in the texture of access: for someone from outside this industry, it is difficult to gain this type of access, and the budgets available to participate in overseas conferences are not the same for researchers and finance practitioners.

Trade fairs produce and distribute access as a scarce resource also through more mundane means such as, for example, the colour of the badges (Entwistle & Rocamora, 2011, p. 257; Havens, 2011, p. 153), which distinguishes between members of the press, non-paying attendees for those conferences that allow for that, different degrees of paying attendees, speakers, and start-uppers. Expo personnel would walk around the room before a paid speech and scan the barcode of each participant, and the machine would automatically detect if that session were beyond one’s paygrade (See Figures 7 and 8).

Figure 7: Attendance badges for several of the expos and fairs I attended. In the lower half of the badge there is some identifiable sign that shows which tier I fall under (paid, unpaid, press, exhibitor, speaker, etc.) The barcodes and QR codes allow the organisers to check whether the badge is authentic, and which access restrictions apply.

Figure 8: Map of an Expo that marks the function of each space within the expo itself. On the right, the sponsors are listed based on the level of contribution and the track they sponsor. Source: Author's own.

Furthermore, as Entwistle and Rocamora (2011, p. 251) have it, fairs distribute resources and prestige through a management of vision and visibility, of "seeing and being seen". However, access and resistance to access are also produced through making things invisible and creating a "backstage" that is co-constitutive of the spectacle that is the fair itself (C. W. Smith, 2011, p. 97). Craft goes into the design of the exhibition space so that, using dark draping and cardboard barriers, sections of the expo were secluded from the general public without this giving the impression of a denial of access. The circulation of participants and of the speakers can be separated from each other without being interrupted: once the speaker was done with their presentation or interview, they would disappear behind the colourful scenography of the stage and into a Daedalus of corridors covered by black drapes. In so doing, speakers could avoid being met in the open expo floor. To book an appointment with them, one could either go in the VIP networking lounges, book an appointment through the conference app, or know the speaker individually and meet them outside the expo floor (see Figures 9 and 10).

Figure 9: Directions showing which areas of the exhibition are for speakers only. Source: Author's own.

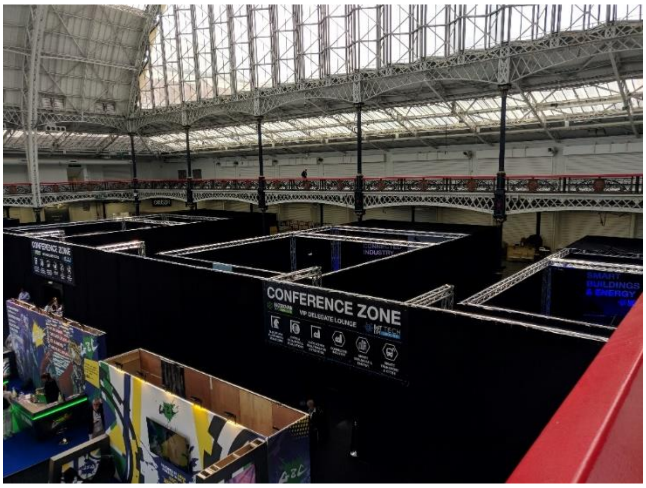

Figure 10: Black curtains shield the VIP (paid) sessions from the rest of the audience. These sessions are also not sound-amplified, and they instead rely on individual headphones to convey the sound, preventing non-paying participant from overhearing what is being discussed. Source: Author's own.

Differential degrees of access were also felt in what Nyqvist (2017, p. 23) calls "scheduled schmoozing" sessions, i.e., post-conference drinks, lunch breaks, generic networking breaks in between sessions. While the email updates sent out from the organisers seems to indicate a common schedule for both formal and social events, by talking to participants it became clear that there were different channels for founders, investors, speakers, and press. As a participant told me: "Once you get to know that, you realise that there are many conferences within a conference" (Field Notes 06/06/2017).

3.2. Access, Expertise, and Self-Promotion in Interviews

Alongside trade fairs ethnography, my research led me to interview informants both among the participants to the conferences I attended, and who worked in Ripple or in companies that partnered with Ripple. I recruited five informants for formal interviews, while I had several other informal chats that were included in my field notes rather than fully annotated and transcribed as they happened. I also sent 120 recruitment emails and 53 LinkedIn messages to current or former Ripple employees, and to individuals and press and PR offices of financial and software institutions that were clients and providers connected with Ripple. I also contacted people through the Ripple Forum – now defunct – and through the mailing lists of the Interledger Protocol and of the original RipplePay project, which preceded Ripple from 2004 to 2012. Through that, I managed to have 28 interviews with 23 informants outlined in Table 1. Of those 23 informants, 13 have been working at different capacity in Ripple, in the original RipplePay project, or in the Interledger Protocol project, 4 were not connected with Ripple but rather with the broader cryptoasset bubble that will be discussed in Chapter 6, 2 were related to projects outside, but connected with ILP and the original RipplePay, 1 was a Bank of England employee on the Ripple-BoE experimentation on RTGS synchronisation, and 3 were not Ripple employees but employed by FinTech firms that were partnered with Ripple. Follow-up interviews are marked with different numbers of stars for different informants.

	Interviewee (anonymised)	Date	Type	Topic
1.	Ripple blockchain software engineer	15/09/2017	Skype	Technology Design and Evolution
2.	Sales at Ripple	22/09/2017	Phone	Sales and Banking
3.	Regulation at Ripple	05/10/2017	Skype	Technology Integration
4.	Regulation and product at Ripple	11/11/2017	Phone	History and governance of Ripple
5.	At an exchange partner with Ripple	23/11/2017	Skype	Integration and Partnerships with Ripple, remittances.
6.	Participant at a blockchain trade fair and VP for a blockchain company in the payment space	04/12/2017	In-Person	Cryptoasset bubble, blockchain conferences, payments
7.	Participant at a blockchain trade fairs and marketing for ICOs	04/12/2017	In-Person	Cryptoasset bubble
8.	Employee at an exchange partnered with Ripple	07/12/2017	Skype	Cryptoasset bubble, integration with Ripple
9.	Participant in the Interledger Protocol community calls and payment system designer	17/05/2017	Skype	Cryptoasset bubble, Ripple, ILP
10.	Former software engineer at Ripple	15/05/2018	Skype	Internal design, evolution of Ripple
11.	Former software engineer at Ripple	24/05/2018	Skype	Internal design, evolution, ILP
12.	Original RipplePay member	30/05/2018	Skype	Origins and evolution of RipplePay

	Interviewee (anonymised)	Date	Type	Topic
13.	Legal firm associate, Ripple partner and ILP community call participant	06/06/2018	Skype	Internal design, Interledger Protocol
14. *	Original RipplePay member	19/06/2018	Skype	Evolution, RipplePay, mutual credit networks
15. **	Former software engineer at Ripple	20&06/2018	Skype	Internal design, evolution of Ripple
16.	Trustlines	21/06/2018	Skype	Mutual Credit and alternative currency systems. History and evolution of RipplePay.
17.	Bank of England	27/06/2018	Skype	BoE Proof of Concept of RTGS settlement through ILP
18. **	Former engineer at Ripple	16/11/2018	Skype	Internal design, evolution at Ripple
19.	Employee at an interoperability protocol firm	21/11/2018	Skype	Cryptoasset bubble, interoperability
20.	Employee at a FinTech firm partnered with Ripple	05/12/2018	Skype	Integration with Ripple, Remittances
21. *	Original RipplePay member	01/04/2019	Skype	Origins and evolution of Ripple, mutual credit networks
22. **	Former software engineer at Ripple	02/04/2019	Skype	Internal design, evolution at Ripple
23. ***	Former software engineer at Ripple	19/04/2019	Skype	Internal design, evolution, ILP
24.	Token designer and blockchain trade fairs attendee	29/05/2019	Skype	Cryptoasset bubble, platformisation, token design
25. ****	Software engineer at Ripple	29/05/2019	Skype	Internal design, evolution at Ripple
26.	Employee at a cryptoasset valuation firm and blockchain conference attendee	30/05/2019	Skype	Cryptoasset bubble, valuation

	Interviewee (anonymised)	Date	Type	Topic
27. ****	Software engineer at Ripple	30/05/2019	Skype	Internal design, evolution at Ripple
28. ***	Former software engineer at Ripple	08/11/2019	In-Person	Internal design, ILP

Table 1: Interview Schedule with role of the informant, date, type (in-person, online, written), and topics.

Shifting from ethnographic settings to recruiting interviewees, I realised that, as Thomson (1995) illustrated in relation to conducting research on corporate elites, being visible is not the same as being accessible, let alone being available to talk. In fact, the banks that participate in Ripple's network are clearly on display on their website, and the people in charge of innovation or blockchain Proofs-of-Concept (PoC) are relatively easy to find through a cursory search on LinkedIn or other platforms such as Crunchbase or AngelList. However, this visibility does not make the easy to recruit, or willing to talk: of the 120 emails that I mentioned above, only around ten bankers replied. Non-disclosure agreements and patents, furthermore, significantly restricted the scope of the answers. This difficulty was by no means shared across the board and identical in all cases. For example, Ripple's software developers were open to discuss regardless of seniority, and with around five of them I managed to build rapport and trust through follow-ups and informal email exchanges. FinTech companies, payment providers, cryptocurrency exchanges and software companies were also available to discuss and led to insightful conversations.

The question, then, becomes to what extent my idiosyncratic identity and personal background influences gaining access and constructing rapport with key informants. While being male, white, in my 30s made me much more similar to the average member of the FinTech and blockchain "in-group", other personal characteristics made me far less interesting for informants to talk to: not having a background in either coding or finance, or not having money to invest. Especially in the frenetic activity of trade fairs, not being a representative of a company, a coder, or an investor made for some awkward dismissals in multiple instances, because talking to me was, to some extent, time wasted for people who were on the expo floor to find money and partnerships. In many cases I was asked whether I could liaise with the University for expertise, facilities, partnership, or even just an opportunity to present on campus, since these companies are always on the hunt for talented students. In other cases, I was asked whether I would be interested in playing a consultant role in the project. In both cases, I declined both because of ethical quandaries connected with me being involved in professional capacity with my informants, and because I lacked power, resources, or the type of expertise they were after. Interestingly, however, my disciplinary allegiance turned out to be an unforeseen asset: in many cases the question "what is Human Geography?" became an ice breaker that kick-started the conversation, in that the subject sounded more exotic than other social science disciplines.

Given the resistance to access in the recruitment process, key informants and gatekeepers acquire an even greater importance in this respect, both because of their expert knowledge and because, by acting as gatekeepers, may allow to "snowball" the sample (Atkinson & Flint, 2001; Vogt, 2005). However, relying too much on individual informants can incorporate bias in the overarching narrative. Here, again, elite research shows how the traditional ethnographic ethos and praxis might require some fine-tuning (Gusterson, 1997; Nader, 1972). Practically, institutions like banks and tech companies are fraught with institutional, economic, and knowledge-based barriers for access that can take years to overcome, often only thanks to fortuitous personal connection or based on one's idiosyncratic background (Seaver, 2014; R. J. Thomas, 1995). Ethically, the ethnographic principle of giving voice to one's informant might work to reinforce, rather than question, the power that informants already have (Pierce, 1995).

One informer laid this risk bare in front of me when I recruited him: in his affirmative reply to my recruitment message, he asked me what my preconceived ideas on cryptocurrencies were, because, he said, everyone has one or more preconceived ideas. He then said: "nearly everybody in this space is in self-promotion mode, and it might be hard to discern what their real agenda is behind self-promotion" (Interview 15th of May 2018). The power asymmetry deriving from access to knowledge and resources must be managed carefully: taking informants at their word might mean becoming a promotional echo chamber rather than a social researcher. Rather than taking informants' accounts at face value, one should "parse corporate heteroglossia" (Seaver, 2017, p. 8) and disentangle the different, sometimes contradictory voices that inform a PR discourse.

Lastly, interviews had necessarily to be digitally mediated. In fact, Ripple has offices in London, San Francisco, New York, and Singapore, and, at the time of data collection, it already had more than 200 clients all over the world. This geographical heterogeneity came with the anxiety of, potentially, having to select where to go to conduct interviews, which offices to prioritise, with the clear awareness that my resources did not allow a fully multi-sited interview-based fieldwork (Hannerz, 2003). In this sense, digitally-mediated interviews not only proved themselves an invaluable support for collecting data on a global network, but they also fit "part of the world in which research subjects live and make meaning" (Seaver, 2017, p. 8). Far from constituting a barrier to conversation, VoIP interviews were the bread and butter of how my informants worked on day-to-day basis. Even technological decisions over coding, design, and standards were made as frequently through online conference calls and forums as in in-person meetings, and software developers and engineers not meeting each other in person for rather long periods of time. As we shall see below, this lack of co-proximity, however, is not fully frictionless: it poses challenges in data analysis and in the creation of rapport (Bengtsson, 2014).

3.3. "Routing Around": Access and Archival Sources.

The scavenger's access strategy cannot be that of prying open the doors to the control room, but to "route around" (Seaver, 2017, p. 10) the multiple resistances to knowledge she will encounter in her way. The Internet is a living archive, both of present and of past interactions (Chun, 2008b, 2013). Online archival sources, hence, provide an important resource to route around constraints to access and gatekeeping. Digital ethnographies are very often used in asynchronous ways that strongly resemble archival research, rather than direct participant observation (Tunçalp & Lê, 2014, p. 70). I employed this research strategy to parse through the archive of the original RipplePay Google Group, as well as the Ripple Forum, XRP Chat forum, Interledger Protocol mailing list.

Furthermore, through the so-called Wayback Machine it is possible to gain access to versions of websites that are no longer online (Arora et al., 2016; Rogers, 2013). Through it, I traced a genealogy of Ripple through the content that was published on the page, but which was no longer visible. Figure 11 illustrates the Wayback Machine's graphic interface. The search bar gives the address of the archived page. The timeline provides the number of times that page was changed or updated each year. However, digital archives are by no means universal or frictionless to access. Even a cursory research on the Wayback Machine, in fact, reveals multiple dead ends and points where data was lost without repair, especially in the case of online forums. Hence, it is important to be constantly wary of the risk of digital ethnography becoming a new form of "armchair anthropology" (Hine, 2017; Tsuda et al., 2014, p. 125).

Figure 11: the Wayback Machine's Homepage. Source: Internet Archive (2014).

The next section delves deeper into the specificities of the online and offline locations that made up my field work, which methodological choices they made necessary, and which analytical avenues they opened or foreclosed.

4. The spatialities of the Field

As Jensen (2007, p. 844) has it, there is an "initial unpredictability as to what is in the field: what connects to what". Issues of access and gatekeeping influenced which spaces were available to me, and which ones were not. However, in assembling my multiple field sites, I did not only rely on "tactical choices" for how best to route around obstacles to access: epistemological and empirical realisation played a pivotal role in understanding the geographies of the field as radically hybrid.

On one side, I came to realise that trade fairs were not just an entry point *to* the field, but an integral part *of* the field itself. Sarah Hall argued that "while much research has focused on cultural economy readings of the technologies through which the international financial system is (re)produced, much less has been made of the ways in which these technologies intersect with specific, place-based contexts" (Hall, 2011, p. 235). Conferences and trade fairs are highly important place-based contexts where a specific set of financial technologies comes into being, is competitively evaluated, and where active form and imaginaries "gel" into complex ecologies. Later into my research project, I remember discussing this with a fellow Ph.D. student in science and technology studies. He told me that, if the technology was indeed important to observe, the hype surrounding it was a key part of the technology itself.

On the other side, I realised that maybe there was no centralised and unified control room to begin with. As Preda has shown regarding electronic retail trading, "electronic finance […] comprises online and off-line activities and institutional formats geared toward producing not only a particular type of copresence, but also transactional activities, the consequences of which lie outside the realm of temporally coordinated copresences" (Preda, 2017, p. 23). The ethnography of electronic markets, then,

> cannot be limited to (hard-to-get) access to a single organisation operating a trading floor, pit, or room […]. Nor does it imply observing face-to-face communication as the unique or the dominant mode. The ethnography of electronic markets requires getting access to various interconnected organisations (Preda, 2017, p. 24).

The field site for electronic finance and digital money is then "a partially existing object emerging from multiple sites of activity that are partly visible, partly opaque to all involved actors, including the ethnographer" (Jensen, 2010b, p. 74). The next two subsections will delve into the online and offline spaces that composed my fieldwork.

4.1. Trade Fairs, Expos, and Conferences.

As I immersed myself in the expo floors of blockchain trade fairs, it became increasingly clear to me that the "nitty gritty" of how money was moved logistically was just as important as the speculation, myths, enchantments connected with the promises held by technological innovations. The trade fairs then became less an entry point to the field but a constituent part of the field in their own right. As argued in Chapter 1 and as it will be further expanded upon in Chapter 6, infrastructures are not only material assemblages but also semiotic and symbolic constructs capable of affective enchantments (Larkin, 2013). Despite the tendency to consider money and finance as purely and simply the realm of pure function and output maximisation, aesthetics clearly plays a role, from the appearance of coins and banknotes (Helleiner, 2017) to the appearance of bank buildings (Frandsen et al., 2013; McGoun, 2004). As McGoun (2004, pp. 1104-1105) has it,

> even in these financially sophisticated times, symbols matter, and the message communicated by these symbols is one which cannot be communicated in any other way. […] There is a visceral appeal of an architecturally distinguished building to the senses that speaks to us in a way that the cerebral appeal of favorable (sic) information cannot. […] The tangible presence of bank buildings may communicate something to us of our economy, our culture, and our society in the same way other monumental structures such as the pyramids of Egypt communicated to those who constructed them.

If the visceral importance of aesthetics in constructing markets and firms is important to scrutinise, then, it is important to see how the change in the structure of markets and financial institutions can bring about, and can be brought about by changes in aesthetics:

> The shift to electronic trading and decentralised markets will lead to much more than just increased transactional efficiency [...] "seeing" the market may be as important as participating in it and that making new institutions visible might be an essential component in making them work (McGoun, 2004, p. 1105).

In a techno-financial world of proliferating "virtual" sources of value, the aesthetics and structure of the expo is just as important as bank architecture was in traditional financial markets.

This led me, on one side, to let go of the sense of frustration or expectation connected with how many informants I would have been able to recruit during the few days each expo lasted, and, on the other side, it allowed me to expand my focus and juxtapose the expo floor to the control room, rather than striving to get to one through the other. As Nyqvist et al. (2017, p. 3) have it, "conducting fieldwork at large-scale professional gatherings entails both the necessity of 'being there,' taking part in the face-to-face interaction and of situating the particular event in a wider societal context". Hence, my sampling strategy for the conferences and fairs that I attended followed the criterion of being relevant both for my specific research questions, and for the fields of FinTech and blockchain technologies. Within the budget constraints of my funding, the conference selection was guided by two criteria: on one side, having Ripple employees or clients as participants and, on the other side, being a well-recognised event by blockchain-related press such as, for example, CoinDesk and CoinTelegraph. Table 2 summarises the sample of conferences and trade fairs that I attended during my fieldwork.

Name	Location and Time	Theme	Type
Westminster eForum on Digital Payments	London, 13^{th} December 2016	Payments and FinTech	Knowledge
MoneyConf 2017	Madrid, 6^{th}-7^{th} June 2017	Payments and FinTech	Expo
Quadriga Consulting's Blockchain Masterclass	London, 12^{th} October 2017	Blockchain and Cryptocurrencies	Knowledge
Blockchain Summit	London, 31^{st} October 2017	Blockchain and Cryptocurrencies	Knowledge + Expo

Blockchain Expo Global 2018	London, 18th-19th April 2018	Blockchain, Crypto, AI, IoT and Cybersecurity	Expo
MoneyConf 2018	Dublin, 11th-13th June 2018	Payments and FinTech	Expo
Blockchain Expo Global 2019	London, 25th-26th April 2019	Blockchain, Crypto, AI, IoT and Cybersecurity	Expo
Blockchain Expo North America	Santa Clara, California, 13th-14th November 2019	Blockchain, Crypto, AI, IoT and Cybersecurity	Expo

Table 2: List of conferences, expos, and trade fairs where temporary ethnography was conducted.

Trade fairs are "recurring, but temporary events where people within the same industry meet and exchange experiences, make contacts and do business […] for both networking and knowledge-creation" (Nyqvist 2017, 27). They are "nodes in complex entanglements of social relations stretching out in different directions […] the trade fair and the conference may be seen as particular, local sites of temporary character [that] resembles a village of professionals" (Nyqvist et al., 2017, pp. 3-4). As Moeran and Pedersen (2011, p. 10) define them, "fairs, festivals and competitive events provide a venue for the (re)enactment of institutional arrangements in a particular industry's field and for the negotiation and affirmation of the different values that underpin them".

Moeran and Pedersen (2011a, pp. 6-7) argue that fairs are spatially, temporally, and socially bounded, yet functionally unbounded events. They are bounded in terms of space, time, and social setting in that they bring the participants to one specific industry in a specific place for a predetermined length of time. On the other hand, fairs are functionally unbounded, in that they can serve multiple purposes. Functionally unbounded is probably unduly broad, and functionally flexible would be more appropriate: whilst any fair has a multiplicity of purposes and uses for its participants and audience, different events have different aims and functions, be it expanding the reach of a company, being a general-purpose expo, providing new knowledge to practitioners, or reaching consensus and making decisions affecting the field.

As noticed by Braudel, fair time has always been, to some extent, carnival time, a time of "noise, tumult, music, popular rejoicing, the world turned upside down, disorder and sometimes disturbances" (Braudel, 1979, p. 85). A town during a fair "would then be invaded by all the jokers, sellers of miracle-cures and drugs, […] fortune-tellers, jugglers, tumblers, tightrope-walkers, tooth-pullers, and travelling musicians and singers. The inns were packed" (Ibid). In a carnivalesque frenzy, fairs often contain suspensions of norms related to, for example, gambling:

> The 'blank' lottery was all the rage: it gave out large numbers of white or blank tickets (the losers) and a few black tickets, the winners. […] But this was as nothing compared to the discreet gaming-tables housed in certain booths of the fair, despite the frowning vigilance of the authorities (Ibid, p. 85)

Fairs, in this respect, materialise in one space the crowds that gather around specific markets and assets during speculative frenzies. Speculation itself has a carnivalesque character: "even if held together by a chimera, crowds themselves were by no means an illusion. A fictional object could produce crowds whose sensuous reality as fascinating. The power of fictionality proved to be quite real" (Stäheli, 2013, p. 104).

Fairs, in this respect, are "bubble in controlled form", i.e., they are temporary and bounded receptacles of the enchantment that traverses a whole industry, collectors and magnifiers of the hype that inspires a new technology. However, this similarity between the fair and the frenzy can be analysed in more direct and material ways: the floorspace occupied by a fair varied over time and it was, to some extent, a proxy for the underlying temperature and dynamism of speculative frenzy. Figures 12 and 13 depict, respectively, a buzzing expo floor in 2018 and one of the many empty exhibition spaces in 2019, one of the many signs of the "crypto winter" and the shrinking industry.

Figure 12: FinTech Trade Fair, 12th June 2018. Source: Author's own.

Figure 13:Empty space at blockchain Expo Global, April 2019, London. Source: Author's own.

As further expanded in Chapter 6, the fairs, the hype traversing them, and their openness contributes to cast speculative investments in a market as a form of spectacle and, simultaneously, to constantly produce and reproduce an insider-outsider divide between professional and popular investors, powerful and non-powerful, experts and amateurs (Entwistle & Rocamora, 2011; Havens, 2011; D. Thompson, 2011). Citing Braudel again,

> In Lyons, according to the tavern keepers who no doubt knew what they were talking about, 'for one merchant who comes to the fairs on horseback and has plenty of money to spend and find good lodgings, there are ten others on foot, who are only too happy to find some

> modest cabaret to lay their heads'. At Salerno or other fairs in the kingdom of Naples, crowds of peasants turned up to take the opportunity to sell a hog, a bale of raw silk or a cask of wine (Braudel, 1979, p. 90).

While the speed of electronic trading has now reached peaks not previously possible (D. MacKenzie, 2017a; Pardo-Guerra, 2019), the process of "producing simultaneity" (Sloterdijk, 2013, p. 141) and of "Industrialising Time and Space" (Schivelbusch, 1977/2014) associated with the Internet and the worldwide fibre optic wiring (Starosielski, 2015), were already embodied by the railways (Schivelbusch, 1977/2014) accompanied by the telegraph (Müller, 2016; Standage, 2009).

The Railway Mania and the Dot Com Bubble show a continuity in promises and imaginaries: the compression of space through connectivity, the conceptualisation of digital telecommunications as a "super-highway" and as a "nervous system of Capitalism" (Chancellor, 2000, p. 150). In 2014, while rewriting his 1979 book *The Railway Journey*, Schivelbusch (1977/2014) found it necessary to add a chapter that re-reads the whole history of the development of the railway network in light of the digital revolution and the Internet. Both digital technologies and the railway are technologies of connectivity that redesign the world in their image by internalising nature in their rules.

Schivelbusch (2014) draws a connection between the expansion of the railroads and the architectural aesthetics of the South Kensington Crystal Palace, built in 1851 for the Universal Expo. Peter Sloterdijk treated that same building as the epitome of modernity, as the diagram for the "world interior of capital", i.e.,

> Not an agora or a trade fair beneath the open sky, but rather a hothouse that has drawn inwards everything that was once on the outside. The bracing climate of an integral inner world of commodity can be formulated in the notion of a planetary palace of consumption (Sloterdijk, 2013, p. 12).

As we shall see in further depth in Chapter 6, railways were caught into a mania and a speculative frenzy in a similar way as the cryptocurrencies and digital payment systems treated in this thesis. Here, what is interesting is how the railway produced a reworking of previously existing spaces – the trade fairs – into new spaces – the open-air expo (See Figures 14 and 15).

Figure 14: The transept from the Grand Entrance, Souvenir of the Great Exhibition, William Simpson (lithographer), Ackermann & Co. (publisher), 1851, V&A.

Figure 15: Interior of a blockchain expo at Olympia, Hammersmith, London. Source: Author's own.

Trade fairs perform two complementary functions. On one side, they are the "front stage" (Goffman, 1990) of performative practices (C. W. Smith, 2011, pp. 97-99) where tournaments of value take place. Appadurai (1986, p. 21) defines tournaments of value in this way:

> Complex periodic events that are removed in some culturally defined way from the routine of everyday economic life […] The currency of such tournaments is also […] set apart through well understood cultural diacritics […] What is at issue […] is not just status, rank, fame, or reputation of actors, but the disposition of the central tokens of value in the society in question. […] [Their] forms and outcomes are always consequential for the more mundane realities of power and value in ordinary life.

As said before, the tournament of value often implies textured access practices and gatekeeping such as the colour of the badges worn by participants, but more in general in entails visibility and location. For example, the size or the aesthetics of the exhibition space convey a more important role in funding or organising the event, although it can also play as a pure marketing strategy. Another way through which prestige is recognised and distributed is by allocating speakers from different companies to different slots, e.g., speaking in an unpaid session, chairing an unpaid round table or workshop, and speaking to a paid-only session.

On the other side, conferences and trade fairs work as "field configuring events" (N. Anand & Jones, 2008; Garud, 2008; Glynn, 2008; McInerney, 2008; Oliver & Montgomery, 2008). Moeran and Pedersen (2011a, p. 20) define field-configuring events first, as places where participants in the field are able to increase their interaction and communication. Second, a set of shared issues are framed as the most important ones to be addressed in the field.

Third, the discussion and the questions are fraught with power and conflicts. This power, lastly, allows those in powerful position to transform one kind of capital (e.g., social, cultural), into another (e.g., economic). The events labelled as "Expo" in Table 2 tend to have a stronger component of tournament of value over field configuration, while the ones labelled as "Knowledge" tend to have a stronger field configuring function. A paradigmatic example of a conference with a field configuring function, albeit one that I unfortunately could not attend, was the Consensus conference in May 2017 in New York where, after years of debates over whether Bitcoin should increase the maximum block size of its blockchain, a group of miners and exchanges reached an agreement on the introduction of a Segregated Witness (SegWit) system to make transaction processing faster (Dinkins, 2017; Wirdum, 2016). That agreement subsequently collapsed leading to forks that, in turn, generated new cryptocurrencies, the most famous of which is Bitcoin Cash.

To some extent, as the cryptoasset bubble swelled and then burst, a different tournament of value ensued between conferences, rather than within them: in a similar way as Feng et al. (2001) argue that, as the Dot Com bubble burst, investors started to look more and more at the "fundamentals" and the actual returns of start-ups from sales and actual products, the bursting of the cryptoasset bubble seems to produce a concern for conference organisers to be less involved in the showcasing of different proof of concept and minimum viable products, and more with discussing technology, regulation, and applications. Speaking with an organiser of blockchain and crypto conferences, she decried the overabundance of expos that live mainly off the fees from expositors and that are too "community-driven", and she argued that her organisation was more concerned with conversations that involved academia and government. As she said "good speakers are one thing, experts are another. Academic institutions are trustworthy because they are not profit-driven institutions" (Interview 11/11/2019). In her mind, too many conferences were in the business of "selling exposure and inclusion in the ecosystem" (Ibid).

4.2. Online Field Sites: Remote Interviews, Archival Spaces.

While a stronger focus on trade fairs, conferences and expos was driven by the realisation that these spaces were more than just entry points to the field, another realisation led me to delve deeper in online spaces such as archives, forums, and conference calls: the realisation was that, maybe, there was no one control room to begin with. The software system that I was studying emerged as much more heterogeneous, fragmentary, and contingent than I originally imagined. Rather than there being one or more control rooms, held at one or more banks, there were multiple “legacy” payment infrastructures using different standards for different types of payments, and each of these instances had a tailor-made synchronisation system. An informant even said that, internally, different national branches of the same banking conglomerate had to rely on a network of correspondent accounts to move money to and from each other. There was not a unified network with a master switch that one could flip to enable or disable a specific connection, but many switches, the shape of which depended on the pair of organisations that were being connected each time. Offices around the worlds were not so much like ports in logistics: they rather served as *pied-à-terre* for the organisation to better understand the situation on the ground in regulatory and industry terms because, as one informant put it, “you cannot be sitting in San Francisco and sell to the world, not in banking” (Interview 29th May 2019).

This realisation came with a mix of relief and renewed anxiety. I was relieved that now I did not have to pry open the doors of a control room, but I was now caught in a potentially endless list of locations, so far apart from each other that it was not thinkable in terms of money, time, and capacity for me to cover them all or even most. I started to think that what mattered were the material or discursive connections made either in-person or online, between different locales by the active production of a multi-sited field. Following must be reappraised in digitally-mediated research and understood also as “intercepting”, studying a single site as a point of intersection, “with an *awareness* of its multisite context” (Burrell, 2009, p. 192 emphasis in the original). “Rather than viewing the asymmetries generated in mediated settings as posing a special kind of problems for ethnographic inquiry”, Casper Bruun Jensen (2010b, p. 73) argues, “such asymmetries can be seen as replications of features of the field”.

The problem of how to bridge and inhabit different spaces was not only an epistemological and methodological problem for me, but it represented a practical problem for my informants as well. In Kavanagh et al (2019, p. 521)’s terms, we can say that different spaces were made to *resonate* with each other in order to produce Ripple and the Interledger Protocol. I had to conduct a fieldwork without clear demarcation of where the field itself started and ended, and they had to build a cross-border payment infrastructure without knowing what was connected with what. At stake was not the best strategy to get to the place *where* my questions could be answered but understanding the *where* of the field as constituted both by trade fairs and by online conference calls.

Ethnographers of the Internet have long argued against a strict online-offline dichotomy, illustrating how the relationship between the digital and the analogue is case-specific, contingent, and mutually constituted. Hence, the choice of methods also must follow the peculiar online-offline relations that the case establishes. This lies on a continuum between studies where the researcher and the informants never meet in person (Schaap, 2002) to studies that rely on offline settings (Burrell, 2009). An ethnography *in* and/or *of* the Internet (Cf. Marcus, 1995), then, can span from a fully online ethnography that takes the Internet as its main focus (Beaulieu, 2004; Kozinets, 2002, 2011), to a mixed approach that focuses on the mutual construction of online and offline settings (Hine, 2000).

My informants gathered, met, interacted, and considered as relevant sites for their activities essentially four types of places: online forums and social media, online meetings where coding and features where discussed and approved, temporary gatherings of the key stakeholders in the blockchain industry, as well as physical offices where coding, negotiation, and harmonisation with local regulation could be carried out. Hence, much as Preda (2017) realised throughout his ethnography of day traders that neither online nor traditional ethnography could fully capture the type of fieldwork he was conducting, this project immediately incorporated “Internet media as continuous with and embedded in other social spaces” (Daniel Miller & Slater, 2000, p. 5). Online ethnography is understood here in an “integrationist” way (Robinson & Schulz, 2009, p. 689), where online and offline settings compenetrate each other, and hence need to be studied together (Dyke, 2013).

Online forums were the privileged locations where to observe the negotiation of different values and potential uses of the same technologies. I observed Ripple’s original forum, RipplePay’s Google group, as well as telegram channels connected with Ripple and Trustlines, and the mailing list, the forum, and the online conference calls organised by the Interledger Protocol. The main risk for online ethnography is to recoil into “armchair ethnography” by the ethnographer limiting herself to “lurking” (Garcia et al., 2009, p. 58) in the background of the virtual space rather than fully engaging. Furthermore, a completely non-participant positionality for the researcher raises ethical questions about covert research and authenticity (Hallett & Barber, 2014; Murthy, 2008). While there is a case for non-participant observation as a form of archival research that allows to route around blockages to access, I was also wary of not being completely invisible to the members of those communities. For these reasons, I always displayed my personal contacts on the profile I used in online settings, where I also explained what my purpose was. Furthermore, I explained my research project by voice in an Interledger Protocol Zoom call in October 2017, and later in a recruitment emails sent to the whole mailing list.

Overall, forums and mailing lists are mainly used to raise questions, propose topics, and to showcase and discuss some developments in terms of new code or new approaches to ongoing problems and conversations. The most important decisions, however, seem to take place, at least for the Interledger Protocol, in the fortnightly Zoom calls they hold. These calls are open to everyone, recorded, and the recordings are posted online, either on the Interledger website, or, before June 2018, on the Interledger YouTube channel. I participated in several of those calls and used the recordings for those I could not attend personally. As Sandler and Thedvall (2017) argue, meetings are omnipresent in any field setting, yet meeting themselves have received very little methodological specification (Schwartzman, 1989). While Goffmann (1966) argued that public meetings are defined by copresence, mutual monitoring and a central situational focus of cognitive and visual attention, Wasson (2006) showed how virtual meetings split the interactional space in two or more spaces: each participant has a local setting, all participants share the virtual meeting space, and some of them might have separate simultaneous online or offline interactions. This is now commonplace because of the almost ubiquitous presence of Zoom for all the interactions that migrated online due to COVID-19, but it is important to remark them for methodological purposes, to understand what exactly makes up a meeting in a virtual environment.

If conferences and trade fairs are tournaments of value, Thedvall (2008) define meetings as "rituals of legitimation": they distribute roles and resources, allow groups to make decisions, and create room for contestation. These fortnightly calls were ways in which decision-making processes were established and fine-tuned, labour was divided between main- and side-projects, and breakthroughs in design were discussed. The most important example of this is the ILP call of 29th November 2017, when the so-called ILPv4 is presented. This new version of the protocol entailed several functionality changes: small instead of large payments, "penny switching" instead of atomic transactions, and end-to-end quoting instead of a separate quoting protocol (see Chapters 5 and 7). That meeting was not only a "'a-ha!' moment" (Hutter & Stark, 2015, p. 8), but an active site and moment of dispute and contention. For example, a participant to that meeting took the floor after the presentation and said:

> I know banks and I know how to sell to banks, and the idea that you can send a whole sum of money from A to B and it either goes through or it doesn't? I can sell that. But I am afraid that the idea that payments are broken up and sent around and some go through and some don't, that was already invented ten years ago (field notes 29/11/2020).

This criticism was addressed by showing how packet-switching allows a similarly frictionless payment experience as atomic transactions[4] (Pesch & Ishmaev, 2019), and it was backed up with a strong reference to the Internet imaginary (Flichy, 2008) of seamless internetworking. Another participant, who did not take the floor, subsequently voiced some concerns saying:

> I think it's a fallacy that the cypherpunks have been falling down for the last twenty years because they like to compare things with packets of information over the Internet, micro payments that stream, and it's never been an economically appropriate model because at the end of the day if someone is going to operate a connector node or any kind of a node, something's got to cover the cost, and if you've covering a stream of micropayments, it's not hard to imagine how, yeah you've been involved in tens of thousands, or hundreds of thousands of payments that day and racked up a whole ten bucks (interview 17/05/2018).

Hence, we can see here how the fieldwork adopted a topology made of multiple physical, virtual, and imagined spaces (Burrell, 2009, p. 181) where the process of production and valuation of new money forms took place, and the spaces that money infrastructures traversed. These places are entry points more than individual field sites (Burrell, 2009, p. 190), i.e., nodes in a network from which one starts a process of following real and imagined connections with other places (Burrell, 2009, p. 191). Spaces are not only physical and inhabitable: they might be concealed or imaginary. These spaces and their connection with material spaces, in turn, shape "real-life" interactions. The imaginary, in digitally-mediated research, is both an empirical object and an ethnographic field site in its own right (Burrell, 2009, pp. 193-194). However, space is not the only dimension of fieldwork: time matters in data collection and analysis, as a constitutive element of data itself through hype and speculation cycle, and as unavoidable limit to decide where and when to stop (Burrell, 2009, p. 194). This will be the object of the next section.

5. Time in the Field.

[4] See also Chapters 5 and 7 on penny switching.

Blockchain? Blockchain is so 2016!

An informant, in June 2017.

In digitally mediated environments, time plays an important role in what counts as data, the process of data collection, and in analysis. I identify three ways in which time played a positive and a negative role in shaping my fieldwork: time as a medium, time as hype and attention cycle, and time as a limit. First, time influenced the rhythms of recruitment, data collection, and analysis. Scheduling online interviews with informants who were several time zones away made it visible that digitally mediated interviews are far from frictionless. On one hand, digitally mediated interviews with informants in far-away locations made room for more paced data analysis. The ostensibly empty time between message and reply, between scheduling and interviewing, and between interviewing and follow-up can be used to start reflecting on the data already collected. On the other hand, the mismatch in time and location often means that the informant did not know what I knew and the other way around. In a "traditional" ethnography, interviews can both build on and expand on previous interviews, because both the researcher and the informant keep mental and written records of past observations and interactions. This is far less likely to happen when interviews are carried out remotely or without the previous building of rapport with the informant through physical proximity (Hannerz, 2003).

For Hine (2000, p. 23), one of the resources afforded by online ethnography is that "ethnographer and participants no longer need to share the same time frame", hence allowing for projects with a much broader geographical spread. However, this lack of synchronicity and physical proximity also poses challenges in terms of building rapport and access. Since interviews did not build on each other, I could only make sense of data in early interviews through the answers and notes collected during much later chats. For example, my fieldwork started in summer 2017, but it was only in 2018 that I was able to retroactively make sense of previously collected material, thanks to the insights of a key informant recruited in May. This, subsequently, helped me to structure subsequent interviews. In a similar way, only later observations of trade fairs and expos provided me with a diachronic sense of perspective that put in context earlier field notes.

Second, time figures as a cycle of attention and hype. Cryptocurrencies and blockchain technologies have gone through wild oscillations in value, popularity, and public awareness between when I started this project in 2016 and the time of writing. Figure 16 shows the total market capitalisation of the cryptocurrency markets from 2013 until 2021. Until 2016, one can see that the size of the market remained extremely contained, even though it was already the object of public attention and scrutiny. In 2016, cryptocurrencies were on the rise, but still a quirky niche conversation topic for most, and a research topic mostly for computer scientists, some monetary and financial economists, and very few social scientists. In 2017, attention picked up momentum. Bitcoin hit and surpassed the $20,000 price threshold in December, and the cryptocurrency market almost reached the trillion dollars in collective market capitalisation.

However, already in late January 2018, prices started to drop and the “crypto winter” set in (Yakubowski, 2019b). The amount of floor space in expos and trade fairs also shrank quite visibly, and news started covering companies that went bust more than those who were launching their operations. Just as this thesis is being submitted in its final form, cryptoasset markets are entering yet another phase of frenzy that makes 2017 pale by comparison. Every peak was seen by enthusiasts as ushering in a new world of digital money, and every drop was seen by the sceptics as the bursting of a speculative bubble. There is even a website that lists all the times Bitcoin has been declared dead by technological and financial commentators, that has now surpassed 350 obituaries (99Bitcoins, 2019). Had my fieldwork lasted 6 months at any point between mid-2017 and 2019, I would have been more prone to seconding the hype of the moment and I would have missed important trends that would have made sense only if put in context.

Figure 16: Total Market Capitalisation of Cryptocurrency Markets, 2013 to 2020. Source: CoinMarketCap (2021).

Third, time acts as a constraint and limit: like in any fieldwork, it is important to decide both *where* and *when* to stop (Burrell, 2009). The boundlessness of hybrid online-offline, and digitally mediated research can just as easily make any fieldwork endless (Reich, 2015). Single-sited intensive ethnographies, however long in their duration, have an endpoint, the crossing of which helps the researcher to take the necessary distance from the field itself before analysis and writing up. A radically multi-sited fieldwork, conversely, lacks not only the topographical, but also the chronological and temporal boundaries typical to conventional fieldwork. I could be “in the field” during a conference call, remain in the field immersing myself in archival documents, then be out of the field while I was teaching, and then go back into the field several days later for an interview or a trade fair. While this allows for data collection and analysis to go hand in hand, a lack of a true boundary between beginning and end of fieldwork also means that the process of data collection could, potentially, go on endlessly.

Theoretical saturation, hence, plays a pivotal role in determining the endpoint of data collection, defined as “the point […] at which theorising the events under investigation is considered to have come to a sufficiently comprehensive end” (Sandelowski, 2008). In my case, given the dynamic nature of my research topic, I had to work on two binaries. On the one hand, I had to isolate theoretical themes that I judged to be relatively stable in the whirlpool of information surrounding blockchain technologies and cryptocurrencies. On the other hand, however, I had to keep my eyes and ears open to the latest developments in the industry, the most recent regulatory measures introduced, and landmark court cases, as well as to the daily oscillations in the price of cryptoassets. While this strategy prevents a thesis written on this topic from becoming old before it is even sent to print, keeping the door to the field constantly ajar can prove itself stressful.

6. Conclusion

Rather than drawing a demarcating line between what is or is not a legitimate field site, this chapter embraced a multi-sited approach of following “the people, the things, the metaphors” (Marcus, 1995) and to be more attentive to co-presence than to co-location (Beaulieu, 2010). Rather than seeing one specific location (the fair) as an instrumental tool to gain access to another location (the control room), this chapter showed that both the fair and the control room are part of one and the same multiplicity of field sites, a multiplicity that is “constructed rather than discovered” (Tunçalp & Lê, 2014, p. 60). In so doing, my fieldwork drew upon and, hopefully, contributed to current research in organisational and institutional anthropology of meetings, conferences, trade fairs, and other temporary gatherings (Høyer Leivestad & Nyqvist, 2017).

This research project started with a specific case study – Ripple – at its core. The chapter showed how the case selection process unfolded, in search for a revelatory case that could shed light on multiple analytical dimensions of the infrastructural qualities of money. The project looked at blockchain technologies as paradigmatic examples of the irreducible infrastructural materiality of money, and at cross-border payments as extreme cases to illustrate the tensions, frictions, and fictions (Pesch & Ishmaev, 2019) that animate interoperability, foreign exchange, and correspondent banking. Furthermore, the project wanted to tap into as many niches in the burgeoning FinTech and blockchain ecologies as possible, i.e., public, private, and grassroot actors, so as to show the different practices, imaginaries, and devices they mobilise. Ripple was shown here to be a very apt revelatory case that showed otherwise invisible connections. However, more than being a single-case research, this project blurred the boundaries of the case, to "imagine the whole" (Marcus, 1989) in relation to the FinTech and blockchain industries. This chapter also contributed to literature on elite research and "studying up" (Gusterson, 1997; Nader, 1972; Seaver, 2014) by adopting a "scavenging ethnographer" subjectivity to "routes around" resistances to access (Seaver, 2017).

In tracing the connections between places and in following a translocal object – money – in multiple online, offline, and imagined localities, my own fieldwork became a "fractal ethnography": "multiple scales and perspectives are thus deployed in different practical and material circumstances, and it is through their intertwinement, transformation, and temporary stabilisations that infrastructures evolve" (Jensen, 2007, p. 833). The mix of online and offline methods that this chapter outlined points to some specific challenges connected with the temporalities of recruitment, data collection, and analysis in contexts without synchronicity and co-presence between researcher and informants. In so doing, this chapter hopefully contributed to ongoing debates on digital methodologies in the social sciences (Ash et al., 2018b; Marres, 2017). As technology evolves and redefine social encounters, and in a post-Covid19 world that poses new practical challenges to the in-person encounters that underpin social research, multi-sited fieldwork and digitally mediated ethnography will acquire new salience and become more and more frequent, making the contribution of this chapter especially timely.

PART II

Chapter 3: The Materiality of Digital Money

1. Introduction

The past ten years have been marked by profound transformations in the field of money and payments. The introduction of Bitcoin in 2009 ushered in a dramatic expansion in the number and market capitalisation of cryptocurrencies, and a proliferation of use cases of blockchain technologies beyond money and payments, e.g., supply chain, healthcare, population and land registry, elections, and so forth. This chapter, then has an empirical and an analytical aim. Empirically, it wants to reconstruct the key determinants in the developments in money and technology in the last ten years, by reconstructing a genealogy of cryptoassets, distributed ledgers, and financial technologies ten years after Bitcoin. Analytically, it wants to use this proliferation as a provocation to develop an infrastructural approach to money. An infrastructural approach to money means to take the materialities of the assemblages that enable money's circulation seriously, as active form having political and social dispositions (Easterling, 2014).

This chapter and the next, then, acknowledge the direct and material politics inherent to technology and infrastructures. While Part III of the dissertation will be organised in a way that is more conducive to reading each chapter in isolation as stand-alone contribution to the unpacking of specific concepts and analytical dimensions, Chapters 3 and 4 ought to be considered two faces of the same coin. This chapter deals with the more directly material building blocks of blockchain technologies and payment infrastructures more in general. Chapter 4 complementarily covers cultural elements, political economies, regulatory interventions, and broader co-evolutionary dynamics that make large technical system change despite, beyond, and often against the individual intentions of their designers. While space requirements and conceptual concerns make it easier to treat these two dimensions in separate chapters, it is important here to state that this dissertation does not draw a line between tangible and intangible materialities, between infrastructures and society, and between technology and cultures. Rather, all these elements ought to be seen as imbricated in what Coeckelbergh (2013) calls "deeply relational techno-human ecologies".

In his seminal paper, Langdon Winner (1980, p. 12) defined "inherently political technologies" as "man-made systems that appear to require, or to be strongly compatible with particular kinds of political relationships". Infrastructures' capacity to require and influence political relationship can be derived, in Jane Bennett's terms, from their *thing power*, i.e., "the strange ability of ordinary, man-made items to exceed their status as objects and to manifest traces of independence or aliveness, constituting the outside of our own experience" (Bennett, 2010, p. xvi). In Keller Easterling's (2014, pp. 71-72) terms, infrastructures' thing power instantiates itself in a disposition, i.e., "relationship between potentials. It describes a tendency, activity, faculty, or property in either beings or objects- a propensity within a context […] that results from the circulation of […] active forms within it". Infrastructures' power is performative in that "materiality is discursive […] just as discursive practices are always already material" (Barad, 2003, p. 822). Infrastructural performativity can be seen as a set of "material-discursive practices […] through which matter is differentially engaged and articulated […] reconfiguring the material-discursive field of possibilities" (Ibid, p. 823).

To some extent, the attempt to define and "clarify" the meaning of key terms is at odds with the analytical concern of showing the politics of infrastructure: standardisation, whether of meaning or of things, is never a neutral matter. Rather, they represent "investments in forms" (Thevenot, 1984) that "codify, embody, or prescribe ethics and values, often with great consequences for individuals" (Star & Lampland, 2009, p. 5). Standards, together with the infrastructures where they are inscribed, become the invisible and overlooked technological substratum of our everyday life. In this respect, blockchain technologies help our analysis in three ways. First, the sole form of material existence of blockchains and cryptoassets coincides with their underpinning infrastructure. Hence, what normally recedes from view in large technical systems, is here on display. Second, the materiality of blockchain infrastructures is more evidently political than in other large technical systems and payment infrastructures. Third, they are a technology still in their infancy, hence the battles over standardisation are still being fought: blockchain technologies occupy a liminal space typical of emerging general-purpose technologies, a space that is fraught with "framing struggles" over terminology, status, and regulation (Hacker et al., 2019b, p. 14). This chapter does not want to resolve this tension, but to keep it visible: while standardisation tends to make meaning unproblematic, this chapter simultaneously teases out definitions and the power struggles that underpin them.

This chapter is centred on the case of Ripple, its genealogy and materiality, and it departs from that to develop a more general political ontology of money infrastructures. As argued in Chapter 2, Ripple is important because it is a "revelatory case" that makes visible hitherto invisible connections, co-evolutions, and conflicts. Ripple, in fact, was born before Bitcoin as a largely alternative form of digital monetary network. It then morphed into a cryptocurrency that took some insight from Bitcoin, changed some major components, and tweaked other elements. The materiality of the XRP Ledger bears the marks of the conflicts over politics and regulation that have traversed, and that are traversing, this entire space. The operations of Ripple and the design of the XRP Ledger have performed and enabled different infrastructural money cultures and practices over time. Hence, Ripple illustrates the ecologic co-evolution of infrastructural money forms and money cultures that this thesis sets out to conceptualise and emphasise. Hence, it serves as a useful heuristic device to provoke investigations into the analytical dimensions of space, desire, and power that will be dealt with, respectively, in Chapters 5, 6, and 7.

This chapter, then, starts by laying a minimum terminology of some of the material components of blockchain technologies, and by illustrating how the meaning of those terms are still very much in flux and contested. It then delves in-depth with the specific materiality of Ripple, and it traces the complex genealogy that led an alternative credit network to turn into a distributed ledger system, from that into an inter-bank cross-border settlement infrastructure, and from that into a generalised interoperability standard for payments. Lastly, section 4 generalises the insight generated from the analysis of the Ripple case to the whole blockchain and distributed ledger industry, by developing a political ontology of the material active forms and dispositions of blockchain systems, based on Easterling's (2014) conceptual framework for the analysis of infrastructure space and of Tasca and Tessone's (2019) taxonomy of blockchain systems.

2. Terminology

The aim of this section is to establish the meaning of key terms and components making up this burgeoning field of technological innovations, so that the subsequent analysis can go in further depth. When dealing with blockchain technologies, in fact, one is confronted with a plethora of partially overlapping and fuzzily delimited concepts and definitions, and with eclectic uses of the same term in rather different contexts and realms of application. As Rauchs et al (2018, p. 11) put it, "The DLT ecosystem is plagued with the use of incomplete and inconsistent definitions and a lack of standardised terminology". This has led to what Rauchs et al. (2019, p. 11) call the "blockchain meme": 77% of the live corporate blockchain platform that were reviewed in their benchmarking study were found to have "little in common with multi-party consensus systems" (Ibid). It is necessary, then, to make some clarity in the definitions of key terms before going deeper in analysing them for their significance for social science research.

Some authors tend to use DLT and blockchain technologies interchangeably: for example, DuPont (2019, p. 29) defines blockchains as:

> Distributed computing technologies that securely record data on append-only digital ledgers and execute code. Blockchain are functionally similar to cryptocurrencies but are not tied to a system of money and therefore have enhanced code execution environment. Also known as 'decentralised ledger technologies' (DLTs).

Other authors tend to use Distributed Ledger Technologies as a broader term for all types of distributed databases, or to define blockchains as those instances of DLTs that employ cryptoassets (Government Office for Science, 2016; Hileman & Rauchs, 2017a, 2017b; Rauchs, Glidden, et al., 2018). For example, Rauchs et al define Distributed Ledger Technologies (DLTs) as

> multi-party systems that operate in an environment with no central operator or authority, despite parties who may be unreliable or malicious ('adversarial environment'). Blockchain technology is often considered a specific subset of the broader DLT universe that uses a particular data structure consisting of a chain of hash-linked blocks of data (Rauchs, Glidden, et al., 2018, p. 15).

The World Bank, defined DLT as "a novel and fast-evolving approach to recording and sharing data across multiple data stores (or ledgers) [that] allows for transactions and data to be recorded, shared, and synchronised across a distributed network of different network participants" (World Bank, 2017, p. vii). The Bank of England defines DLT as distributed databases whose control is decentralised, reliable in trustless environments, relying on cryptography (Benos et al., 2017, p. 5). Blockchains are often defined as a subset of DLT that employ cryptography. Iansiti and Lakhani (2017) define blockchain as "an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way". Similarly, Zachariadis et al (2019, p. 109) define a blockchain as "a distributed database system managed by a peer-to peer network of computing devices that provides a shared, yet accurate record".

A concise definition of a blockchain would then be: a distributed, time-stamped, append-only ledger of data connected with addresses, simultaneously kept on all the nodes within a decentralised network, and updated through a set of rules and instructions called consensus algorithm. Blockchains employ public key cryptography to guarantee that only the possessor of the public and private cryptographic keys associated with an address, can initiate transactions involving amounts associated with that address. Transactions are then propagated by direct messages between connected nodes – facilitated through so-called gossip protocols (Decker & Wattenhofer, 2013) – and then collected by validators in transaction pools (See Figure 17). The consensus algorithm ensures reliability, authenticity, and accuracy of the records in it. While Bitcoin's white paper used the words chain and blocks separately (Nakamoto, 2019), and while concepts like "chains of time-stamps" was already present in the cryptographic literature since the early 1990s (Haber & Stornetta, 1991), the very term "blockchain" only emerged between 2014 and 2015 (Tapscott & Tapscott, 2016).

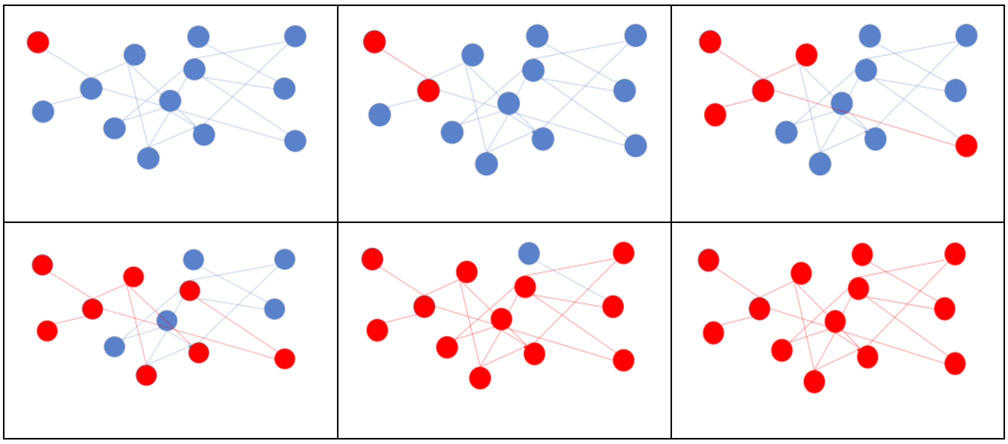

Figure 17: Schematic representation of gossip protocols' role in propagating information across a blockchain network. Source: Author's own.

First, blockchains are distributed in that the ledger is stored and updated simultaneously on multiple machines. Second, they are time-stamped, that is, each block of transactions carries the time when that block was added to the blockchain. In so doing, the network reaches consensus on a chronology or chain of events and transactions recognised as legitimate. The blocks of data are time-stamped and connected sequentially, forming a chain, and no valid block can be changed without having to replace all the subsequent ones (see Figure 18).

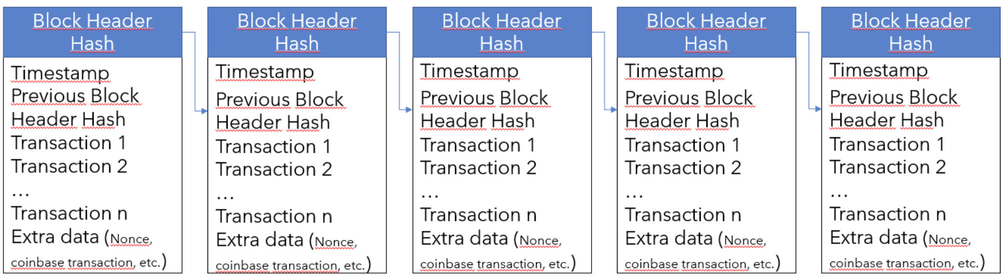

Figure 18: Example of a blockchain data structure. Source: Author's own.

Third, blockchains are append-only in that a given blockchain can only be updated by adding new blocks. Let us consider a book: page numbers can indicate whether some pages have been taken out or added after the book was printed. Conversely, blocks in blockchains are indexed by a header that summarises its content, and which includes the header of the preceding block. With the page number metaphor, if someone changes the content of the page, or the page order, or the content of a preceding page, the header changes, and so do the headers of all the blocks subsequent to the tampered one. This is what makes a blockchain an “append-only” register. In case different portions of the validating network start considering valid two different versions of the ledger, then the result is a “hard fork”, i.e., the network effectively splits in two (see Figure 19). This cryptographic layer is what made someone define Distributed Ledgers as “triple entry bookkeeping” (Grigg, 2005; Ijiri, 1982; Taylor, 2017; Tyra, 2014), i.e., double entry bookkeeping with the additional layer of encryption and time stamping.

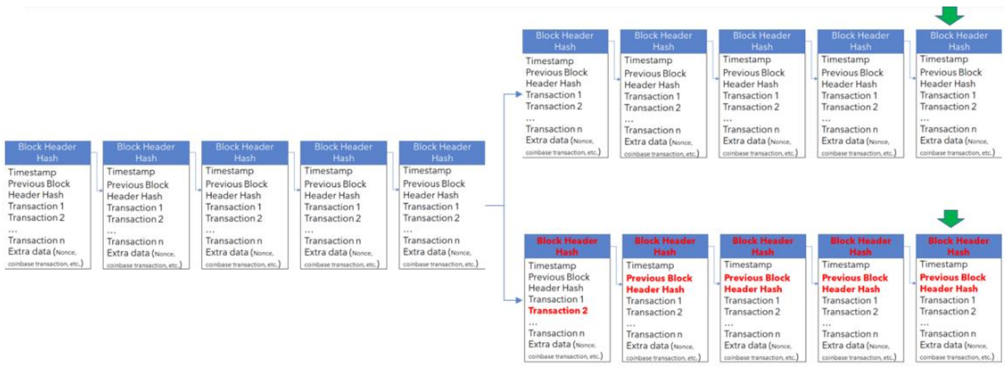

Figure 19: Schematic representation of attempted tampering and hard fork. Source: Author’s own.

Cryptography is defined as the set of techniques that secures communication in presence of an adversary (Rivest, 1990). Cryptography allows only sender and receiver – or any other pre-authorised third party – to understand the messages being exchanged, and not potentially malicious third parties (Lamport et al., 1982). Bitcoin, and most of the subsequent blockchains, use so-called asymmetric or public key cryptography, i.e., a system whereby each user has a private key, that ought to remain secret, that is used to encrypt outgoing messages, and a public key, that is broadcasted to the person who receives the message, that allows to decrypt the message. A public key is derived from the private key using a so-called one-way – or collision-free – cryptographic function, i.e., algorithms that produce an encrypted output from which it is almost impossible to derive the input. Bitcoin uses elliptic curve multiplication to derive the public key from the private key. Then, it uses a hash function to derive the Bitcoin address from the public key. A hash algorithm is a cryptographic function that takes an alphanumerical string of arbitrary length (anything from a letter to a full sentence) and returns a hexadecimal string of fixed length. For example, SHA-256 returns 256-bit strings, i.e., 32 bytes, or a string of 64 hexadecimal characters (numbers going from 0 to F) (Antonopoulos, 2017, p. 65). Figure 20 shows how insignificant changes in a string of text can cause large modifications in the hashed value for the same text.

Bitcoin	*b4056df6691f8dc72e56302ddad345d65fead3ead9299609a826e2344eb63aa4*
bitcoin	*6b88c087247aa2f07ee1c5956b8e1a9f4c7f892a70e324f1bb3d161e05ca107b*

Figure 20: SHA-256 hashing function of two almost identical words. As one can see, the change in one letter (uppercase v. lowercase "b") causes the hash to change significantly and randomly, i.e., without any apparent correlation between input and output. Source: (Movable Type Scripts, n.d.)

Lastly, the fact that blockchain technologies found their first application in the alternative currency Bitcoin has created the misplaced impression that cryptoassets are essential components of a blockchain. Rather, blockchain technologies and cryptoassets are conceptually independent: digital assets and virtual currencies can exist without relying on blockchain-based storage of balances and transactions, such as DigiCash and E-Gold, Second Life's Linden Dollar, World of Warcraft's Gold, and Fortnite's V-Bucks (European Central Bank, 2012). At the same time, blockchain technologies do not necessarily deploy an asset adopted as the internal unit of account and means of payment. Consortium or private blockchains operate without any reward system because the consortium has adopted other reward and cost structures associated with validation of transactions and update of the distributed ledger. Cryptocurrency implies that their sole or main function is to be a unit of account, a store of value, and a means of payment. However, their use cases have proliferated beyond these three functions, hence cryptoasset is probably a better term to define these instruments (Burniske & Tatar, 2018).

Standards "are socially constructed tools: [t]hey embody the outcomes of negotiations that are simultaneously technical, social, and political in character" (P. N. Edwards, 2004, p. 827). One of the indicators of the increasingly political nature of this standardisation battle is the setting up, by the International Organisation for Standardisation (ISO) (Murphy & Yates, 2009), of the ISO Technical Committee 307 on blockchain and distributed ledger technologies (ISO, n.d.). This battle is geopolitical in its consequences and import: ostensibly, Russian authorities have been investing quite heavily in lobbying to "make blockchain a Russian technology" in the same way as the Internet has been "an American technology" (Popper, 2018). Mark Zuckerberg echoed a similar concern from the American side during a US Senate Hearing on the 23rd of October 2019:

> China is moving quickly to launch a similar idea in the coming months. We can't sit here and assume that because America is today the leader that it will always get to be the leader if we don't innovate. Libra will be backed mostly by dollars and I believe it will extend America's financial leadership as well as our democratic values and oversight around the world. If America doesn't innovate, our financial leadership is not guaranteed (Cant, 2019).

As we shall see later in this chapter, more and more states are jumping in on adopting or regulating blockchain technologies and cryptocurrencies. Another instance of this struggle over standardisation is happening in the private sector through patenting and the introduction of proprietary standards and technologies. The European Patent Office's (EPO) database Espacenet returns 6,790 entries that have "blockchain" in their title, more than 10,000 that have that word in their title or abstract, and 1,669 that use "distributed ledger" in either their title or their abstract (Espacenet, n.d.).

3. Case Study: Ripple

This section provides a genealogy of Ripple, it positions Ripple within the blockchain landscape using the above-defined ontology in terms of its active forms and dispositions, and it clarifies Ripple's terminology. The term "Ripple", in fact, is used interchangeably to refer to a pre-blockchain payment system, a fintech company, and a distributed ledger. This section disentangles this ambiguity, and it provides the basis for the subsequent analysis of the active forms, dispositions, cultures, and their ecological co-evolution.

3.1. History

Ripple is, in some respects, older that Bitcoin, and it draws on the tradition of alternative and complementary currencies outlined above. Ripple as a multi-currency payment system was initially designed in 2004, and it did not rely on a distributed ledger (Fugger, 2004). Rather, it was a peer-to-peer mutual credit network that represented money as credit-based trust lines. In this respect, it resembled a middle ground between a *hawala* and a Local Exchange Trading System, as we shall see in further depth in the chapters in Part III of this dissertation. As Thompson (2008, pp. 93-94) says, "'Hawala' is an Arabic term that denotes a 'transfer', and in commercial terms the practice of transferring money and value from one place to another through service providers, known as 'hawaladars'". Martin illustrates the differences between formal finance and Hawala networks of payments in these terms:

> Both hundi/hawala and formal payment transactions share an *obligation to discharge*, but where modern payment systems operate by conforming to a series of regulations and legal instructions, [*hawala*] is regarded as being bound by nothing more than a code of honour and reciprocal trust amongst hawaladars (M. Martin, 2009, p. 923)

Participants create money by issuing credit or “trusting each other”, and they redeem money by settling their accounts. Ripple routed payments from payer to payee through chains of mutually trusting intermediaries, similarly to packet switching and routing over the Internet (Flichy, 2008; Fugger, 2006). The system was used to power the payment system RipplePay in 2007 (RipplePay, n.d.), but it did not expand beyond a first group of users. In 2011, Ripple’s designer Ryan Fugger and others launched Villages.io, which implements a worldwide time bank on RipplePay denominated in hours of labour time (Villages.io, 2017). This worldwide time bank tries to achieve social justice by anchoring its unit of account to a decent minimum wage, and to avoid that unit to be exchanged speculatively for arbitrage: “a Village Hour is not a speculative unit, it’s equal to a sustainable hour of wage in your community, so in each community [its value] is very different” (Interview 19th June 2018). In 2012 Fugger ceded the right to the name Ripple to the start-up OpenCoin, which changed its name into Ripple Labs in 2013, and into Ripple in 2015.

In 2013, OpenCoin developed the Ripple Consensus Ledger, later called the XRP Ledger. This Ledger combined Fugger’s credit network with a distributed currency exchange, a blockchain-like distributed ledger, and a cryptocurrency called Ripple or XRP. Even if the company Ripple developed the Ripple Consensus Ledger or XRP Ledger, the two remain conceptually separate (Hayden, 2019). When the Ledger went live, the company Ripple was endowed 80 of the total 100 billion XRP that was mined, and the developers received the other 20 (Larsen et al., 2012). However, the company does not, strictly speaking, “own” the Ledger. For clarity, this thesis will use “RipplePay” for the original payment system designed by Fugger, “Ripple” for the company that acquired it in 2012, “XRP Ledger” for the distributed ledger, and “XRP” for the cryptoasset operating on the XRP Ledger. At the time of writing, XRP is the fourth highest cryptoasset by market capitalisation, with a market price of $1.32 per XRP and a total market capitalisation of $60 billion (CoinMarketCap, 2021).

In 2014, Ripple split, with the exit of its co-founder Jed McCaleb, previously CEO at the cryptoasset exchange Mt. Gox (Long, 2014c). The terms of that exit and split were the object of a lawsuit (Larsen et al., 2012) which resulted in a settlement whereby Jed McCaleb was compelled not to sell more than a certain amount of his XRP stake, to avoid influencing its price. He later said that the XRP sales will have benefitted charitable causes such as Give Directly and MIRI (McCaleb, 2016). The result of this split was the creation of Stellar. This cryptoasset and DLT uses a similar consensus algorithm as Ripple, with differences in distribution strategies, ostensibly more encouraging towards charities and non-for-profits, and which entail the creation of new units of the cryptocurrency in the future (Stellar Development Foundation, 2019). Inflation, however, was discontinued in 2019 (Stellar, 2020).

3.2. Materiality

The XRP Ledger combines trust lines, which resemble a *hawala* credit network, the XRP cryptoasset, a Practical Byzantine Fault Tolerant consensus algorithm, and a distributed currency exchange (Chase & MacBrough, 2018; XRP Ledger Project, 2019). The trust line, deriving from the mutual credit network designed by Ryan Fugger, allows each user to issue money in any currency by extending trust to another user. The Ledger records all trust lines set up in the network, and it routes payments across trust lines from a sender to a receiver. When the two addresses are connected by an uninterrupted chain of mutually trusting intermediaries, the payment "ripples" successfully to its destination. Otherwise, the payment is routed through the distributed FX marketplace described below. Trust lines can be frozen in the case of fraudulent behaviour, and an address can prevent payments from rippling through specific trust lines. Figures 21 and 22 illustrate the functioning of trust lines and rippling of transactions.

```
{
    "TransactionType": "TrustSet",
    "Account": "ra5nK24KXen9AHvsdFTKHSANinZseWnPcX",
    "Fee": "12",
    "Flags": 262144,
    "LastLedgerSequence": 8007750,
    "LimitAmount": {
      "currency": "USD",
      "issuer": "rsP3mgGb2tcYUrxiLFiHJiQXhsziegtwBc",
      "value": "100"
    },
    "Sequence": 12
}
```

Figure 21: Node.js code representing the creation of a trust line on the XRP Ledger. Source: XRP Ledger Dev Portal (n.d.).

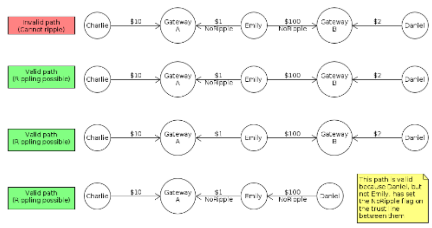

Figure 22: Rippling of a transaction across trust lines from payer to payee. Source: XRP Ledger Dev Portal (n.d.).

If trust lines represent money as credit-debt based on trust, XRP is a radical form of commodity money. XRP is an asset that is no-one's liability: no one issued it, no one can freeze it, and it can be sent from any address to any other. Unlike Bitcoin, XRP is "pre-mined": all 100 billion XRP was created in one instant when the XRP Ledger went live in 2013, and one can only own XRP by buying or receiving it. To limit the number of addresses and trust lines that people can open, each address needs to store at least 20 XRP at any given time, plus 5 per each additional trust line and currency exchange offer. Furthermore, each transaction burns a fraction of XRP to prevent Distributed Denial of Service (DoS) attacks. The expression "no one issued XRP" here means that the system issued the whole amount of XRP in one instalment, by imputing that balance to one genesis address. However, the subsequent "Founders Agreement" divided the 100 billion XRP between 80 entrusted to Ripple Labs, and 20 divided among the funders (Larsen et al., 2012). Hence, while XRP per se does not have an individual issuer, its distribution is almost a monopoly of a private company registered in Delaware in 2014 (SEC, 2014).

The XRP Ledger adopts a unique consensus algorithm, based on the "Practical Byzantine Fault Tolerant" class of consensus algorithms, which will be dealt with in further detail in the next section of this chapter. Each validator votes on which transactions to add to the Ledger, and on amendments to the code. The network only adopts the amendments and features that command and maintain a majority among validators. Validators vote in rounds: each round, a validator adapts its vote to the one expressed by a supermajority of other trusted validators, included in a Unique Node List (UNL). The XRP Ledger is permissionless, at least on paper: Ripple's consensus algorithm allows anyone to join as a validator (Cawrey, 2014; Chase & MacBrough, 2018; D. Schwartz et al., 2014). However, only those who are included in the Unique Node List of many nodes in the network have any chance for the blocks they validate to be included in the accepted version of the XRP Ledger. For this reason, Ripple has been defined as the "benevolent dictator" of the XRP

Ledger (Rauchs, Glidden, et al., 2018, p. 79). Figures 23 and 24 illustrate the phases of the XRP Ledger consensus process.

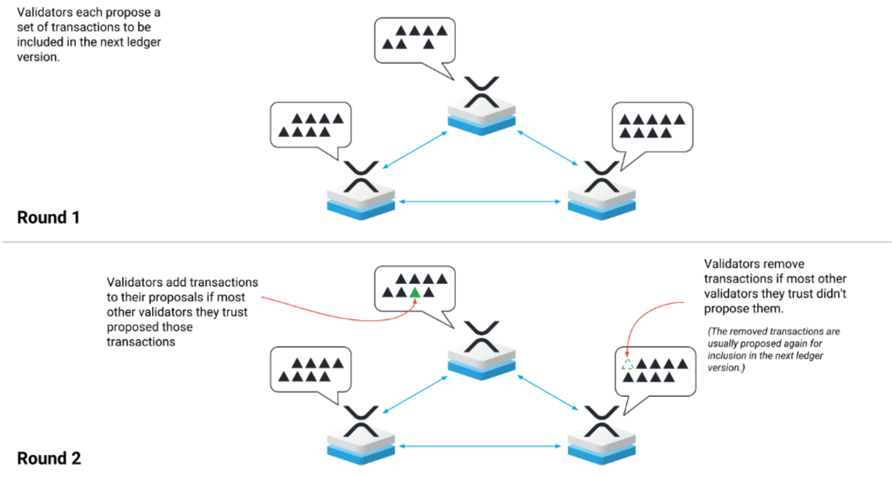

Figure 23: First phase of the XRP Ledger's consensus algorithm. Source: XRP Ledger Dev Portal (n.d.).

The UNL prevents the network from splitting or forking into clusters of validators that systematically validate different sets of transactions. To assure this consistency, Ripple itself runs many nodes, and it strongly suggests an "official" UNL that other validators should adopt. The UNL makes the XRP Ledger de facto permissioned, in that any validator outside the recommended UNL is not taken into consideration for validation (Rauchs, Blandin, et al., 2018).

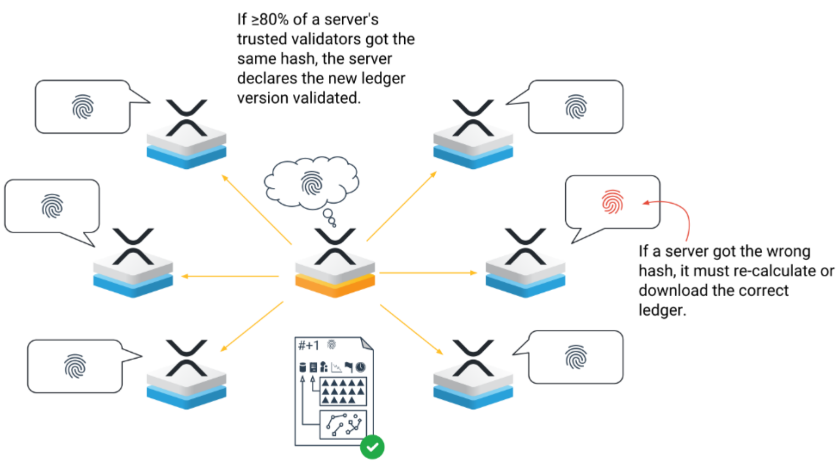

Figure 24: Second phase of the XRP Ledger's consensus algorithm (voting). Source: XRP Ledger Dev Portal (n.d.).

Lastly, the XRP Ledger includes a distributed currency exchange. Each address operated by FX liquidity providers and market makers can publish offers to convert trust lines denominated in any currency into any other currency. They can also publish offers to currencies with XRP and vice versa. When a payment requires a currency exchange, or when there are no uninterrupted chains of intermediaries from sender to receiver, the Ledger calculates the most efficient path across the distributed exchange, by ordering them according to exchange rates and transaction fees. Through a feature called "autobridging," the system automatically includes any offer to exchange either the sending or the receiving currency with XRP, to see whether than path provides a more favourable exchange rate. Figure 25 summarises the type of transactions enabled by the XRP Ledger.

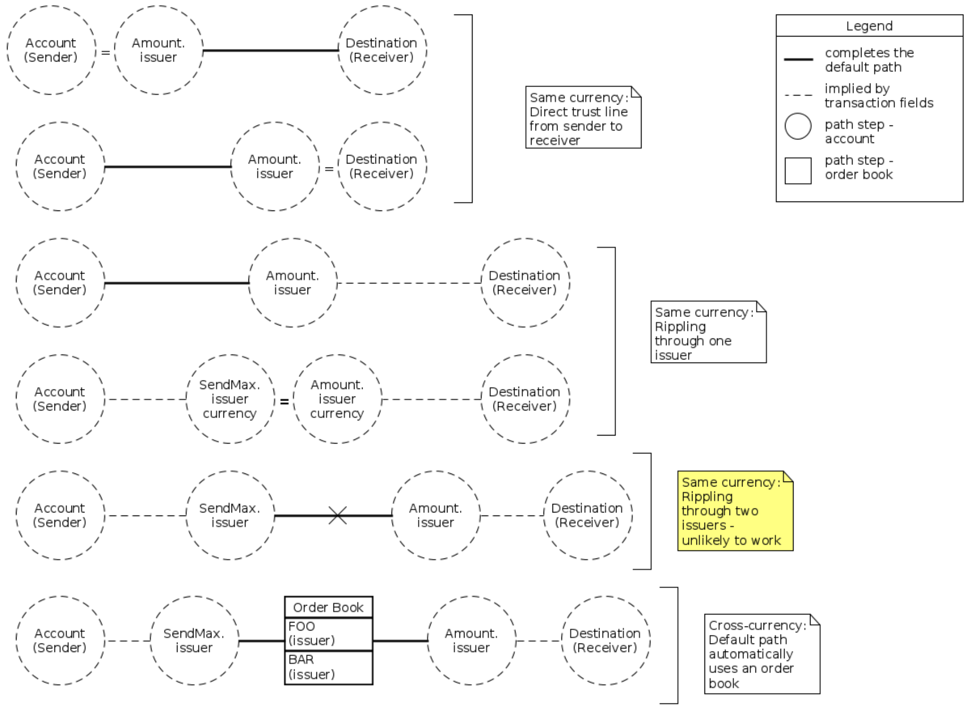

Figure 25: Diagram showing all possible payment types and paths between any two accounts on the XRP Ledger. Source: XRP Ledger Dev Portal (n.d.).

By providing interoperability, seamless circulation, and payment automation or Straight-Through Processing (STP), the XRP Ledger promises to be the cornerstone of the "Internet of Value" (Cf. Flichy, 2008; Pardo-Guerra, 2019; Rambure & Nacamuli, 2008). As we saw in Chapter 2, the internal complexity of Ripple was motivated by the ambition to "model the entire financial ecosystem" (Interview 15th May 2018). As we shall see in Chapters 5 and 7, however, this complexity came with its own internal tensions and frictions, that induced some design transformations.

However, the XRP Ledger is not only an interoperability layer between payment systems: it is itself a payment system, with its standards, requirements, and rules. As illustrated by the concept of “blockchain paradox” deployed by Tasca and Piselli (2019), and by the lack of native interoperability between blockchain in the “Wiring” sub-section of the next section of this chapter, interoperability is not neutral and it entails a smoothing of political differences between the materialities and cultures of different payment infrastructures. As Pesch and Ishmaev (2019) illustrate, there is always tension, friction, and competition between the dream of achieving zero frictions and costs, on one side, and capitalising on the flows that interoperability affords, on the other. To overcome this paradox, Ripple developed the open-source Interledger Protocol (ILP) that synchronises separate ledgers without creating a separate ledger (S. Thomas & Schwartz, 2015). This project was later endorsed by the World Wide Web Consortium’s Web Payments Working Group (W3C, n.d.), and it is no longer directly managed by Ripple (Interledger, n.d.). The ILP will be the core concern of Chapter 5, for the transformation it represents of the topology of money into interoperable Stacks.

Ripple’s materiality, then, is a hybrid between traditional accounting, blockchain technologies, and pre-blockchain alternative credit systems normally used for time banking and complementary currencies. As we shall see in Chapter 4, this internal heterogeneity originated from an internal multiplicity of money cultures, and in turn it resulted in multiple deployments in highly heterogeneous fields such as alternative currency networks, cryptocurrency exchanges, and inter-bank cross-border payment systems. Here, what is of import for our analysis is that Ripple reveals both the politics of materiality deployed by blockchain infrastructures, but also their internal heterogeneity and complexity. If we need to take the material politics of infrastructures seriously, then we also need to be precise and accurate in what political consequences and affordances certain material components have. This is going to be the aim of the next section.

4. Active Forms and Dispositions of Blockchain.

The aim of the next four sub-sections is to reconstruct a political ontology (Cf. Chandler, 2018) of blockchain infrastructures to retrieve the effects of the material components that populates blockchain infrastructures. As noted by Rauchs et al (2018), the variation between taxonomies is as wide as the variation between definitions. Xu et al (2017) differentiate these technologies based on their design choices around decentralisation, data storage and computation, configuration, anonymity, incentives, and types of deployment. The UK Government’s Office for Science (2016) groups blockchains based on their openness, i.e., the freedom they afford to edit the software code, to access, read, and modify the content of the blockchain, and to participate in the consensus process, and they divide them into public, consortium, or private. Okada et al (2017) build and expand on that classification based on openness, by providing a two-dimensional taxonomy based on the existence or non-existence of an external authority running the system (permissioned v. permissionless), and the type of incentives provided to participants (market v. non-market incentives). Glaser (2017) adopts a layered taxonomy based on differences in infrastructure or fabric, applications, and user presentation.

This section will analyse the active forms of blockchains and DLTs mainly through Easterling's (2014) conceptualisation of infrastructured spaces as endowed with dispositions deriving from tangible and intangible active forms. These material active forms will be retrieved through Tasca and Tessone's (2019) taxonomy, with some modifications for ease of analysis. In so doing, this chapter concurs with Çalışkan (2020, p. 544) that "Assuming the homogeneity of blockchains and not controlling for their actor-network heterogeneity may lead to erroneous theoretical generalizations or empirically partial observations". The fine-grained distinction between active forms goes precisely in the direction of more nuanced understanding of the heterogeneity of blockchains. At the same time, the infrastructure-oriented typology I propose here leaves necessarily leaves less room for a nuanced discussion of the subjectivities that these infrastructures generates, which will be further discussed in the Conclusion to the dissertation.

The investigation of money's infrastructural materiality requires that typically neglected and overlooked materialities are made visible, and the politics inscribed in their design should be open to scrutiny. More specifically, Keller Easterling (2014, p. 71) defines an infrastructural disposition as a "relationship between potentials. It describes a tendency, activity, faculty, or property in either beings or objects-a propensity within a context". Active forms are, in turn, "markers of disposition, and disposition is the character of an organisation that results from the circulation of these active forms within it" (p. 72). Easterling's insights enable us to go beyond a purely metaphorical appreciation of the materiality of money infrastructures, and to apprehend money's internal design in its own terms. This section, hence, teases out definitions for the main active forms of blockchain technologies from the existing literature on the topic, to provide a definitional substratum for further analysis. The analysis of blockchains' dispositions provided in this section "is [a] diagnostic tool for assessing undisclosed capacity or political bearing in infrastructure space" (Easterling, 2014, p. 80).

As Dourish (2017) and Blanchette (2011) showed for the Internet, design choices at the level of coding, standards, and protocols can have very material consequences in terms of the type of hardware required to carry out some tasks, and, indeed, it can work towards making certain tasks possible or impossible and, among the possible ones, making some tasks feasible or unfeasible. DeNardis (2009, 2014) showed how intangible elements like the address space breadth of the Internet Protocol engenders power struggles for the distribution of finite resources. In Dourish's (2017) words, the Internet as an imaginational diagram is very different from *this* Internet as it is produced by specific design choices at the protocol level, which in turn require different pieces of hardware and equipment (see also Chapter 5). While some design choices make things possible, the material components forming a technology make certain things *feasible* and others unfeasible. Easterling defines as "active forms" these contentious material elements of the infrastructure space, and she divides active forms into multipliers, switches, governors, wiring, and topologies. Table 3 illustrates briefly what each active form implies in terms of blockchain design choices and features, and how each active form influences the overarching disposition of a blockchain infrastructure.

Active Form	Material Component	Influence over Disposition
Governor	Consensus algorithm.	Defining the interplay between variables.
Topology	Validation Network.	Concentration and dispersion of power, control, and resources.
Wiring	Interoperability, transaction capability, storage requirement, Turing-completeness, anonymity.	Influencing feasibility and expensiveness of each action. Making things possible or impossible, feasible or unfeasible.
Switch	Reserve (XRP and XLM), coin supply (Bitcoin and XRP), difficulty adjustments (Bitcoin) Coins and Tokens[5].	Suppressing or activating functions and active forms.
Multiplier	Trustlines (XRP), Coins and Tokens, Open Access Code, hard and soft forks, smart contract capability, fees structure.	Multiplying possibilities, altering the overall disposition through its multiplication across the infrastructure space.

Table 3. Typology of active forms with associated blockchain design features and their influence on the overarching disposition.

[5] As it will be shown below, some design elements operate as more than one active form depending on the contextual combination of elements they fall within.

4.1. The Governor: Consensus Algorithms

First, blockchain technologies vary depending on their consensus algorithm, i.e., "the set of rules and mechanics that allows for the maintenance and updating of the ledger and guarantees the trustworthiness of the records in it, i.e., their reliability, authenticity, and accuracy" (Tasca & Tessone, 2019, p. 7). Consensus algorithms are what Easterling (2014) calls a "governor", i.e., an interplay between active forms that deeply shape the disposition of the infrastructure space.

> When the object of design is not an object form or a master plan but a set of instructions for an interplay between variables, design acquires some of the power and currency of software. This spatial software is not a thing but a means to craft a multitude of interdependent relationships and sequences – an updating platform for inflecting a stream of objects. (Easterling, 2014, p. 80)

The need for different algorithms depends on the use case, on the presence or absence of cryptoassets, and on how these cryptoassets are generated and distributed. The list of consensus algorithms is continuously growing, with new entries such as Delegated Proof-of- Work, Delegated Proof-of-Stake, Proof-of-Authority (Angelis et al., 2017), Proof-of-Burn (Karantias et al., 2019), Proof-of-Capacity, Proof-of-Storage (Sengupta & Ruj, 2017), Proof-of-Cooperation, Byzantine Fault Tolerant algorithms (Bessani et al., 2017; Lamport et al., 1982; Stifter et al., 2019; Y. Yang, 2018), etc (Mingxiao et al., 2017). In open blockchains that use cryptoassets, the two most prominent algorithms are Proof-of-Work (PoW) and Proof-of-Stake (PoS).

Proof-of-Work is the consensus algorithm implemented by Bitcoin in the form of mining (Cachin & Vukolić, 2017). Specific full nodes in Bitcoin's network, called miners, gather transactions broadcasted through the network and keep them in a pool of transactions waiting validation. Each miner collects these transactions, together with the coinbase transaction with which brand-new bitcoins are created, adds a timestamp, and the hash of the previous block, and then hashes all these values together. The hash must fall within a specific value interval called the difficulty target, determined by the number of zeros that the hash must start with. This difficulty is dynamically adjusted every 2016 blocks, depending on the computing power of the network, represented by the average time it took to compute the last 2016 blocks (Garay et al., 2016; Kraft, 2016; Meshkov et al., 2017). If that average time shrank over time below 10 minutes, the system dynamically adjusts the difficulty to make the average oscillate around 10 minutes per block (Chou et al., 2018).

The target narrows when computing power increases, e.g., because more powerful machines join the system, and broadens when the computing power lowers, so that, on average, a new block is mined every 10 minutes. To meet that target, miners must add an arbitrary number to the values in the block, called nonce.

Since it is difficult to compute the right input given the hashed value, the only efficient strategy for miners is to try different nonce values at random until they find the right one. Difficulty effectively operates like an archery target: the shortest the diameter of the target, the harder – or the less likely – it is for the target to be hit, and the more attempts that are required to get a correct result. When a miner finds a correct result, it then broadcasts this new block to the network by the same means followed to broadcast transactions, the nodes attach this new block, and the process starts anew. The cryptocurrency associated with the blockchain is an incentive for miners to keep the system running (Antonopoulos, 2017, pp. 194-195).

Proof-of-Stake, conversely, attributes the right to append new data based on the ownership of the digital asset associated with a specific blockchain (Bentov et al., 2016; Gao & Nobuhara, 2017). The consensus works like a lottery: each node is extracted with a probability corresponding to the fraction of the total supply of a cryptoasset that a node holds, often weighted according to the coin age, i.e., the time that each coin has been kept (Bentov et al., 2014). Peercoin was the first altcoin to implement a type of Proof-of-Stake, called minting, that combines stake, coin age, and randomisation to assign the right to append new blocks and to generate new coins (Peercoin, n.d.). This incentive structure privileges people who have a vested interest in the network's health and wellbeing, and who have shown loyalty by holding coins for a long time.

The benefit of PoW is its capacity to operate on extensive networks, but it is limited in the transaction speed because solving the mathematical puzzles is very time-consuming. Furthermore, depending on the type of cryptographic puzzles that computers must solve, it can lead to either concentration of computing power in few miners or validators, and in rather high levels of energy consumption. While PoS makes for a faster and less energy-consuming system, it relies heavily on large owners of a specific asset and, to some extent, they do not entirely do away with the need for trust in members of the network (Ganesh et al., 2020).

Byzantine Fault Tolerant algorithms decouple node behaviour from reward systems, and they do not base the achievement of consensus on lottery-like mechanisms. Rather, a collective of nodes reaches an agreement on *how* to build a block, rather than on *who* is rightfully entitled to decide. In fact, Byzantine Fault Tolerance refers to the Byzantine Generals problem, where a group of generals have to collectively decide whether to attack the enemy or to stay put. Attacking is effective only if all generals agree, but the generals do not know whether there are malicious actors in their midst that might conspire with the enemy and lead the other generals to a crushing defeat (Lamport et al., 1982). Proof of Work and Proof of Stake try to circumvent this problem by creating a situation where it is almost impossible for someone to be consistently selected as the final decision-maker.

Byzantine Fault Tolerant algorithms try to achieve a system whereby 1) every non-malicious node decides in finite time; 2) all non-faulty nodes reach the same decision; 3) both 1 (yes) and 0 (no) are available as final results (Attiya et al., 1984). Traditionally, previous attempts to solve the Byzantine Generals problem have stated that a network can reach agreement if malicious nodes are fewer than one third of the total, although different implementations oscillate between half and one fifth of the total (Lamport, 1989; Wang et al., 2018, p. 6). This type of consensus algorithm requires an internally centralised topology – a leader is tasked with initiating consensus – and the complexity and time and latency requirements within the network require a rather limited number of federated validating nodes, hence Byzantine Fault Tolerant algorithms tend to be used in permissioned environments. For example, Hyperledger uses an algorithm called PBFT – Practical Byzantine Fault Tolerance (Castro & Liskov, 2002). Ripple and Stellar, however, implement Byzantine fault tolerant features in permissionless blockchains. Ripple allows consensus to happen through rounds of voting based on deterministic criteria for acceptance and rejection of transactions and based on quorums achieved among validators included in Unique Node Lists. Stellar, in its new iteration, is built on each validator choosing their own “quorum slices”, but such slices are organised hierarchically from top tier to leaf tier (Mazières, 2016).

4.2. Topology: Consensus, Authority, Control

Second, blockchains can vary depending on consensus *topology*, i.e., how the capability to participate in the consensus process is distributed across participants. Topologies are active forms, in that they are

> Intuitive markers of disposition in an organisation, and they can be considered to be assemblies of multipliers and switches. […] Topologies are also markers of political disposition insofar as they highlight the

> ways in which the authorities circulate or concentrate information (Easterling, 2014, pp. 76-78).

Hence, we will have decentralised, hierarchical, and centralised consensus network topologies depending on whether consensus is operated by a network of pure peers, like Bitcoin and others, or by a sub-set of trustworthy actors in the network, like Ripple and Stellar, or by one or few authorities that are by design entrusted with providing truth about the state of the network. This topology is also influenced by *openness*, i.e., the degree of freedom afforded to accessing and editing the source code, and in terms of visibility of the data, i.e., who is authorised to decipher the encrypted data stored on-chain (Tasca & Tessone, 2019, p. 26).

A combination of network topology and openness produces three discrete types of blockchain: public or permissionless, consortium or permissioned, and fully private blockchains. A public, open, or permissionless blockchain usually relies on open-source code, whereby anyone can access the blockchain, propose additions, and contribute to the consensus process. Permissioned blockchains, in contrast, can be either consortium-led or private blockchains: in consortium blockchains, consensus takes place among a pre-decided set of agents. These consortia can operate on proprietary as well as open-source code. Federated consensus blockchains is a term that can denote blockchains laying in between permissionless and permissioned: while consensus is potentially open to anyone's contribution, the actual topology clusters around a specific set of validators either by design or because of in-built incentives (Ambili & Jose, 2019). Lastly, private blockchains decentralise only the storage of the data contained in the blockchain, while validation and addition of new content remain centralised. In this case, the software is often proprietary and protected by patents and registered trademarks.

Topology's effects on the disposition of the infrastructure space go beyond the architecture of the consensus process: a blockchain that is decentralised on paper can become highly centralised in practice. For example, Proof of Work blockchains are famously vulnerable to so-called 50% attack, i.e., to a miner or pool of miners owning more than half of the computing capacity of the network, which then achieve a veto power over which transactions to validate and which to reject (Dey, 2018; Duong et al., 2016; Eyal & Sirer, 2013). While this scenario has not materialised yet, and while it would probably be extremely costly in terms of the plummeting value of the attacked cryptoasset, Bitcoin shows a massive concentration of computing power in the hands of few mining pools (Sheehan et al., 2017).

Furthermore, more serendipitous topology features can engender political problems and glitches in the fabric of blockchain infrastructures. In 2013, Bitcoin forked because different sub-groups of miners and full nodes were running different version of the Bitcoin Core software, and they were far enough apart from each other in the network topology, as to start validating different sets of transactions (Walch, 2015, 2019, p. 62). Ripple, likewise, was shown to be vulnerable to forks if the Unique Node List stored in XRP Ledger full nodes differs even only for one validator (Chase & MacBrough, 2018; MacBrough, 2018; Riszo, 2015; D. Schwartz et al., 2014).

Authority can be exerted beyond control over the source code or the validating process, such as in the case of oracles in smart contracts. While we will deal with smart contracts in more detail in the next sub-section, here it is important to stress that these blockchain-based computations need data input to trigger them. This data often refers to events happening outside the blockchain network: in this case, smart contract often need *oracles*, i.e., specific entities in the blockchain that are tasked with providing a source of truth about the state of something that lies outside the network (Lianos, 2019, p. 340). Let us think about a decentralised app that automatically fixes the price of oranges sold on a platform based on the quantity that is being collected. In that case, an oracle would have to broadcast the quantity at the end of a collection day, so that the smart contract can compute the price accordingly (Lo et al., 2020). This, however, goes somewhat counter the idea that a blockchain does not rely on centralised authorities and delegated sources of truth (Arruñada, 2017).

4.3. Wiring: Software Architecture and the Limits of the Possible

Third, blockchains also differ in terms of their software architecture, i.e., their internal functioning and capabilities. This, writ large, includes the data structure and how data is stored on the blockchain. The software architecture makes up the "wiring" of the blockchain in a way that is not as directly influential on the disposition as the governor. Rather, "Just as an electronic network is wired to support specific activities, so can space be 'wired' to encourage some activities and routines over others" (Easterling, 2014, p. 80). The wiring determines what is possible and what is feasible: it might create unbearable costs for some activities or open opportunities to perform other tasks with ease.

There are several examples of the relevance of software architecture in influencing blockchains' dispositions. First, there is transaction capability: as we shall see in Chapters

4 and 5, Bitcoin has a scalability trade-off associated with its maximum block size of 1 MB[6]. Increasing the block size would increase the speed of Bitcoin, making it more viable as a payment system, but it would also increase the size of the Bitcoin blockchain as a whole, which is now roughly 286 GB (Blockchain.com, n.d.). This, in turn, would make it harder for people to run full nodes, because they would have to allocate more storage capacity to record the entire blockchain.

Another difference in architecture is whether the system is based on transactions and transaction outputs, like Bitcoin, or on traditional bookkeeping and on balance tracking, like Ripple. In short, the Unspent Transaction Output (UTXO) system used by Bitcoin "destroys" a sum of BTC every time that sum is used for a payment. If Alice has 10 BTC and wants to give 3 BTC to Bob, the transaction will spend and destroy the 10 pre-existing BTCs and generate two new unspent outputs: 7 BTC owned by Alice, and 3 BTC owned by Bob (Antonopoulos, 2017, p. 112; Narayanan, 2016, p. 54). Each of them affords different scalability issues: as we shall see later in this chapter, Ripple's data structure makes it faster as a payment system. However, the number of Bitcoin users can increase indefinitely, while Ripple has some degree of address space exhaustion due to the fact that the balance associated with a given address are tracked all the way from the genesis block and from the moment in which that address reached the minimum reserve requirements.

Another difference is whether a blockchain is Turing-complete or not, i.e., whether it can be used for universal distributed computation, or it can only be used for a set of instructions (Herken, 1995). This includes whether the blockchain allows the use of smart contracts or not. Ethereum runs an entire decentralised Virtual Machine on top of its blockchain, and Golem allows the crowdsource of computation on its network (Golem, 2016). Ripple and Bitcoin, conversely, are only used for payments: Ripple allows for more transaction types, while Bitcoin only supports payments. In general, the capability of a blockchain for distributed computation is strongly associated with so-called smart contracts. They were first defined by their inventor Nick Szabo (1996) as digitalised, self-executable interpersonal agreements written in software code. Smart contracts would remove or reduce the risks of breach and misbehaviour, and they would do away with the need for interpretation, in that they require completeness and lack of ambiguity to be machine-readable. As Melanie Swan has it,

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[6] Block size is the size in Megabytes per block.

> A contract in the traditional sense is an agreement between two or more parties to do or not do something in exchange for something else. Each party must trust the other party to fulfil its side of the obligation. Smart contracts feature the same kind of agreement to act or not act, but they remove the need for one type of trust between parties. This is because a smart contract is both defined by the code and executed (or enforced) by the code, automatically without discretion. In fact, three elements of smart contracts that make them distinct are autonomy, self-sufficiency, and decentralization (Swan, 2015, p. 16).

The most radical application of smart contracts is Decentralised Autonomous Organisations (DAO), i.e., organisations, firms or institutions that can run without any human input and management (De Filippi, 2014). Confusingly, one example of Decentralised Autonomous Organisation was precisely called "The DAO", and it was meant to be a fully automated venture capital company. When it launched, the DAO allocated capital to projects based on the votes of individual investors, weighed by the size of their stake, and then it would have automatically paid returns to investors (Shier et al., 2017). However, the DAO was the object of the most infamous example of blockchain hacks, and the remedy to the damage of the hack was to "fork" the Ethereum blockchain, effectively erasing history subsequent to the hack (DuPont, 2018b; Morrison et al., 2020).

Blockchain also differ based on whether they can communicate with other systems "natively", or whether it needs the provision of external services and intermediaries to interoperate with other platforms. Interoperability is a growing concern across the blockchain industry (Cf. DeNardis, 2011), and it is one of the core concerns of this thesis as a whole, as we shall see in Part III. Most blockchains, however, are not natively equipped to automatically interoperate with other blockchains. Rather, there are three models of interoperability (Tasca & Piselli, 2019): first, one blockchain "takes over" and becomes, through market dynamics, the hegemon providing "blockchain as a service". Second, modular interoperability creates ad-hoc interchanges between blockchains, i.e., nodes that belong to two different networks and which can, then, speak to both. Third, there is a generalised and layered form of interoperability. These forms will be explored in further detail in Chapter 5.

In general, the idea that there can be one blockchain that achieves monopoly or standard over interoperation is becoming increasingly unlikely, as it is often the case in internetworking technologies (Pesch & Ishmaev, 2019). Tasca and Piselli call it the "blockchain paradox": it is almost impossible to try "to make two or more socio-technical-economic constructs communicate with each other, despite the fact that they were built by different communities to function as independent systems” (Tasca & Piselli, 2019, p. 40).

Blockchains’ software architecture can also differ on whether they are anonymous, pseudonymous, or KYC and AML-compliant. Bitcoin and most other cryptocurrencies are so-called pseudonymous systems, i.e., systems that do not directly associate a real-world identity to an address, but which can potentially be de-anonymised by studying the behaviours and patterns of transactions associated with certain addresses (Dupont & Squicciarini, 2015; Nick, 2015; ShenTu & Yu, 2015; Srivatsan, 2017). To offset the risks of de-anonymisation, mixing and ring signatures are often employed (Cao et al., 2019; Y. Liu et al., 2018; Sun et al., 2017). Mixing pools together multiple transaction inputs to make the provenance of an actual sum of money harder to trace, whereby ring signatures use joint authorisations of a transaction where it is deliberately unclear who is the real initiator.

Truly anonymous blockchains are exemplified using so-called zero-knowledge proof (Banasik et al., 2016; Sánchez, 2020). This type of cryptography makes it possible to separate validation of a message with its content: a validator can say that a transaction is valid without knowing the address of the sender, the address of the receiver, or the amount sent. However, the achievement of true zero-knowledge proof is contested and very hard in practice: for a system to be zero-knowledge, one needs to encrypt the blockchain using a completely random input (Banasik et al., 2016). For example, the most famous use case of zero-knowledge blockchain, Zcash, was encrypted using digits derived from the inputs of a Geiger counter measuring radiation from a piece of radioactive waste from Chernobyl. The whole process happened in an aircraft to ensure that external attackers could not access, and the equipment used to write the code was destroyed after use (D. De Nikhilesh, 2018). Monero, rather than using complete zero-knowledge proof, aims at anonymity by using “stealth addresses” used only once for a transaction (Moneropedia, n.d.). Finally, KYC and AML compliant blockchains require for people to disclose their identity to have access to the system. Tasca and Tessone (2019) list Stellar and Ripple to this latter category, even though their status is more ambivalent, as we shall see below.

4.4. Switches and Multipliers: Coins and Tokens

The last type of active forms are switches and multipliers. In observing how the repetition of specific houses and housing patterns, and the spread of technologies like the car, the elevator, or the mobile phone and Wi-Fi change the urban infrastructural space at a macro scale, beyond the individual impact of the single device or building being deployed, Keller Easterling (2014) notices how specific technologies, through programmed repetition, proliferates possibilities or obstacles, and it makes things possible and impossible. Switches and multipliers

> Establish potentials [...] they may suppress or redirect. The switch may generate effects some distance down the road or the line. It is a remote control of sorts-activating a distant site to affect a local condition or vice versa. Exceeding the reach of a single object form, the switch modulates a flow of activities. (Easterling, 2014, pp. 75-77)

The first type of multiplier is software code itself: blockchain technologies can evolve by using the same base code and make minor or major changes. Some cryptocurrencies, in fact, have emerged out of a hard fork in an existing cryptocurrency. The two most prominent examples of hard forks are the Ethereum-Ethereum Classic fork of 2016, and the Bitcoin-Bitcoin Cash fork of 2017. Other examples of forked blockchain systems are Litecoin, which used Bitcoin's code while changing some parameters, Stellar, which forked Ripple (see below), and J.P. Morgan's Quorum, which forks Ethereum but, unlike the latter, does not use a cryptoasset.

In 2016, an Ethereum smart contract called the DAO, which was a software-run Venture Capital fund, was attacked by a hacker that exploited a flaw in the smart contract's code. The attacker managed to steal $50 million worth of Ether from investors' accounts before it was caught. It was then proposed to edit Ethereum's blockchain to remove the consequences of the attack (DuPont, 2018b; Morrison et al., 2020). This solution, while compensating those affected by the hack, ran against the principle of blockchains' immutability. This caused a split between Ethereum, which runs in the version of the blockchain that erased the consequences of the attack, and Ethereum Classic. Later, in 2017, Bitcoin was debating whether to increase the size in bytes of blocks to increase Bitcoin's scalability (Brekke, 2018; De Filippi & Loveluck, 2016). What looks like a technical detail hides a profound political dilemma, as the size of a block has implications regarding bandwidth, storage space, and computing power required for mining, that in turn might lead to increased centralisation of mining. The result was a hard fork between Bitcoin which maintained the original block size, and Bitcoin Cash, that raised this parameter.

Lastly, blockchain technologies differ on whether they do or do not employ cryptoassets and, if so, how they fit in the overall functioning of the blockchain. Coins and tokens are here switches and multipliers: depending on their presence or absence, they influence and shape how interactions happen within the network. Cryptoassets also vary depending on whether they are *native* to a specific blockchain, or whether they are issued through a smart contract that connects an app to an already existing blockchain – see for example the case of CryptoKitties with the Ethereum blockchain explored in Chapter 6. In the first case they are called coins, otherwise they are called token or tokenised assets. Most of the tokens currently in circulation comply with the ERC-20 Ethereum smart contract standard, built on the Ethereum blockchain, as we shall see in Chapters 4 and 6.

Depending on their function and structure, tokens can be divided into non-fungible tokens, utility tokens, security tokens, and stablecoins. Non-fungible tokens are used to identify unique digital objects, and they will be further analysed in Chapter 6. They are often used in videogames to allow buying and selling of unique items and artefacts, or to identify unique real-world items such as artworks. Occasionally, non-fungible tokens have been used or considered as an option for platforms that wanted to earmark sums of money only for specific ends, i.e., to limit the fungibility of a sum of money.

Utility tokens are “digital assets designed to be spent within a certain blockchain ecosystem” (R. Campbell, 2019). The “utility” of a utility token is precisely the work that the token performs within the ecosystem: it can be a reward for likes in social media, or a system to pay internet browser users to watch ads, and a host of different types of platform-based interactions. A security token, much like a traditional security, provides investors with a fungible instrument representing either equity or debt in a company or other ventures. They are most often used to manage equity, e.g., by implementing fractional ownership of real estate, or by representing shares in the capital of a company. These are in a relatively shaky position vis-á-vis financial regulation because, by modelling themselves after official securities, they fall within the regulatory oversights of securities trade, brokerage, and custody laid out by bodies such as the Securities Exchange Commission (SEC) in the United States and the Financial Conduct Authority (FCA) in the United Kingdom (Clayton, 2017; FCA, 2019).

Lastly, stablecoins are a burgeoning asset class within the cryptoasset market, aimed at hedging risk and volatility. A stablecoin is essentially a cryptoasset that issues and destroys units based on a smart contract synchronised with reserves in “real-world” assets like currencies, raw materials, and commodities. In so doing, stablecoins aim to maintain price stability and work as “anchors” for cryptoasset markets, or as currencies, for example in the case of the Venezuelan Petro, issued by the Venezuelan government and officially backed by gold and oil reserves to stabilise the currency and protect it from inflation (GBV & SUPC, 2018)[7]. The most famous, or notorious stablecoin is Tether, ostensibly backed by 1:1 reserves in US dollars (Higgins, 2018). It will be dealt with in Chapter 6 as it is often considered a source of distortion of the real size, value, volume, and prices of cryptoasset markets. Coinbase, one of the largest cryptocurrency exchanges, has now issued its own stablecoin, also backed by the US dollar, USD Coin or USDC (Coinbase, n.d.). Other examples of stablecoins are backed by raw materials, commodities, and existing currencies, especially gold, oil, and the US Dollar (Cement, n.d.; GBV & SUPC, 2018; Klumov, 2020). They will be further explored in the next Chapter when we will deal with Central Bank Digital Currencies and other implementations of blockchain for financial stability.

Cryptoassets may vary depending on their monetary policy or asset supply management (Tasca & Tessone, 2019, p. 20), which can assume three structures. First, they can be limited and deterministic, like Bitcoin, in that the source code is programmed to recursively issue new coins until a maximum cap is reached. Bitcoin, for example, started from zero BTC in January 2009 and it will reach a hard cap of 21 million BTC in 2140. Bitcoin's system is programmed to issue progressively fewer and fewer BTC: it started with a reward of 50 BTC per block and then it has been halving that sum every 210,000 blocks. The last halving happened on the 11th of May 2020, and the next one will be on the 9th of May 2024 (bitcoinblockhalf.com, n.d.). Second, cryptoassets can be limited but non-deterministic: Ethereum has no supply cap, but the system is designed for issuing a pre-determined amount of ETH at each block, to strike a balance between rewards and inflation (EthHub, n.d.). Third, cryptoassets can be pre-mined, i.e., all the existing units of the asset have been issued at once. Ripple XRP and Stellar lumens or XLM are the most important pre-mined coins, but most of the tokens operating on top of existing blockchains are pre-mined as well.

Just like the monetary policy of traditional currencies, the emission of a cryptoasset is far from being a neutral device. Rather, it can operate as both a multiplier and a switch, alternatively enabling and preventing certain behaviour, prioritising some user subjectivities, and pricing out other ones from using the system. Recently, as we shall see in Chapter 6, "cryptoeconomics" and "token design" emerged as research and practice fields in their own rights to try to hardwire "positive" incentives and write off "perverse

[7] See also Appendix B.

incentives" (Abadi & Brunnermeier, 2018; Batsaikhan, 2017; Berg et al., 2019; Conley, 2017; Davidson et al., 2016, 2018; H. M. Kim et al., 2019; Swan et al., 2019; Walch, 2019, p. 77). Chapter 6 will analyse utility tokens as the epitome of platformisation and assetisation of blockchain and cryptoassets. Cryptoassets, in fact, influence the overall disposition of the blockchain within which they operate not only through their total supply, but also through the rewards and cost they impose.

Fees also create implicit hierarchies between transactions and enable and prevent different behaviours. Bitcoin has a so-called optional fee system: users may or may not include a fee to pay to the miner who will validate the block in which the transaction is included, but miners also have the freedom to include or not include transactions based on the fees they pay. For this reason, a transaction without fees is likely to take longer to be validated, or not being validated at all. Conversely, the XRP Ledger has several compulsory costs: each account must store at least 20 XRP at all times to be operational, and each transaction implies the payment of a fee, the amount of which is lost forever rather than paid to validator, which works as a firewall against adversaries performing Denial of Service (DoS) attacks[8], which flood a network with messages to saturate it and saturating and stopping it. However, while this fee and reserves structure prevents attacks, it entails also costs that may make unfeasible certain behaviours. As we shall see in the next chapter, Ripple could no longer be used to create alternative currencies and mutual credit networks, which was its original use case, because transaction fees and minimum reserves became too costly once XRP jumped in value.

While we deployed the distinction between governors, topology, wiring, switches, multipliers, and remotes to denote distinct material components, in reality the typology of active forms is messier than here presented. Multipliers can be switches and vice versa, and disposition is always "a propensity *within a context*" (Easterling, 2014). The *milieu* within which any technology is deployed is just as important as the materiality of the technology itself. For example, the open source nature of many cryptocurrency codes – which was categorised as the "wiring" (Ibid, p. 80) of cryptocurrencies – enables to create new cryptocurrencies through forking, hence acting like a multiplier. At the same time, the "monetary policy" and rewards schemes of many cryptoassets are constitutive elements of the "governor" (Ibid, p. 80) that is the consensus algorithm. For example, mining is

[8] See also Appendix A.

completely uneconomical if one takes the reward in BTC out of the equation. Lastly, smart contracts, which are part and parcel of the "wiring" of blockchain technologies, especially Ethereum, often require a change in the blockchain's topology through the introduction of the oracles. As Parra Moyano (2017) showed, there is a paradox in a trustless system that relies on authorising entities, because it cannot tell how and whether those authorising entities authorised themselves. Hence, some pre-agreement is needed on who is allowed to play the role of the oracle and who is not. As we shall see in the next chapter, this is the main reason why, to a neomaterialist appraisal of the material components of an infrastructure, it is important to juxtapose an ecological appraisal of the relationship between an infrastructure as a whole and its associated *milieu*. An Infrastructure

> Is an ecology in the sense that it is an interconnected series of parts, but it is not a fixed order of parts, for the order is always being reworked in accordance with a certain 'freedom of choice' exercised by its actant (Bennett, 2010, p. 97).

This is going to be the aim of the next chapter.

5. Conclusions

This chapter showed how blockchain technologies, at ten years from their inception, show fluidity and contestation in terms of terminology and standardisation. This chapter, then, wanted both to explain the definition of some of the key terms that are going to be used throughout the thesis, and to show how standardisation itself is a highly political endeavour, which deeply impacts on the dispositions of a specific technical system. The case of Ripple provided an important starting point for our analysis, due to the heterogeneity of its internal components, the particular genealogy of these components, and the peculiar vicissitudes that made the XRP Ledger into what it is today. The chapter then generalised the insight produced by the case study material into a full-fledged political ontology of blockchain-based money infrastructures. This analysis was based on the latest taxonomies of blockchain technologies, and on Keller Easterling's (2014) conceptual framework for the comprehension of the infrastructured space.

Ripple works in this dissertation as a revelatory case that allows to maximise our knowledge of both the empirical evolutions and the analytical dimensions that this chapter has isolated. Empirically, Ripple over time morphed from an alternative credit network to a cryptocurrency system, to a cross-border payment provider for banks and non-bank financial institutions (NBFI). Further, its technology performed many of the different cultures and imaginaries that traversed the blockchain industry as a whole in the past ten years.

Read together with Chapter 4, then, this chapter shows that infrastructural materiality matters, that it is directly performative of diverse politics, and that it must be taken seriously in its own terms. Through the experimentation with multiple material active forms and their practical effects, the number of techno-social and economic imaginaries that populate monetary infrastructures also proliferated. Money, then, is more material *and* more social than ever, precisely in a moment in which, through digitalisation, it appears to be nothing more than "bits and blips on screens" (Gilbert, 2005).

As Chapter 4 will argue, however, any technical system needs to be analysed in conjunction with the cultures and imaginaries that animate it, the politics that surround it, the political economy that rely on the existence of specific technical system, and that in turn foster competition, conflict, and proliferation of those same technical systems. Any technical system needs to be understood as a "seamless web" (Star, 1995b), as an osmotic complex where each component influences the other in ways that cannot be reduced to connection-disconnection, inside-outside, input-output.

In short, infrastructures and technical systems are always ecologies where devices and their *milieux,* networks and their *Umwelts* are always in connection, communication, and co-evolution. However, this interaction is not the smooth, rational, and orderly dynamic described by the "ecosystem" design trope. In fact, Ripple's internal transformations outlined in this chapter were also brought about by changes in the external *milieu* and *Umwelt* where Ripple operated – through changes in regulations and policy, through conflicts and lawsuits, and through splits and disengagements. Some of these changes in the external environment were counteracted by the materiality of the XRP Ledger, some were magnified and enhanced, and some required the abandonment of the XRP Ledger altogether, and a migration towards a different infrastructural configuration predicated on layered interoperability. The concept of ecology places politics, conflicts, inequality, and value capture and extraction front and centre. This will be the aim of Chapter 4.

Chapter 4: An Ecology of Money Infrastructures

1. Introduction

As Ulfstjerne (2020, pp. 100-101) encapsulates, "Present scholarship has brought critical attention to the mundane things of payment technologies and their ideological formations. […] Less attention, however, has been given to growing blockchain 'ecologies' and the ongoing negotiations between central stakeholders in the field". An ecological approach to infrastructure, then, invites us to see infrastructures as deeply relational, beyond dichotomies of input and output, connection, and disconnection. Moreover, it frames dynamics, change, and outcomes as non-linear and osmotic, more than direct and intentional. Yet at the same time, the concept of ecology invites a more political and critical view of the conflicts and hierarchies that populate infrastructures.

This chapter, informed by neo-materialist understandings of infrastructures as "deeply relational techno-human ecologies" that were discussed in Chapter 1 (Coeckelbergh, 2013; Nardi & O'Day, 2000; Star, 1995b), will thereby question the ubiquitous corporate discourse that depicts FinTech and blockchain technologies as a more or less orderly, albeit complex, ecosystems (Adner & Kapoor, 2010; Adomavicius et al., 2007; R. P. Dos Santos, 2017; Winner, 1984). Ecology, in short, is a concept that allows for a combination of new materialism and political economy concerns in the analysis of money infrastructures, as well as an analysis of both tangible and intangible materialities of infrastructures, such as cultures, institutions, and regulation.

The concept of ecology is deployed also to counteract the progressive co-optation and incorporation of the idea of "ecosystem" in entrepreneurial parlance (Granstrand & Holgersson, 2020; J. F. Moore, 1993). Leveraging complexity theory (Carvalho et al., 2019; Hendrikse et al., 2019; Holmes, 2009), ecosystem has emerged as an imaginary of the market as "not the symbolically pitiless storm or inescapable octopus of nineteenth-century labour fiction; instead, it is a manageable, benevolent force of nature" (Leary, 2019, p. 74). Ecosystem forwards ideas of adaptation to change and of embrace of uncertainty (S. A. Jackson, 2009) that offer more of a rationalisation of extant pressures towards competition and entrenchment of market power rather than real analysis of capitalisation and innovation. In this way, inter alia, labour is ignored and made invisible, overshadowed by either the genius of the hacker, engineer, or entrepreneur, or by the self-fulfilling *telos* of the technology itself (Christensen, 1997; D. J. Jackson, 2011). Ecology, conversely, does not stress the orderly and "harmonic" competition that are deemed to be inherent to market dynamics (J. F. Moore, 1997; Oh et al., 2016).

The key dimensions of this chapter's ecological investigations are, first, to show the material role of intangible components like stories and imaginaries in determining the dispositions of blockchains. Second, it will show the expansion of the size and volume of cryptoasset markets, and the explosion in number of blockchain applications. This multiplication happened in co-evolution with other forms of monetary and financial technologies, such as FinTech companies and alternative credit systems. Each step with this expansion will also be shown to have come with a different response by regulators, which adopted radically different views towards private cryptoassets and distributed ledgers, that went from enthusiastic adoptions to bans and many intermediate positions.

Lastly, the chapter will show how the evolution of blockchain technologies was deeply imbricated in the geopolitics of regulation and competitive dynamics with powerful market actors. To further strengthen its analytical contribution to the thesis, this chapter also defines and situates the Ripple case within this broader ecology of money infrastructures. Ripple is able to "maximise" our knowledge of the ecology represented by blockchains, distributed ledgers, financial technologies, and alternative credit systems, not least because over time it morphed between one and another of these entities and entered into partnerships with all of them. As such, Ripple harboured most of the different, oftentimes contradictory imaginaries that populate this infrastructural ecology of money. The remainder of the chapter, then, is structured as follows. The next section outlines the forces driving change within and outside Ripple and the XRP Ledger. The third section "zooms out" of case-specific variables and understands Ripple as a revelatory case of broader ecological co-evolutionary trajectories traversing blockchain technologies, fintech, alternative monetary spaces, and financial regulation.

2. The Case Study: Ripple

The operations of Ripple and the design of the XRP Ledger have performed and enabled different infrastructural money cultures and practices over time. Hence, Ripple illustrates the ecologic co-evolution of infrastructural money forms and money cultures that this thesis sets out to conceptualise and emphasise. As shown in the previous chapter, Ripple started by being a *hawala*-like alternative credit network, it then morphed into a blockchain technology, and it lastly transformed itself into an interoperability platform for interbank cross-border payment systems. This transformation, as we shall see in this section, was far from accidental, and the results were highly consequential both for the materiality of the technologies deployed by Ripple, and by the distribution of power and resources they engendered. The XRP Ledger originally promised interoperability through an ostensibly neutral medium that could mediate between apparently incompatible approaches to money, as the following quote from Ripple's archived website suggests:

> John Maynard Keynes proposed a supranational currency [...] Friedrich Hayek called for increased currency competition. [...] The underlying conflict is technical not ideological. As with so many other historical problems, this currency conundrum seemed intractable until technology caught up with the theory. Ripple's distributed exchange is the 'electronic calculator' that Hayek dreamed of, but on a scale he could never have imagined. [...] If a global currency is like the universal language Esperanto, then Ripple is like the 'Babel fish,' the universal translator of science-fiction, and, more recently, Google. (Ripple, 2013)

This quote retrieved from Ripple's archived website shows that the XRP Ledger promised an ostensibly neutral medium (the calculator) to provide interoperability (universal translation) between apparently incompatible political designs of money (Keynes and Hayek). As we shall further reflect in the Conclusions, this imaginary also frames an idea of interoperability as translation, both considered as technical operations of conversion. This neutrality of the interoperable medium, however, is far from what happened: both active forms and different money cultures did not develop peacefully alongside each other, but rather engaged in multiple conflicts on which active forms to promote and which to deprecate, and they were influenced by forces outside the XRP Ledger. Originally, in fact, Ripple's website listed a host of different applications of its technology, from trading of gold through Gold Bullion International (Ripple, 2014), to activating an XRP Ledger account using just Amazon vouchers (Tong, 2014).

In 2015, however, the company Ripple tilted towards using the XRP Ledger and, subsequently, the Interledger Protocol for interbank cross-border payment services for financial institutions. This pivot was due to both regulatory pressure and new market opportunities. In terms of regulatory pressures, Ripple was forced into KYC compliance by a FinCEN and Northern California District Attorney investigations and subsequent settlements (U.S. Department of Justice, 2015). By 2015, in fact, the only point of access to the XRP Ledger at that moment was through Ripple's web client. In 2015, the Financial Crimes Enforcement Network (FinCEN) sued Ripple for failure to abide by the US Bank Secrecy Act regarding Know-Your-Customer (KYC) and Anti-Money Laundering (AML)

(FinCEN, 2015). Ripple settled the lawsuit on the 5 of May 2015, by committing to an extensive KYC programme and by paying a sum of $ 700.000. It jointly settled with the Northern California District Attorney for $ 450,000, plus reparatory measures to ensure compliance (U.S. Department of Justice, 2015). Shortly after, Ripple applied and obtained a New York State “BitLicense” for institutional sales of the cryptoasset XRP. Ripple, then, pivoted towards financial institutions to partially outsource due diligence: serving banks rather than individuals meant for Ripple to be able to rely on banks’ compliance departments rather than on its own forces. This is why Tasca and Tessone (2019) claim the XRP Ledger is KYC compliant, as mentioned in Chapter 3: the biggest use case became financial institutions, which are already obliged to abide by KYC regulation. However, there is nothing in the XRP Ledger itself that requires personal information to be disclosed for an individual to open an account.

Simultaneously, by 2015, the whole payments industry was caught in the enchantment of blockchain disruption. Central banks like the Bank of England, the Federal Reserve, and the Saudi Arabia Monetary Authority had collaboration with Ripple connected to domestic payments updating (Bank of England, 2017; A. Liu, 2015b; Ripple, 2018a). Ripple was also invited SWIFT’s conference SIBOS from 2014 to 2016 (Sibos, 2015, 2016), and several senior executives spoke at Money2020 in 2018. In 2017, Ripple launched its own conference SWELL, with keynote speakers Ben Bernanke in 2017 and Bill Clinton in 2018. Furthermore, Ripple started hiring several professionals from incumbent financial and regulatory institutions. For example, Marcus Treacher, hired as Senior VP for Customer Success, was previously a member of the Global Board at SWIFT between 2010 and 2016. Amongst Ripple’s board of directors appear Anja Manuel, previously U.S. Department of State official, responsible for South Asia Policy, and Ben Lawsky, the New York State official who drafted the BitLicense regulation (Ripple, 2019a).

Ripple’s Venture Capital funding rounds also mirror the payment industry’s enchantment with blockchain technologies, as we shall see in further detail in Chapter 6. Ripple received $93.6 million in 9 funding rounds between 2013 and 2017, including a $32 million Series A funding round led by Santander InnoVentures, the VC branch of Banco Standander, which later implemented Ripple’s technology for retail cross-border payments (Banco Santander, 2018; Crunchbase, n.d.). In December 2019, Ripple sought a $ 200 million round of Series C funding, which brought Ripple’s overall valuation at $ 10 billion (Dillet, 2019; J. J. Roberts, 2019). As we shall see in Chapter 7, Ripple entered into deals with remittance leader MoneyGram for $ 50 million, partially paid in XRP for handling cross-border payments

(Ripple, 2019c; T. Wright, 2020). In January 2020, Ripple was included in the CNBC list of 50 disruptive companies (CNBC, 2020), and in February 2020 it was included in Fortune's list of 50 blockchain companies (Castillo, 2020).

This process of re-orientation of Ripple towards financial institutions, however, was far from linear and conflict-free: Ripple entered a partnership with the blockchain provider and consortium R3 – the company that powers Corda. However, in 2017, R3 sued Ripple for breach of an agreement that would have entitled R3 to purchase XRP at a discount. In 2018, Ripple reached a settlement, the content of which remain confidential (Alexandre, 2018). At the same time, XRP is still the object of complaints issued by individuals to the SEC to investigate whether XRP can be configured as a security according to the Howey test, but no decision has been issued by that regulatory body (N. De, 2019; Floyd, 2018).

Ripple's pivot towards financial institutions was not the sole driver of change in the materiality, cultures, and distributive results of Ripple's technologies. The rise of XRP's price also contributed to the tension between the "alternative" ethos of the XRP Ledger and the "mainstream" use it was made of that technology for speculative exchanges and cross-border payments. In fact, as illustrated in the previous chapter, XRP is not just an asset, but a switch that modulates the XRP Ledger. To activate an account, open a trust line, and issue offers on the distributed currency exchange, everyone needs to hold reserves in XRP.

This turned XRP into a battleground between competing interests. LETS supporters need for XRP to be cheap in order to activate trust lines and to pay transaction fees. Traders want its price to be volatile to make higher margins through arbitrage. Payment providers want XRP's value to be stable, to mitigate the exchange rate risks associated with using it as bridge asset. Ripple's management had to reconcile these three tensions with the need for making a market for XRP: to reassure the market, Ripple froze 55 billion XRP in an account that automatically releases only 1 billion XRP a month (Garlinghouse, 2017). Over time, the terms of trade favoured crypto traders over LETS communities, and these users drifted towards other projects such as Stellar, which uses a very similar source code, but has lower reserve requirements (Stellar, n.d.), and the Trustlines Network, implemented on Ethereum (Hees et al., 2017).

Adoption and market-making constitutes a chicken-and-egg problem for cryptoassets: people will not use an asset until a market has developed around it, and such market will not develop if people do not use the asset (Presthus & O'Malley, 2017). Over time, Ripple tried different strategies to expand XRP's liquidity and ecosystem. XRP was first distributed either freely, or as remuneration for developers who spotted errors in the code. In 2017 and 2018, however, XRP's price skyrocketed: from US$0.01 in March 2017, it surpassed US$3.2 in January 2018 (CoinMarketCap, 2021). Previous distribution strategies became unprofitable for Ripple, and XRP became more palatable as an investment. Hence, Ripple started distributing XRP through loans and sales to market makers and liquidity providers in the cryptocurrency exchange markets. This price hike did not go unnoticed by financial institutions. As one informant put it, in late 2017 "Ripple was worth more than all but maybe twenty banks in the planet. And that made the phone ring!" (Interview 19th April 2019).

In 2018, Ripple created the subsidiary Xpring, that distributes XRP to fund fintech companies that might expand XRP's ecosystem (Ripple, 2018c) in a broad market-making effort. Ripple also performed large-value, highly publicised charity donations. In March 2018, Ripple donated $ 29 million worth of XRP to the charitable crowdfunding platform DonorsChoose.org, which funded all projects advertised at that moment (Elkins, 2018). Later the same year, actor and Ripple investor Ashton Kutcher donated $ 4 million worth of XRP to the comedy show host Ellen DeGeneres's Wildlife Fund (Huddleston, 2018).

Hence, we can say that the XRP Ledger witnessed an interlocking conflict and co-evolution of three money cultures, influenced by the pivoting of the company Ripple Labs (subsequently Ripple), by regulatory interventions, by oscillations in XRP's price, and by different dispositions in the XRP Ledger triggered by amendments to the code and by the oscillations of the price of the XRP cryptoasset itself. The first money culture underpins RipplePay's mutual credit network, and it foregrounds trust, distributional fairness, and mutualism. After the acquisition of Fugger's project by Ripple, this culture persisted through experiments such as the LETS-inspired currency Goodwill (GWD), started by one of the earliest Ripple employees (Ripple Forum, 2013). However, after the pivot of Ripple towards financial institutions in 2015, many of LETS enthusiasts abandoned the project, as the last sub-section shows. The second culture emphasises the liquidity of XRP as a means of payment and as a speculative cryptoasset, and it is a variation of digital metallism, which will be further discussed in the next section, as well as in Chapter 6. XRP is compared to gold not as a substitute for interpersonal trust, but as the most liquid of assets in terms of speed, value, and exchangeability. The third imaginary foregrounds the logistics of money, by leveraging the similarities between liquidity on trust lines and FX offers over the XRP Ledger, and data packets over the Internet (Fugger, 2008; Interledger, 2018b).

The promise of a neutral medium, hence, remained just a promise: the changes in the imaginaries associated with the XRP Ledger also entailed a shift in the overall disposition of the XRP Ledger. This changed the distribution of power and resources among its users. Ripple's market-making efforts turned XRP mainly into an investment, sought after for its liquidity, while Ripple's technology solutions became more focused on the Interledger Protocol, providing smoother logistical management of payments. This came at the price of marginalising, within the XRP Ledger community, of the mutualism originally embodied by RipplePay. Several people in the RipplePay community grew disenchanted and left the project (Confidential exchange over twitter, 25 September – 15 November 2018, interviews on 19 June 2018 and 1 April 2019).

Money cultures are not mutually exclusive, they do not evolve in a vacuum, and their co-evolution is always power-ridden. Every metaphor and imaginary can "heal or create, erase or violate, impose a voice or embody more than one voice" (Star, 1990, p. 52). Hence, the story of Ripple is not necessarily just a story of elimination of alternative money cultures by the hegemonising force of market-driven cultures. Rather, it shows more broadly how the same materiality may perform different cultures at the same time, and that the interplay between these cultures is just as important as the materiality of infrastructures themselves. Furthermore, it illustrates how external interventions such as regulation, competition, and speculation can have profound effects on a technical system, regardless of the original intention of their designers. The next section will generalise the insight produced through the analysis of Ripple to the whole blockchain industry, seen in conjunction with FinTech and alternative finance.

3. An Ecology of Money Infrastructures: Stories, Power, Evolution.

The concept of ecology is here deployed for four aims. First, it captures infrastructure's dispositions as deriving from more than its material components: infrastructures are semiotic, linguistic, cultural, and affective devices as much as they are material and technological (Larkin, 2013). The first sub-section, then, expands on the cultural content of blockchain technologies. Second, ecology illustrates the dynamism and evolution that propelled blockchain technologies in the last decade, to question the ostensible fixity of infrastructures and to foreground their malleability and liveliness (Amin, 2014; Harvey & Knox, 2008). Sections 3.2 and 3.3, respectively expand on the drivers of expansion in the number of use cases to which blockchain technologies and DLT are applied, and on the proliferation of cryptoassets and the explosion of their market capitalisation. Third, by not considering blockchain technologies in isolation, ecology is used to analyse the evolution and expansion of blockchain technologies together with, and as a part of the broader emergence of FinTech, and the longer trajectory of alternative financial networks and spaces (D. Fuller et al., 2016; Leyshon et al., 2003; North, 2007). Section 3.4 reviews the developments in FinTech and alternative monetary technologies and applications. Fourth, ecology provides an analytical tool to unpack the power struggle over regulation exerted by public regulators, private corporate actors, and grassroot groups. Sub-section 3.5 provides a brief overview of regulatory developments.

3.1. Stories and Imaginaries.

While Chapter 6 will delve deeper in the enchantments and libidinal investments that sustain blockchain infrastructures and their expansion, this sub-section will delve into the stories and cultures that propelled the technological development of many of the active forms we just analysed. As Keller Easterling has it, "stories […] however immaterial, are powerful enough to buckle concrete or bend steel, and they can maintain an inescapable grip on the disposition of infrastructure space" (Easterling, 2014, p. 137). As the analysis of Ripple showed, it is neither easy nor straightforward to isolate distinct money cultures as they traverse a specific monetary network: they are always plural, co-evolving, and negotiated and contested. However, five distinct themes emerge both from the secondary literature that emerged in the social sciences and beyond in the past ten years, and from an analysis of interviews and fieldwork material. The five themes that emerged most strongly are trust, decentralisation, anonymity, politics, and logistics.

While speculation could be considered another culture, this dissertation will argue that speculation as a strategy for the leveraging of libidinal and economic investments is more an overarching force driving market expansion and capitalisation, rather than a specific and distinct culture, imaginary, or discourse. In this way, the more-than-representational and the more-than-discursive element of enchantment, speculation, and desire emerge as forces that animate in different forms all the aforementioned cultures, and that turn these symbolic, semiotic, and discursive components to "productive use" in the achievement of profits and in the leveraging of material infrastructures.

The first overarching theme of blockchain and DLTs is trust: money and trust have been shown to be quite literally two faces of the same coin by a large body of literature on monetary history and social theory (Coggan, 2011; Granovetter, 1985). After all, credit as a term derives from the Latin *credere*, to believe or to trust (N. Gillespie & Hurley, 2013). As repeatedly stated in the whitepaper, Bitcoin aimed to remove either interpersonal or institutional trust in money and payments, e.g., between payer and payee, or between payers and validators. Bitcoin's roots are intertwined with the growing distrust in financial institutions wrought by the Financial Crisis: Bitcoin is "money for an age in which trust had collapsed" (Eich, 2019, p. 93). Blockchain itself, for this reason, has been defined the "Trust Machine" (Brekke, 2019; Werbach, 2018; Winter, 2018). The relationship between blockchain and trust has been effectively encapsulated by Maurer et al. (2013, p. 263) under the concept of "digital metallism", i.e., a system where "trust in the code substitutes for the (socially and politically constituted) credibility of persons, institutions, and governments". At the same time, as this and the previous chapter showed, the original RipplePay network was precisely predicated on money as an interpersonal relationship of trust: anything can become money as long as it is connected to a promise to pay each other's debts between to members of a community.

The trustless nature of blockchains has been problematised by multiple authors (Baldwin, 2018). Rauchs et al (2019), for example, separate "network consensus" from "social consensus" to show how the trustless nature of the consensus algorithm can only be predicated upon a shared trust and adoption of the key tenets of the network consensus by the broader "social ecosystem" surrounding a technology. De Filippi and Loveluck (2016) call "social consensus" and "network consensus" as, respectively, governance *of* the infrastructure and governance *by* the infrastructure. In Lana Swartz's (Swartz, 2018) words, digital metallism is only made possible by "infrastructural mutualism" (Swartz, 2018, p. 632), i.e., the invisible labour of care for and repair of the distributed infrastructure of Bitcoin's blockchain. Walch (2016, 2019) went so far as to consider coders and software developers as *de facto* fiduciaries, who should also be subject to the regulation and liabilities of fiduciaries, because trust in code is just trust in coders and their ability to code "well". As we saw in the previous Chapter about oracles, furthermore, some degree of pre-agreement on authorised entities is sometimes required in blockchain systems (Parra Moyano, 2017).

The second story about blockchain is decentralisation. Bitcoin aimed to create a currency that was able to run without centralised authorities, that could not be controlled or stopped by any government, whose emission and supply could not be subject to political intervention and discretionary monetary policy, and whose circulation was disintermediated rather than requiring a banking system. This decentralising ethos also draws on early neoliberal claims to private issuance of money and free banking (Glasner, 2005), but also on open source software (Rushkoff, 2015) and peer-to-peer network advocacy (Benkler, 2006; Mallard, Alexandre et al., 2014). This is what Kostakis and Bauwens call "netarchical capitalism" (Kostakis & Bauwens, 2014), where the corporation with its market power is supplanted by the network and the value it affords through reach and connectivity. As it is the case more broadly with the FinTech revolution (Lai & Samers, 2020) and, before that, the Internet itself (DeNardis, 2009, 2014; Flichy, 2008), however, the tale of blockchain as an inherently disintermediating technology is problematic and hardly tenable. Disintermediation of peer-to-peer networks and reintermediation of walled-garden blockchains and new fiduciaries like the ones outlined above, create a more fraught cultural economy surrounding these innovations (Nelms et al., 2018; Pesch & Ishmaev, 2019).

The third story is about anonymity. Many of the ideas that Bitcoin heralded related to Cypherpunks, cryptoanarchists and libertarian theories of free money and free banking, anonymity, anti-censorship, and self-governance (Brunton, 2019; Golumbia, 2016; Kostakis & Giotitsas, 2014). It draws on earlier concerns with the "independence of cyberspace" and the capacity to resist censorship and control. Timothy May (1992), in the "Crypto Anarchist Manifesto", states

> Just as the technology of printing altered and reduced the power of medieval guilds and the social power structure, so too will cryptologic methods fundamentally alter the nature of corporations and of government interference in economic transactions. Combined with emerging information markets, crypto anarchy will create a liquid market for any and all material which can be put into words and pictures.

In the declaration of independence of cyberspace, Barlow (1996) states "We are creating a world where anyone, anywhere may express his or her beliefs, no matter how singular, without fear of being coerced into silence or conformity". Despite this being exemplified by the adoption of Bitcoin by counter-information group Wikileaks, it is interesting to notice that such adoption was strongly resisted by Satoshi Nakamoto themselves, because a network in its infancy could have not withstood the regulatory pressure deriving from that association with Julian Assange (Nakamoto, 2010).

The fourth story is about politics, not so much understood as "power" but as the capacity to make arbitrary and potentially open choices in the face of uncertainty and without pregiven blueprints to establish which alternative is preferable. As a mnemonic technology, "money is [also] a technology for managing time – futures, faith, and forecast – and it contains a model of society" (Brunton, 2019, p. 6). Bitcoin's genesis block encodes the picture of January 3rd, 2009 where the London *Times* announces the possibility of a second bailout of the UK major banking institutions, both to prove the day when that block was mined and to mark Bitcoin's distance from mainstream finance (Bitcoin News, 2020; BTC.COM, n.d.). "Digital metallism" in fact, is not only a metaphorical reference to trust in a material – either gold or networking technologies – but also a remnant of metallism understood as "quantity theory of money" predicated on scarcity and decoupled from politics.

Many authors have illustrated the paradoxical politics of cryptoassets and in specific Bitcoin. Eich (2019), for example, understands Bitcoin as the last instalment of a struggle between a Hayekian depoliticisation of private commodity money versus a Keynesian view of political credit money. For Lianos (2019), Bitcoin represents the first time when the Polanyian countermovement to the disembedding force of markets – exemplified by the 2008 Financial Crisis – is represented itself by a disembedding force – exemplified by Bitcoin's fascination with quantity theories of money and Hayekian proposals of private commodity money (Karlstrøm, 2014). Golumbia (2016) went further and claimed that Bitcoin's political roots draw on right-wing conspiracy theories. Amato and Fantacci (2018) show that cryptocurrencies are hardly "alternative" because they are not predicated on the sociality of credit-money, but on the liquidity and scarcity of the credit-asset.

The fifth story is about logistics and interoperability. Blockchain technologies are often considered not just as a way to arrange a payment system or a network, but as a blueprint for the networks to come, a general-purpose technology (Hacker et al., 2019a) that will provide smooth circulation and interoperable telecommunications across networks and infrastructures. One of such teleologies is provided by Melanie Swan (2015) and her periodisation of blockchain 1.0, 2.0 and 3.0 corresponding, respectively, to *currency*, *contracts,* and *applications* beyond money and finance. Blockchain technologies, then, are the last instalment of the performative power of transaction cost theory over the expansion of network technologies, as Pesch and Ishamev (2019) have it: network technologies of all kinds are always purported to bring transaction costs – both economic and non-economic costs – down to almost zero (Rifkin, 2014).

However, there are two problems with this assumption: first, the promise of fluidity will bring more and more firms to seize first mover advantage, which in turn will increase transaction costs because of the increased number of new intermediaries (Pesch & Ishmaev, 2019). The struggle to establish interoperability, in that case, will become political, in that it will have to establish interoperability standards between established competitors (DeNardis, 2011). The second problem, illustrated by Tasca and Piselli (2019), is that blockchains are, as shown earlier, both technological and political constructs. Different standards also produce different intended and unintended social effects. Interoperability, then, is hardly a neutral endeavour, and it instead requires the levelling of this political diversity: as shown in the previous chapter, interoperability is part of the "wiring" of a blockchain (Easterling, 2014, p. 80).

One of the features that make of the blockchain a "cosmogram", i.e., "an object that contains a model of the universe and a plan for how to organise life and society accordingly" (Brunton, 2019, p. 10) is its real or purported telos and aim. These imaginaries act as hyperstition[9], understood as "semiotic productions that make themselves real" (Land, 2012, p. 579) "through fictional quantities functioning as time-travelling potentials" (Cybernetic culture research unit, 1999). In succinct terms, Dodd (2018) showed how Bitcoin is inhabited by multiple money cultures and represents multiple things for multiple people. These promises and cultures, then, are multiple and often contradictory. Cryptoassets, then, are boundary objects: they mean different things for different communities of practice (Star, 2010; Star & Griesemer, 1989). It is this internal, oftentimes contradictory diversity that fuelled the idea of blockchain as a general-purpose technology (Hacker et al., 2019a) and that, in turn, propelled the expansion of blockchain and DLT into just about any socio-technical domain of application.

3.2. Expansion and Change

Ecology is also a concept that does justice to the genealogies and dynamic evolution of technical systems. As shown before, and in Chapter 3, Ripple is older than Bitcoin, and it draws on even older alternative financial technologies, as it will be shown in section 3.3. Bitcoin itself, furthermore, has a longer genealogy that it is often accounted for, and its

[9] I would like to thank Jaya Klara Brekke for suggesting hyperstition with regards to the future-oriented nature of blockchain imaginaries.

innovation comes more from the creative repurposing and repackaging of previously existing devices and software, than a ground-breaking and unprecedented invention. The story of blockchain technologies, in fact, tends to proceed as follows: the first blockchain was introduced through Bitcoin by the person or collective under the pseudonym of Satoshi Nakamoto (Nakamoto, 2019). In an email in the Cryptography Mailing List on the 1st of November 2008, Nakamoto announced the publication of the Bitcoin white paper (Nakamoto, 2018). In January 2009, Bitcoin went online with the mining of the genesis block.

However, Bitcoin would not have been possible without a host of previous technological breakthroughs as old as computation itself. As Narayanan and Clark (2017) show in their genealogy of Bitcoin, time-stamping dates back to the 1990s (Bayer et al., 1993; Haber & Stornetta, 1991, 1997). Hashing as a way to require effort from nodes to prevent fraudulent behaviour was experimented with in the early 1990s too, to prevent the proliferation of e-mail spam (Dwork & Naor, 1993). A quasi-Proof-of-Work system was introduced by Adam Back whereby honest nodes could "spend" the effort they put into hashing to send an email (Back, 1997, 2002a, 2002b). Merkle trees, which are the data structure whereby transactions are stored, date back to the 1980s (Merkle, 1980), as does the conceptualisation of the Byzantine Generals dilemma, which models the problems with reaching consensus in a network with faulty or adversarial nodes (Castro & Liskov, 1999; Lamport, 1989; Lamport et al., 1982), which Bitcoin proposed to solve. Furthermore, there were multiple previous attempts at establishing "cash for the Internet" before Bitcoin, such as David Chaum's DigiCash (Chaum, 1990; Chaum et al., 1990), Nick Szabo's Bit Gold (Szabo, 2008), Wei Dai's Bmoney (Dai, 1998a, 1998b).

Bitcoin started gaining attention beyond cryptographers in 2010: on the 22nd of May, the first real-world transaction took place when a pizza was purchased for 10,000 BTC, worth US$ 600 million as of April 2021 (G. Moore, 2020). Cryptocurrency exchanges were also born in 2010, with the most famous example being Mt. Gox (Schumpeter, 2014). In the same year, VISA, MasterCard, and PayPal barred Wikileaks from accessing their infrastructure for receiving payments, and the website turned to Bitcoin because of its decentralisation and anonymity. While this was met by the opposition of Nakamoto (2010), Wikileaks's official adoption of Bitcoin in June 2011 contributed to introduce this asset to the broader public.

In February 2011 Silk Road was launched: it offered a variety of illegal goods and services, and it accepted Bitcoin among other means of payment to protect customers' anonymity (Barratt, 2012). Silk Road's endorsement of Bitcoin caused regulators to pay attention to the cryptocurrency, which eventually led to the closure of the website by the US authorities in October 2013 (Brito & Castillo, 2016; Trautman, 2014). In parallel with Silk Road, Bitcoin became famously associated with the growth and bust of the cryptocurrency exchange Mt. Gox, which came from controlling 70% of Bitcoin's daily transactions in 2014 to go bankrupt later that same year, after reporting the theft of more than 800,000 BTC (Schumpeter, 2014). More recent lawsuits claim that the vulnerabilities were in place as early as 2011, when Mt. Gox was owned by Ripple's and later Stellar's founder Jed McCaleb (Zhao, 2019). Recently, a new company, Gox Rising, is proposing to step in in a Japanese bankruptcy rehabilitation lawsuit to make whole Mt. Gox creditors (Constine, 2019a; Singer, 2020).

Cryptocurrencies' expansion was initially driven by experimentations and amendments of Bitcoin's code: in fact, early Bitcoin "rivals" were called *altcoins* precisely because they were "other" than Bitcoin (Hayes, 2015). One cluster of altcoins had their aim at changing Bitcoin's monetary policy. For example, Litecoin, one of the first cryptoassets to be introduced after Bitcoin, aimed to reduce hoarding by changing the difficulty adjustment and incrementing the number of LTC issued, hence making this asset less scarce or, in the words of Litecoin's developers, make LTC silver to BTC gold (Torba, 2013). Another group of cryptocurrencies emerged to provide additional features that Bitcoin did not support at that time. For example, anonymity emerged as a strong use case: the most famous privacy-oriented altcoins are ZCoin (ZCoin, 2016/2018), ZCash (Hopwood et al., 2018), and Monero (dEBRYUNE et al., 2018).

Other altcoins strived to implement additional features, such as transaction speed, energy efficiency, and utility of the cryptographic puzzles to improve scalability, energy efficiency, and decentralisation (Forte et al., 2015, 2016; Janczuk-Gorywoda, 2019). Ripple and Stellar exclude mining altogether to improve speed and energy requirements, but with the downside of creating a quasi-permissioned blockchain. Primecoin, conversely, made cryptographic puzzles "useful" by having miners calculate prime numbers to mine the next block, so that the calculations can be used by the mathematical community (King, 2013). It has been estimated that the whole Bitcoin network required, as of 2018, 2.55 GW to function, or the equivalent to the energy consumption of Ireland (Eich, 2019, p. 95). Furthermore, the types of cryptographic puzzles employed in mining engendered a proper mining rig arms race (Peck, 2013) whereby the only way to having a fair chance to be the lucky miner who validates a new block is by owning a machine powered by Application Specific Integrated Circuits (ASIC), which are costly in terms of energy and money. This, in turn, generated a tendency towards concentration of mining power in the hands of a small number of mining pools, further undermining the ostensible decentralisation of Bitcoin's blockchain (Eyal & Sirer, 2013; Harvey-Buschel & Kisagun, 2016).

The birth of Ethereum in 2014, created by Vitalik Buterin and others (Buterin, 2014, 2016) speeded up this proliferation dramatically. As outlined in Chapter 3, Ethereum runs a so-called Turing-complete programming language on top of a blockchain: software can be executed by the whole network rather than by individual machines, which allowed for wholly self-executing smart contracts. Ethereum showed that blockchains could be used for more than money and payments, and it triggered a change in the attitude of press, regulators, and industry incumbents. Two protocols for the emission of tokens on top of Ethereum, the ERC20 and the ERC721 standards, gained traction as the most used protocols for, respectively, utility tokens and non-fungible tokens, as Chapter 6 will expand on[10] (Fenu et al., 2018). Table 4 reports the number of cryptocurrencies over time. Figure 26 shows the oscillation and volatility in the total market capitalisation of cryptocurrencies over time. Market Capitalisation is the market price of a cryptoasset multiplied by its circulating supply.

Year	Assets	Market Cap (bn US$)
2013	7	1.6
2014	268	5.7
2015	411	7
2016	659	17.8
2017	1480	566.8
Jan 2018	1359	828.5
2018	2474	103.8
2019	2662	191.7
2020	7567	401
2021	9443	1,981.6

Table 4: Number of Cryptocurrencies and Market Capitalisation. Source: CoinMarketCap (n.d.).

Figure 26: Cryptocurrencies Market Capitalisation. Source: CoinMarketCap (2021).

[10] See Chapter 3 and Appendix A: Glossary for a definition and discussion of utility, non-fungible, and security tokens, as well as of stablecoins.

The main driver behind the proliferation of tokens has been the phenomenon of token sales, token offerings, Initial Coin Offerings (ICOs), and Initial Exchange Offerings (IEOs). ICOs are a process of business financing carried out through

> open calls for funding promoted by organisations, companies, and entrepreneurs to raise money through cryptocurrencies, in exchange for a 'token' that can be sold on the Internet or used in the future to obtain products or services and, at times, profits (Adhami et al., 2018, p. 64)

Often compared to crowdfunding (Zook & Grote, 2019), ICOs differ from the latter, as well as from VC and IPOs, in that they do not necessarily entail the cession or dilution of equity and control of the associated company. An IEO, conversely, resembles an Initial Public Offering (IPO). To partially improve the trustworthiness outlook of the company, a start-up enters into an agreement with a cryptocurrency exchange that underwrites the IEO by acquiring the tokens and distributing them (Beedham, 2019).

ICOs are often conducted in stages (Loizos, 2018): people first develop a white paper that outlines the technology they want to market. After that, they disseminate that white paper together with software code uploaded to GitHub, and they announce their leadership team and endorsements. Then, the ICO is initiated with a pre-sale or private sale: professional investors enter at this stage through personal contacts and purchase a large amount of the token at a discount (Howell et al., 2019). After the pre-sale, popular and non-professional investors can participate in public sales, with or without discounts for early buyers (Interview 4th December 2017). To foster adoption and experimentation, firms sometimes combine sales with airdrops: with this system, some units of the token are distributed for free based on subscription to forums and mailing lists, participation in sponsored events, or even geo-localisation (Bogart, 2017). Only at the end of this process, the token is listed on one or more exchanges and it can then be traded, bought, and sold.

The token offering phenomenon gained an enormous traction with the approval of the smart contract standard ERC20 for Ethereum. ERC20 – short for Ethereum Request for Comments number 20 – is a template for smart contracts for the issuance of new tokens (William, 2018). Other blockchain platforms have, over time, developed their own token issuance smart contract standards, and different project sometimes prefer different platforms because of geographical specific reasons, for technological features, or other reasons. Table 5 illustrates the number of smart contract tokens sorted by blockchain used as infrastructure.

Platform	Number	Platform	Number
ETH	1494	NEM	6
NEO	25	VeChain	5
Stellar	23	Ardor	3
Binance Coin	21	Bitcoin Cash	2
EOS	18	Ontology	2
Waves	17	Omni	2
BitShares	10	ICON	2
TRON	10	Others	18
Qtum	9	TOTAL	**1667**

Table 5: Number of Cryptoasset by Platform. Source: CoinMarketCap (n.d.)

Ethereum also made inroads in the corporate world through the creation of the Ethereum Enterprise Alliance, "a member-driven standards organisation whose charter is to develop open blockchain specifications that drive harmonisation and interoperability for businesses and consumers worldwide" (Ethereum Enterprise Alliance, n.d.). Indirectly, Ethereum also gained traction among financial incumbent actors: J.P. Morgan's platform Quorum is based on the Ethereum source code, but which does not employ any token to run (J. P. Morgan, 2016). This platform has been turned subsequently into the "JPM Coin" system for interbank settlements (J. P. Morgan, 2019; Palmer, 2020).

Since the introduction of Ethereum, the attention shifted away from Bitcoin and towards the disruptive potential of blockchains, Distributed Ledgers, and smart contracts (Moy, 2018). The use of corporate distributed ledgers is still overwhelmingly represented by financial application: in a survey of 160 stakeholders and 67 live enterprise blockchains, Rauchs et al (2019) find that 43% of DLT applications are in the financial sector. However, this newly discovered versatility of blockchain and DLTs has led several private companies to develop their own tailored and permissioned blockchain infrastructures, designed specifically for each use case. Although sizeable, payments amount only for 7% of all corporate permissioned use cases, while supply chain tracking is the biggest single use case with 19%, followed by trading (15%), certification (10%), and trade finance (9%) (Rauchs et al., 2019, p. 34).

The use of larger consortia-run blockchains on a case by case basis is often called consensus-as-a-service or blockchain-as-a-service (De Meijer, 2020; Lam, 2019; Swanson, 2015; Tasca & Piselli, 2019, p. 31). The two most important permissioned blockchains with no native cryptoasset are Hyperledger and R3 Corda (Androulaki et al., 2018; M. Brandenburger et al., 2018; R3 Corda, 2018; Thakkar et al., 2018). Hyperledger is used in 48% of the cases reviewed by Rauchs et al (2019, p. 37), while Corda is used in 15% of the cases, MultiChain in 10% of the cases, and J.P. Morgan's Quorum, has a share of 6% of the market. Stellar also counts for 3%, especially thanks to the recent partnership with IBM to develop the cross-border infrastructure WorldWire (Wolfson, 2019).

Fabric, in a similar fashion as Ethereum for decentralised applications, is a deeper, infrastructural level for purpose-specific blockchains. IBM currently uses it for managing cross-border payments and foreign exchange (FX) transactions and tracking shipping in logistics, Everledger relies on Hyperledger Fabric for tracking the origin of diamonds to make sure that they do not originate from conflict-ridden areas, and Fujitsu and the Japanese Bankers' Association use this infrastructure for inter-bank communications and transactions (Fujitsu Limited, 2017). Hyperledger Cello is the platform that allows to use Hyperledger Fabric in a blockchain-as-a-service fashion (Hyperledger, 2017/2020). R3 Corda, on the other side, has a more limited scope, in that it is designed to handle financial contracts and transactions (R3 Corda, 2018). In general, both permissionless and permissioned blockchain technologies have found fertile ground in as disparate fields as identity and personal data; health insurance and credit scoring; property; elections; fair trade and aid; smart grids and energy; and IoT.

3.3. Beyond Blockchain: FinTech and Alternative Finance

When this chapter claims that infrastructures, such as blockchains, interact and evolve ecologically with each other and with their external *milieu*, it also means that they did not emerge nor change in isolation, and it wants to acknowledge the parallel development in both incumbent financial actors and in emergent firms. Blockchain technologies are part and parcel of FinTech, i.e., "a new financial industry that applies technology to improve financial activities" (Schueffel, 2017, p. 45). Blockchain technologies also need contextualising vis-à-vis a broader array of alternative techno-financial practices and networks.

First, the so-called FinTech revolution (The Economist, 2015) incorporates the proliferation of digitally mediated monetary practices and the "shadow payment system" (Awrey & van Zwieten, 2018; Greenacre, 2019). However, FinTech also involves different "verticals" of finance – such as lending (Clarke, 2019; Kinai et al., 2017; Langley et al., 2019), payments (Bátiz-Lazo & Efthymiou, 2016; Maurer, 2015b; Swartz, 2020), insurance (Downing, 2018; VanderLinden et al., 2018; Wei, 2017), financial advice (Gomber et al., 2018), asset management (Haberly et al., 2019), investing, and real estate (Fields, 2019). These innovation processes have longer trajectories (Maurer & Swartz, 2017; Rona-Tas & Guseva, 2014; Schueffel, 2017) and heterogeneous and variegates geographies (Donner & Tellez, 2008; Duncombe & Boateng, 2009; Shim & Shin, 2016), as well as ambiguous patterns of adoption and success (Kshetri, 2017; J. P. Singh, 2019).

Just like the blockchain-as-a-service described above, FinTech is often associated with a proliferation of “X-as-a-service” (Sadowski, 2020) that enables new forms of rent and data extraction and reintermediation, which problematise the idea of FinTech as purely disruptive. More and more often, in fact, large incumbent institutions have developed FinTech capacities “in-house” or by acquiring competing start-ups and their intellectual property (Hendrikse et al., 2018, 2019). Entire verticals, such as asset management, never really had a FinTech disruption, but rather caught up with the introduction of technological innovation through co-optation by existing institutions (Haberly et al., 2019; Zalan & Toufaily, 2017).

In parallel with, and often in a way that is enabling of FinTech expansion, regulatory agencies have often used a non-territorial off-shore regulatory approach that is based on the partial and temporary suspension of due diligence procedures for FinTech start-ups, such as sandboxing (Tsai & Peng, 2017). Regulation and due diligence itself are becoming more and more introjected by these innovations under the label of RegTech (Barberis et al., 2019; Schizas et al., 2019), i.e., a set of devices and applications that allow for the automatisation of compliance and for the “plug-and-play” enforcement of specific juridical provision, for example, when a company moves from one jurisdiction to another.

Central Banks themselves have not been impervious to the promise of faster transactions and improved efficiencies inherent to FinTech firms. For example, the Bank of England and the Federal Reserve have launched several updates to their Real Time Gross Settlement Systems (RTGS) through the introduction of liquidity saving mechanisms, and real time settlement for retail payments through Faster Payments (UK) and FedNow (USA) (Bacs Payment Schemes Limited et al., 2016; PwC, n.d.). Open banking in the UK and EU have further fostered FinTech firms by “forcing” financial institutions to open their APIs so that platforms of multiple kinds – e.g., payments, saving, credit checking and scoring – can access and exchange data (Zachariadis & Ozcan, 2016).

On the other side, alternative currencies, credit networks, and cooperative credit, saving, consumption, and insurance agreements have existed long before the publication of the Bitcoin white paper (Gerber, 2015; Meyer & Hudon, 2019). *Hawala* and *hundi*, which will be dealt more in-depth with in Chapters 5 and 7, are multilateral networks of bilateral transferrable repayment claims that date back to medieval Islamic and Jewish finance (de Goede, 2003; El Qorchi et al., 2003; Geva, 2011; M. Martin, 2009; Rusten Wang, 2011; E. A. Thompson, 2008; Vlcek, 2010). To some respect, the Bill of Exchange of Renaissance Europe was a form of alternative currency created by merchant bankers to transact across borders (Boyer-Xambeu et al., 1994). A similar configuration was shared by the so-called "flying cash" during the Tang dynasty in China (L. Yang, 1971, pp. 51-52). More recently, probably the first modern alternative currency was the WIR currency – short for *Wirtschaftsring* or economic circle – created in 1934 in Switzerland based on the theories of heterodox economist Silvio Gesell (Gesell, 1958; Mainelli, 2012; Stodder, 2009; Stodder & Lietaer, 2016; Vallet, 2016).

The first "time bank" was Ithaca hours, established in the New York state town with the same name, where people could transact in goods and services with units of account denominated in labour time. This system was meant to give equal value to equal labour time (Grover, 2006). Michael Linton, on the other side, created the Local Exchange Trading System in 1983 in Comox Valley, Vancouver Island, Canada, and it then spread to New Zealand, Australia, and the UK (North, 2007). Since 2005, the Transition Network in the UK has fostered the emergence of multiple local currencies such as the Brixton Pound in Brixton, London, and many others (North, 2010). Amato and Fantacci (2018, p. 11) define LETS and time banks thusly:

> A central counterpart keeps account of the exchanges between participants; participants benefit of an overdraft facility that allows each of them to buy before having started to sell; balances are kept in an internal unit of account and are not convertible in official money; the unit of account is normally pegged to the official currency at a fixed rate, but it can also be linked to the time required to offer a given good or service, as in time banks.

In Japan, a recent yet vibrant tradition of ecologically minded credit networks developed between the 1990s and the 2000s, with one prominent example being the iWAT: a credit network of currencies denominated and redeemable in energy (B. Lietaer, 2004).

Other currencies were created as emergency credit networks in post-crisis contexts. While some early examples can be traced back to the 1980s, post-1990s-crisis Argentina saw the emergence of several credit networks such as the Argentino, the Patacon, the LECOP, and the *Club de Trueque* which together accounted for a user basis of 10% of Argentinian population. These schemes shrank in size after 2002, mainly due to the recovery of the national economy (Blanc, 2011; Gomez & Helmsing, 2008; Pearson, 2003; Sahakian, 2014).

Sardex is another example of a currency emerged to support local production and consumption networks, based on the two principles of clearing – i.e., the mutual cancelling out of bilateral debts and repayments – and *demurrage*, i.e., negative interest as an incentive to throw money back into circulation (Lucarelli & Gobbi, 2016). In short, blockchain can be seen as an instantiation of broader trends in technology and finance to harness ubiquitous network connectivity and peer-to-peer architectures to develop ostensibly intermediary-less markets and platforms, as well as community-driven alternative monetary networks.

3.4. Power and Regulation

Lastly, ecology is here deployed to capture the power dynamics and conflicts at play in controlling and influencing the materiality and disposition of infrastructures. These conflicts are a far cry from the orderly dynamics inherent to "co-opetition" (A. Brandenburger & Nalebuff, 1996) or even creative disruption (Schumpeter, 2006). They entail regulatory capture and market power entrenchment, dramatic overhauls of the initial plans of whoever deployed that infrastructure in the first place. This sub-section, then, will deal with regulation, geopolitics, and market dynamics that concurred in shaping blockchain technologies as they look like currently, and tries to trace trends and patterns. While a full review of regulation is almost impossible, this section tries to provide a summary of the interventions so far. For more information, Appendix B reviews most of the jurisdictions worldwide in terms of regulatory approaches, CBDC, and taxation regimes.

Much like the evolution of blockchains themselves, regulation has evolved in stages. The first such stage, connected with Silk Road and Wikileaks, was directed at anti money laundering and combating the financing of terrorism (AML and CFT), law infringement and tax and sanction avoidance. The most representative measure is the FBI arrest of Ross Ulbricht, a.k.a. Dread Pirate Robert, founder, and manager of Silk Road, in October 2013 (J. Lane, 2013). A second stage of regulation accompanied the spread of altcoins and crypto exchanges, and the rise and fall of Mt. Gox (Schumpeter, 2014). This phase consisted in two efforts: first, financial regulators tried to come to terms with what cryptocurrencies and blockchain were through reports and scoping research, to assess risk for financial markets, customers, and, potentially, monetary policy (FATF, 2014b).

This effort translated into early regulatory decisions that, in many cases, extended to cryptocurrency operators some of the existing compliance obligations of financial institutions and payment system providers. The note 2014-21 of the Internal Revenue Service and the deliberations by the Commodities and Futures Trade Commission (CFTC) in September 2015, for example, equated cryptocurrencies to property and commodities (CFTC Docket No. 15-29, 2015; CFTC Docket No. 15-33, 2015; Internal Revenue Service, 2014). In 2014, the New York State Department for Financial Services passed the BitLicense Regulation on money operators handling cryptocurrencies, which barred any licensed entity from doing business with unlicensed firms (New York BitLicense, 2015). Recently, the Office of the Comptroller of the Currency issued a notice that allowed banks, for the first time in the US, to act as custodian for cryptocurrencies on behalf of their customers (OCC, 2020).

The third stage of regulation focused on tokens and ICOs. The American national regulator, through the SEC guidance and the Supreme Court's sentence *SEC v. Howey* of 1946, has developed the so-called *Howey test* to identify a financial product as a security. According to the Howey test, a security is "(i) an investment of money; (ii) in a common enterprise; (iii) with the expectation of profits; (iv) resulting solely from the managerial efforts of a promoter or third party" (Shadab, 2019, p. 249). However, State-level regulators have some degree of freedom in regulating, for example, exchanges and other service providers that might be connected with ICOs. Overall, utility tokens are generally not considered securities, in that they are purchased for their utility in the platform ecosystem, rather than to generate profits through sales (Shadab, 2019, p. 250). The example of the DAO, however, is an example when the SEC *did* apply the Howey test (SEC, 2017). After the hack described in Chapter 3, the American regulator looked into the rights and obligations of individual investors, as well as the structure of the token, and concluded that each of the four criteria of for the Howey test was met. The DAO issued unregulated securities and, hence, should have abided by licensing obligations already in place.

A fourth stage of regulation, still in its infancy, concerns the co-optation of blockchain technologies by state actors under the guise of Central Bank Digital Currencies (CBDC). These "sovereign" cryptoassets are not a homogeneous group: rather, they are divided between digitalised central bank reserves, retail means of payment, new state funding instruments, and collectibles (CPMI, 2018). Two prominent examples of CBDC, Singapore's Project Ubin (Deloitte, 2017a) and Canada's Project Jasper (Bank of Canada, 2017), are oriented towards digitalising central bank reserves to improve high-value domestic and cross-border payments. Sweden, conversely, is looking into adopting e-Krona as a retail means of payment because, with the waning relevance of cash in Swedish society, the risk is that the Riksbank will lose control of most of monetary supply, aside from central bank reserves (Peebles, 2021; Zimmermann, 2019). China has been reported to be working on its own CBDC (Suberg, 2019c, 2020), which seems to be oriented towards the retail market and digital mobile payments, as Chinese authorities issued and distributed wallets to individuals and businesses in the Shenzhen province through a lottery system, for a combined value of 10 million Yuan or $ 1.5 million (Kharpal, 2020). An Indian bill launching a "Digital Rupee" has been retrieved, but there have been no official confirms nor denials (Huillet, 2019a). Iran and Kuwait were working on two separate CBDCs, but there has been no update since January 2019 and 2018, respectively (Peyton, 2018; Suberg, 2019a).

The Eastern Caribbean Central Bank, operating a currency union comprising many Caribbean countries, has ostensibly entered an agreement in 2018 to pilot the issuance of a digital currency (Law Library of Congress, 2018). France's announcement of a CBDC is a recent development, and it should take place in late 2020 (Partz, 2019c). Venezuela and the Marshall islands are, to date, the only two states that issued a cryptoasset (Declaration and Issuance of the Sovereign Currency Act 2018, 2018; GBV & SUPC, 2018), the former as an anchor to the sovereign currency, backed by gold and oil, the latter as a retail payment instrument. Estonia was also considering issuing a cryptoasset called estcoin, largely resembling a bond, but it has been stopped by the European Central Bank (Canepa, 2017; Canepa & Chopra, 2017). Lithuania launched a coin, which was conversely deemed legitimate by the ECB because it is a collectible rather than a means of payment (Bank of Lithuania, 2018). The Netherlands created DNBCoin, which was however only used in internal pilots (Berndsen, 2016). Iceland is often mistaken as the first country to issue a CBDC called Auroracoin, but this was not ordered by, or had the say-so of any Icelandic authority. Rather, a private individual or group under the pseudonym of Baldur Friggjar Odinsson launched Auroracoin and issued an airdrop to all Icelandic citizens, which could have claimed their amount of AUR by showing their personal number (Hofverberg, 2014).

Some authors envisage blockchain as itself embodying a fifth stage of regulation, an emergent *lex cryptographica* resembling the *lex mercatoria* of Renaissance Europe (A. Wright & De Filippi, 2015). This form of law would be based *on* and enforced *through* blockchains and smart contracts as self-enforcing hybrids between Law and Code (T. W. Bell, 2018; M. Casey & Vigna, 2018; De Filippi et al., 2020). Leveraging the capabilities of blockchain technologies to record and secure property and ownership, which we shall deal with in Chapters 6 and 7, these authors conceive of smart contracts as a new form of contractual relation (D. W. E. Allen et al., 2018; Cf. Garrod, 2019). Self-executing code would allow for immediate arbitration and enforcement, while the array of self-enforcing tools provided by smart contract would allow to “blockchainise” the state itself (Jun, 2018), hence transitioning from a phase where Code is Law to one where Law itself resembles software code more and more (De Filippi & Hassan, 2018; De Filippi & Wright, 2018; A. Wright & De Filippi, 2015; Cf. DuPont & Maurer, 2015; Garrod, 2016). However, as Herian (2018a, 2019) points out, a purely solutionist (Morozov, 2013) reading of blockchain technologies can actually hinder their broader social revolutionary potential and hand this technology over to uses that perpetuate existing power structures and political economies (see also Lawrence & Mudge, 2019; Levy, 2017). Velasco (2017, p. 723) frames this discussion through Winner (1980) and Engels (1978): if unchecked, power can seamlessly transition from institutions and become ingrained and hard-wired into code itself. In a similar fashion, technological developments, for Engels (1978), might have threatened to displace the power of capitalists only by reasserting the even mightier power of steam and the steam engine themselves.

Aside from blockchain-specific pieces of regulation, existing laws are impacting on this industry in different and sometimes unintended ways, e.g., the EU’s General Data Protection Regulation (GDPR) (Berberich & Steiner, 2016; Piekarska et al., 2018; Vido, 2020; Wirth & Kolain, 2018). GDPR states that data need to be stored and process only to the extent of the specified and limited purposes for which they were gathered. Furthermore, it provides the right to rectify, amend, access and erase data upon request, if feasible, i.e., the right to be forgotten. Blockchain technologies stand at odds with many parts of this regulation: they can record data permanently, they do not have any actor being able to enforce changes to the records, and they can work across jurisdictional boundaries. The tension between blockchain technologies and data protection are unforeseeable at this moment.

Blockchain regulation remains inhomogeneous geographically (Dimitropoulos, 2019). Some jurisdictions and local authorities are trying to position themselves as blockchain hubs, like Malta (Vaghela & Tan, 2018), Gibraltar (Tassev, 2018a), Zug’s Cryptovalley in Switzerland (Williams, 2018), Andhra Pradesh in India (Khatri, 2018), and some US states like Delaware, California, Wyoming, Colorado, Texas, and Ohio (O’Neal, 2019; Rizzo, 2017). Estonia is the individual country that made the most extensive use of blockchain technologies for its activities, and its E-Residency system made it conducive to the establishment of blockchain companies in the country. Other countries have taken a strict approach: China banned ICOs, mining, and cryptocurrency exchanges that allowed cryptocurrencies to be traded for fiat currencies in September 2017, and other jurisdictions such as Bolivia and Indonesia banned cryptocurrencies to be used as means of payment (Banco Central de Bolivia, 2014; Diela, 2019). Moreover, regulation is uneven within each jurisdiction: each regulatory agency and standard-setting body might have a different attitude towards what to regulate, and how to do so. Indonesia's Central Bank, for example, has categorically banned the use of anything other than the Indonesian Rupiah as means of payment and unit of account (Bank of Indonesia, 2014), yet the Ministry of Trade regulated in favour of cryptoasset exchanges and their trading activities (Zhao, 2018).

Industry actors and institutional investors started paying attention to this market when the Chicago Board Options Exchange (CBOE) introduced Bitcoin futures contracts under the ticker XBT on December 10th, 2017 (CBOE, n.d.). The Chicago Mercantile Exchange, the world's largest exchange for futures contracts, introduced its own Bitcoin futures contract, under the ticker BTC, on December 17th, 2017 (CME, n.d.). CBOE subsequently discontinued the issuance of new contracts in March 2019, adducing a need to review its approach to digital asset derivatives (Rooney, 2019b). NASDAQ was planning the introduction of a similar derivative in the first half of 2019, but there has not been any follow-up on that plan (Rooney, 2018). Lobbying is also gaining traction: the US Congress created a blockchain Caucus in 2017 (Congressional Blockchain Caucus, n.d.), and Coinbase (a crypto exchange that surpassed $1 billion in revenue in 2017) has established its own Political Action Committee (PAC) (Wood, 2019).

Probably the most important example of corporate co-optation of blockchain technologies is Facebook Libra. This cryptocurrency was launched in June 2019 as a two-token system where investors would have held tokens backed by their stake in the venture, while users could have purchased Libra coins, which were stablecoins backed by a basket of currencies (Kaminska, 2019; Kelly, 2019). The original purpose of the system was to facilitate remittances and other types of retail cross-border payments. Launched by Facebook, Libra was supported by a network of unprecedented proportions for its infrastructural reach: while no major bank was part to that conversation, VISA and MasterCard were both in the original Libra foundation, alongside Vodafone – famous for relaunching M-Pesa in Kenya – and several platform economy start-ups such as Ebay, Lyft, Uber, PayPal, Stripe and Spotify.

However, the already high level of regulatory pressure and scrutiny subsequent to the Cambridge Analytica scandal brought Facebook's endeavour into the spotlight, which culminated with the two US Senate hearings of 16th July 2019 with Calibra's CEO David Marcus, and of 23rd October 2019 with Facebook CEO Mark Zuckerberg (Cant, 2019; Post, 2019; US Senate, 2019). At this event, Libra came under attack from liberal senators such as Sherrod Brown, from its Republican chairperson, and from members of the White House such as Treasury Secretary Steve Mnuchin (Constine, 2019b; Rooney, 2019c). As a result, Libra entered a period of quiescence, and some of the consortium members dropped out of the project altogether. In April 2020, a new set of whitepapers were licensed (Libra, 2020), which show, instead of one stablecoin operating throughout the whole network, multiple stablecoins, each pegged to the currency of a jurisdiction in which Libra would have been registered as a payment system. The result, then, looks more like a network of national e-money providers than a global cryptocurrency.

The example of Libra clearly shows the import of regulation and power have over the materiality of infrastructures and the overall disposition that descends from that materiality (T. W. Bell, 2018). This anecdote is far from unique: despite the idea that blockchain technology are unruly and unproblematically disruptive of existing hierarchies, Rauchs et al (2018) find that more than a third of surveyed cryptoasset companies have shut down operations or relocated based on regulatory changes in the jurisdiction where they were based. As DuPont (2019) notices, the idea is that blockchain technologies will disrupt just about any intermediary, but that ignores the historical, political, economic, and legal roots of those intermediaries and their obligations. Wholesale adoption is not so much about technological update, as friction between new and legacy technology, new and old interests, and new and old cultures, the results of which are far from unproblematically inscribed in the new technology alone (Alvi, 2011; Hornborg, 1992, 2001; Hornborg & Malm, 2016; Morozov, 2013; Winner, 1984).

4. Conclusions

This chapter concludes Part II of this thesis. Together, Chapters 3 and 4 advance a holistic view of the last ten years and the developments they brought in money, payments, and distributed computing technologies. While each chapter has its own, stand-alone, and individual contribution, the combination of the two chapters serves to further an infrastructural approach to money and an ecological approach to infrastructure. This conjoint conceptual and empirical effort has demonstrated how the materiality of infrastructure must be taken seriously, but it also showed that imaginaries, political economies, regulatory interventions, and other intangible materialities influence the dispositions of infrastructural systems.

This chapter summarised the changes that traversed the field of FinTech, blockchain technologies, and their regulation in the ten years subsequent to the introduction of Bitcoin, starting with a reconstruction of Ripple's vicissitudes as revelatory case for the interplay between materiality, cultures, and regulation. This past decade has been marked with a series of innovations and experimentations with the material forms of money and with the infrastructural power that payment systems afford. The proliferation of cryptocurrencies, the experimentations with their monetary policies, and the explosion in their market capitalisation that were here analysed will be further explored in Chapter 6. This chapter also unpacked the proliferation of alternative currency and credit network that leveraged the same network technologies for radically different forms of politics. It also traced the evolution of regulation, which went from having to grapple with ostensibly unprecedented forms of money and means of payment, to increasingly co-mingling and co-opting these technologies in extant payment systems and monetary instruments, albeit with radically heterogeneous approaches geographically.

What the chapter wanted to show through the deployment of the concept of ecology, then is that the politics of infrastructural materiality works in more complex ways than dichotomies like connected-disconnected, input-output, node-edge can account for. The materiality of infrastructures is not fixed, but it is constantly changing in ways that are neither teleological predetermined in the type of socio-technical imaginary associated with the use of the technologies, but in ways that do not have pre-set end and aim. In short, the evolution and change is more akin that of an ecology than that of a network. Ripple, then, while being the central case study of this thesis, is here shown as a revelatory case within a broader ecological context. Its specificities are relevant only insofar as they provoke an investigation into hitherto unseen connections with spatialities, enchantments, and power structures that traverse money infrastructures.

PART III

Chapter 5: Chrono-Topologies of Payments

1. Introduction

Part III of this dissertation is composed of three chapters, each of which fleshes out one analytical dimension of money infrastructures: respectively spaces, desires, and political economies under the overarching concepts of topologies, bubbles, and formalisation. In particular, this chapter will further develop an infrastructural approach to money by focusing on the relational and topological spaces of cross-border payments that are produced through money's infrastructures, and the ostensible changes wrought by infrastructural change. The chapter brings debates about topological spaces in contemporary human geography to bear on debates within the social theory of money and international political economy around the role of power, technology, and cultures in shaping monetary spaces.

In so doing, the leading questions are *Which monetary spaces do money infrastructure produce, maintain, and question? Through which material devices and practices are monetary spaces separated, connected, transformed, and maintained? Which internal and external boundaries and hierarchies do actors, devices, and practices produce?* This allows this chapter to contribute to the overarching methodological claims of this thesis, i.e., how to follow money (Christophers, 2011b) and how to situate its materiality in time and place (Gilbert, 2005).

In Chapter 1, this thesis argued that monetary infrastructures and computation share a layered ontology, due to their shared connection with memory and its stratifications and folds. Here, this layered ontology is analysed in the heterogeneity of configurations that different material arrangements of that layering make possible. If one wants to take seriously the claims that money is an infrastructure, that money infrastructures produce topological rather than topographical spaces, and that such topology is stacked and layered, one has to stay close to *how* those layers combine together, *which* design choices end up being inscribed in the infrastructure, and *which* shape that topology takes, as well as how it changes over time.

This chapter, then, analyses four different cross-border payment infrastructures corresponding that are each have distinctive topological arrangements. The task here is to unfold the layered topology of money, where unfolding is "not the contrary of folding, but follows the fold up to the following fold" (Deleuze, 1993, p. 6). As further argued in Chapter

2, following money is an analytical and methodological strategy aimed at observing money from the inside (Desan, 2014), in its devices, institutions, layering, spacing, distributive outcomes, and less about tracing individual financial products or monetary transactions.

The geographical imagination (Gregory, 1998) that is necessary to apprehend the heterogeneity of monetary spaces is supplied by the reflections in geographical literature and cognate disciplines around the concept of topology (John Allen, 2016; Harvey, 2012; Lata & Minca, 2016; Lury et al., 2012; Mol & Law, 1994). Topology has at its core the idea not so much that Euclidean space is no longer valid or correct as a diagram to apprehend physical space, but to "understand Euclidean space as one possible topology among others" (L. Martin & Secor, 2014, p. 430). Topology is conceptualised in this chapter "not just as a theory to be adopted, but equally as a device that is deployed in social life in a variety of ways" (Marres, 2012, p. 288). Hence, topology "does not start with a space but starts with a problem [...] then explores the space in which it has a solution" (Lury, 2009, cited in Rogers, 2012, p. 121).

Martin and Secor (2014, p. 423) argued that poststructuralist geographers ought to develop a post-mathematical topology which "is less concerned with fidelity to mathematical principles than with articulating a poststructuralist idea of space". This thesis agrees with Martin and Secor's approach to topology vis-à-vis mathematical principles: the issue here is not to apply Euclidean, spherical, or hyperbolic geometry to money and payment system infrastructures. However, this thesis argues that at stake is less a conceptualisation of space as such – whether space is topological or topographic – and more the "material-discursive fields of possibilities" (Barad, 2003, p. 823) conditions of possibility that material configurations create and destroy, open up and obscure. This neomaterialist topology should be close enough to the material configuration of relations and distribution of resources embodies in things, devices, and infrastructures. Till Straube defined this approach as metonymical rather than metaphorical, i.e., topology needs to be considered as capable of providing analytical tools "that take a real technical model (actually informing system building practices [...]) and slightly widens its scope while staying close to the original context" (Straube, 2016, p. 6).

Understood topologically, monetary spaces and borders are multiple, overlapping, proliferating (Mezzadra & Neilson, 2012) and not always coinciding with the neat Euclidean geometry of Westphalian borders and sovereign currencies:

> Borders, thresholds, and historical shifts can then be seen as sites of active mediation to be examined in their own terms, alongside economic analyses based on the reductive assumptions of currency uniformity and frictionless equivalence established through competitive market processes. (Guyer, 2012, p. 2214)

The chapter develops a fourfold typology of monetary topologies based on what Deleuze and Guattari call their internal diagram or "abstract machine". Deleuze and Guattari (1987, pp. 501-516) outlined three abstract machines informed by as many dispositions: First, abstract machines of overcoding and axiomatics are centralising and totalising. Second, abstract machines of consistency, constantly creating new connections. Third, the abstract machines of stratification, always in tension between internal uniformity and external differentiation with other layers.

Ripple here illuminates and allows to illustrate all four of these machines. First, Ripple has cooperated with national payment system regulators like the Bank of England, the Federal Reserve, and the Saudi Monetary Authority, and it competes with existing cross-border infrastructures like SWIFT and CLS. Second, Ripple was originally designed as an abstract machine of consistency, a potentially world-wide *hawala,* a borderless time bank, and a truly smooth space of mutual credit networks. Third, the XRP Ledger, alongside other blockchain platforms such as Bitcoin and Ethereum, are the very epitome of platform, where data, infrastructure, ecosystem, and monetisation tools are one and the same thing. Fourth, the Interledger Protocol originally developed by Ripple, alongside other Layer 2 and 3 interoperability technologies, are examples of abstract machines of axiomatics that are predicated on the practical overcoming of monetary borders, the inherent tendency and desire of capital to cast any barrier as a mere site of technical friction, and the drive towards interoperability and widespread application of logistics to multiple social fields (B. Neilson, 2012), in this case money.

The next section will expand on the concept and typology of abstract machines that Deleuze and Guattari provide. It will further discuss how axiomatics and overcoding, which are considered connected in *A Thousand Plateaus*, need to be decoupled. The subsequent section will expand on each diagram in turn, i.e., pyramids, rhizomes, platforms, and stacks, and it will discuss each diagram conceptually and empirically with reference to cross-border payments and blockchain technologies.

2. The Stacked Chrono-Topology of the Memory Machine

This chapter argues that the specific designs of money infrastructures emerge from the tensions between coding and decoding, territorialisation and deterritorialisation that are inherent to money. Deleuze and Guattari (1987, p. 514) define three abstract machines: "abstract machines of consistency, singular and mutant, with multiplied connections; abstract machines of stratification that surround the plane of consistency with another plane; and axiomatic or overcoding abstract machines that perform totalisations, homogenisations, conjunctions of closure". Abstraction here "does not refer to dissociation, misappropriation, detachment, or distancing from the 'real.'" (Raunig, 2010, p. 106). Rather, abstraction is more akin to the Marxian "real abstraction" of Capital (Carrier & Miller, 1998; Toscano, 2008) or Easterling's (2014) disposition of the infrastructure space. The abstract machine is an underlying disposition and tendency, a series of commands encoded in the materiality of the machine, yet not fully determined by it.

As Keller Easterling (2014, p. 80) notices when reviewing the type of active forms that populate the infrastructure space, "Like the engine of interplay that philosophers Gilles Deleuze and Félix Guattari call a 'diagram,' an active form does not represent a single arrangement. It is an 'abstract machine' generative of a 'real that is yet to come.'" If active forms are abstract machines, and if abstract machines are here used to denote the inherent propensities of specific topological constructs, then we can say that these abstract machines are made of "spatial active forms" that contribute to produce a "spatial disposition" of monetary spaces.

Abstract machines here operate at three levels. First, abstract machines materially organise (money-)signs by defining the hierarchy of monies in terms of their capability to discharge obligations with certainty and finality, which in payments is called settlement. Second, abstract machines organise settlements through the definition of rhythms: "Rhythm reunites quantitative aspects and elements, which mark time and distinguish moments in it – and qualitative aspects and elements, which link them together, found the unities and result from them" (Lefebvre, 2004, p. 9). Third, abstract machines organise monetary spaces through the definition of syntax, semantics, and addressing of internal – and, sometimes, external – communication. The result of the combination of this emphasis on the temporalities and rhythms of money is what Lotti (2018) calls a "chrono-topology": money is unique because it scripts the time and temporalities it itself traverses (Christophers, 2011b).

This chapter takes Deleuze and Guattari's typology as an explanatory tool to describe the morphologies and topologies of monetary spaces defined by distinct payment infrastructures throughout history. This chapter defines the first abstract machine as the pyramid as the archetype of the state apparatus (Deleuze & Guattari, 1983), the second as the rhizome of *hawalas, hundis,* and other mutual credit networks (Vlcek, 2010), and the third as the platform (Langley & Leyshon, 2016; Srnicek, 2017a). This chapter, however, develops four, and not three abstract machines by decoupling overcoding and axiomatics. Overcoding aims to centralise and subsume all economic activities under the umbrella of state-run institutions, while axiomatics is more concerned with the production anew of the "smooth space" of the market where multiple payment system infrastructures continue to exist, yet their internal differences are smoothened and levelled enough so as to allow seamless circulation. Deleuze and Guattari describe axiomatics thusly:

> To the extent that capitalism constitutes an axiomatic (production for the market), all States and all social formations tend to become *isomorphic* in their capacity as models of realisation [...] Worldwide organisation thus ceases to pass 'between' heterogeneous formations since it assures the isomorphy of those formations. But it would be wrong to confuse isomorphy with homogeneity. For one thing, isomorphy allows, and even incites, a great heterogeneity among States [...] For another thing, the international capitalist axiomatic effectively assures the isomorphy of the diverse formations only where the domestic market is developing and expanding, in other words, in 'the centre'. But it tolerates, in fact it requires, a certain peripheral polymorphy, to the extent that it is not saturated, to the extent that it actively repels its own limits. (Deleuze & Guattari, 1987, p. 436)

Axiomatics is also different from stratification in that the latter tends to subsume diversity within the strata while struggling to differentiate one layer from the other. Axiomatics, conversely, does not create a uniform layer, platform, or ledger, but rather it creates interoperability at the point of intersection between ledgers: rather than subsuming within a stratus, axiomatics co-ordinates across strata. Lastly, axiomatics is differentiated from consistency because consistency represents the truly "smooth space" for the free development of connections, while axiomatics is a densely striated space that only allows interconnection insofar as the minimum set of protocological standards are met, and which allows interconnection only between nodes accepted within a previously defined address space. Axiomatics, then, resonates with the new form of money that Deleuze envisioned emerging out of the turn from disciplinary societies – which can be connected with overcoding here – to societies of control: "discipline always referred back to minted money that locks gold in as numerical standard, while control relates to floating rates of exchange, modulated according to a rate established by a set of standard currencies" (Deleuze, 1992, p. 5).

3. A Typology of Money Machines

The purpose of this section is to deploy the conceptual apparatus outlined above to real-world examples, so as to reconstruct a typology of the historical shapes that monetary stacks can assume and have assumed, as a consequence of both technical capabilities and social practices. This chapter uses the concepts of abstract machines of overcoding, consistency, stratification, and axiomatics as instructive for framing the differences between the topologies, respectively, of interbank cross-border payments, hawala networks, blockchain platforms, and interoperability technologies. Furthermore, it shows how interoperability is far from a purely neutral exercise of connecting separate system together, but it entails the refashioning of the whole topology of money. Lastly, it illustrates how the metaphor of the Internet Protocol stack, strongly mobilised in building the ILP, obscures more than illuminates, and creates unforeseen problems of design and integration, and how the deployment of ILP is fraught with deterritorialising forces.

3.1. Pyramids

Money in domestic payment systems is shaped as a pyramid: as payments flow through space horizontally, they also travel vertically across a layered structure of claims that works not only chronologically, but hierarchically. The pyramidal form of payment systems derives by the unevenness of access of lower-tier institutions to upper-tier payment rails. At the top, the central bank keeps in its books the accounts of the banks incorporated in the jurisdictions. These assets also work as final settlement assets, the only other asset assuring settlement other than cash. Below central banks, there are Real Time Gross Settlement (RTGS) payment systems, which settle so-called large value, low volume payments. Being defined as systemically important payment system, they settle in central bank money: "assets used for settlement should preferably a claim on the central bank; where other assets are used, they should carry little or no credit risk and little or no liquidity risk" (CPSS, 2001, p. 34). RTGS systems also act as settlement layer for so-called ancillary systems, such as securities clearing systems.

Below RTGS systems, there are Deferred Net Settlement systems: these payment systems do not settle payments instantaneously and for the full amount, but rather they accumulate payment instructions during the business day. At the end of the day, they calculate net positions either bilaterally or multilaterally. These net positions are normally sent to RTGS systems for settlement, although nowadays most RTGSs have Liquidity Saving Mechanisms that order transactions by priority (Rambure & Nacamuli, 2008). Below DNS payment systems there are Clearing Houses. These typically have direct and indirect members, with indirect members having to rely on correspondent relationships to send payments across books, especially if far away from their area of business. Figure 27 is a synthetic diagram of the topology of domestic payments.

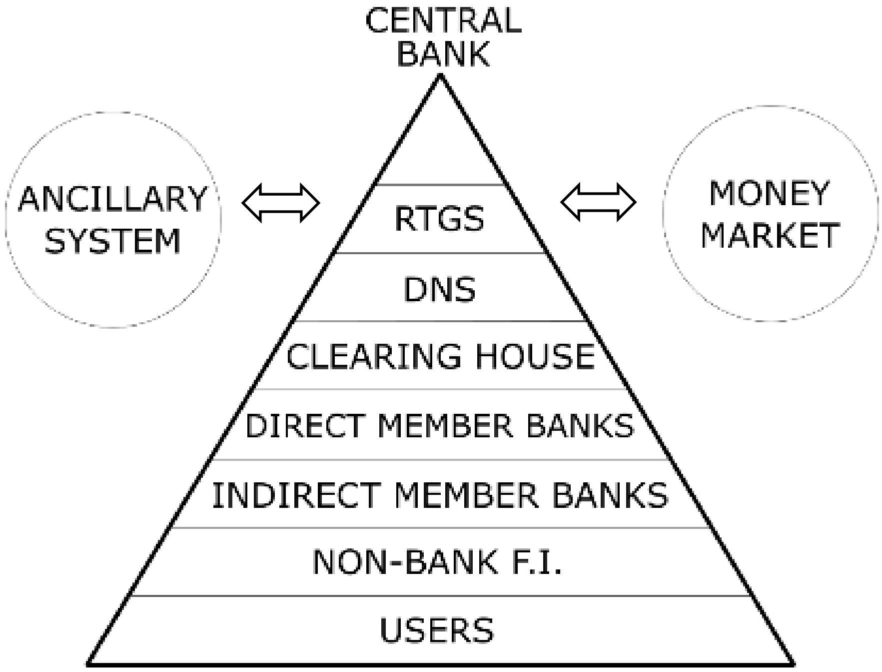

Figure 27: The Pyramid of Domestic Payments. Sources: Author's own, adapted from Geva (2011, pp. 646-648); Rambure and Nacamuli (2008, p. 13).

The standardisation of coin and note issuance in national currency areas was a painstaking effort that took centuries to achieve (Gilbert & Helleiner, 1999; Helleiner, 2003). Likewise, the concentration, alignment, and synchronisation of interbank payments is neither the natural outcome of endogenous market dynamics, nor the immediate effect of sovereign fiat. Rather, the convergence towards this pyramidal shape happened throughout four centuries, from the early 1500s through to the 1970s, through the stratification of layers of correspondent accounts – called Nostro and Vostro accounts – held by financial institutions on behalf of other financial institutions. These layers act as "special purpose monies" (Guyer, 2012; Zelizer, 1989), used only in specific social groups and difficult to exchange with money on other layers.

In the past, these special purpose monies used to be credit-based correspondent accounts, i.e., accounts that actors such as merchants, banks, or asset custodians maintained in each other's books in separate accounts called Nostro-Vostro accounts, which now form the skeleton of the global correspondent banking infrastructure. While nowadays correspondent banking seems to be an aberration, an "uninfrastructured" anomaly in the payment space, correspondent banking is not the exception but the norm of payment systems. In fact, the birth of banking and double-entry bookkeeping coincides with the birth of correspondent banking: as recalled in the first theoretical Chapter of this thesis, money is a double-entry operation whereby "The unit of matter, the smallest element of the labyrinth, is the fold, not the point" (Deleuze, 1993, p. 6). Each book where money is issued represents a fold in the layered ontology of money. Already Luca Pacioli's seminal treaty on double entry bookkeeping, in fact, records instructions for accounting Nostro and Vostro accounts (Yamey, 2011). If the accounting book allows for money to be generated in the first place, the correspondent banking network allows for money to flow and pool across books. Each additional layer needs "tropic points", i.e., "connectors between the rankings that [have] to be brought together to make a transaction" (Guyer, 2012, p. 2218), so that lower-layers monies can be exchanged for upper-layer ones.

As documented by Boyer-Xambeu *et al.* (1994), the European trade space of the XVI century was populated by a deluge of public currencies. The mercantile class, which needed to trade across the borders of these public currencies, used a particular form of private paper money defined by a purely imaginary unit of account, the *Écu de Marc*. When a merchant (called the remitter) needed to pay across borders as part of their trade, they would deposit money denominated in one currency by another merchant (called the taker). The taker would then issue a bill in the name of a correspondent of the remitter (called the drawee), that would then pay with that bill a correspondent of the taker, called the payee (Geva, 2011). Since a system like this would create imbalances between merchants, Champagne fairs, held four times a year in Lyon and Besançon, were used as places where merchants would net their reciprocal positions and settle them (Pezzolo & Tattara, 2008). Indeed, as Braudel shows, fairs themselves were envisaged as a pyramid and as a clearinghouse (Braudel, 1995, p. 508):

> the base consists of the many minor transactions in local goods, usually perishable and cheap, then one moves up towards the luxury goods, expensive and transported from far away: at the very top of the pyramid came the active money market without which business could

not be done at all – or any rate not at the same pace. (Braudel, 1979, pp. 90-91)

Figure 28 depicts the circuit of issuing, drawing, clearing, and settling of bills of exchange from the creation of the bill by the Remitter to the Drawer to the multilateral clearing and settlement of the same bill between the Payee and the Remitter.

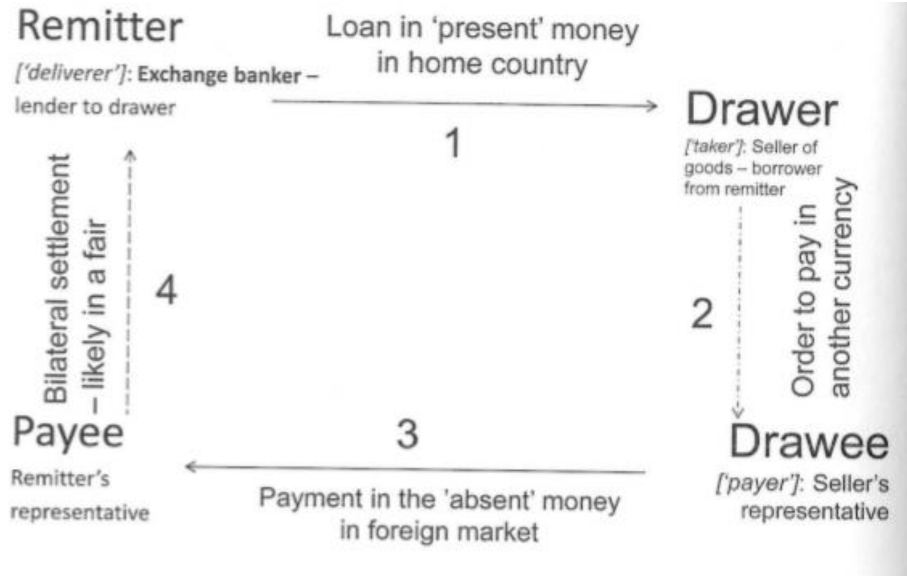

Figure 28: Diagram of Four-Party Bill of Exchange. Source: Geva (2011, p. 666).

Over time, central clearing institutions superimposed themselves on top of this network of correspondent accounts and, by acting as the ultimate tropic point (Guyer, 2012, 2016), made correspondent banking redundant. This was some kind of an embryonic form of central banking (CPSS, 2003; Timberlake, 1984). Already in the 14th century in Venice the correspondent banking network between Venetian institution was so dense and fraught with systemic risks that a central authority charged with netting the open positions that banks had with each was proposed as early as 1356, although the Bank of Rialto was only created in 1587 (Mueller, 1997; Norman et al., 2011).

Bills of exchange were progressively included, alongside notes and cheques, into national payment systems between the 17th and the 19th centuries, and cross-border payments became essentially executed through cross-border correspondent banking (Christophers, 2013). In a similar vein, in early XVII century England and Netherlands, goldsmiths kept gold as custodians, but they increasingly rarely exchanged gold itself, issuing notes drawn on each other's books, and exchanging those instead. The Bank of Amsterdam and, subsequently, the Bank of England progressively acquired a monopoly on the custody of specie and of note issuance, and these notes became the settlement asset within their payment infrastructure (Norman et al., 2011).

Check clearing followed a similar process of synchronisation with other payment systems from the 1700s until the early 20th century. The Bankers' Clearing House was created in 1833. In 1854, this institution started settling in central bank money rather than in cash. In 1864, the Bank of England became a member of the Clearing House itself (Campbell-Kelly, 2010; CCCC, 2019). Similarly, in the USA, the New York Clearinghouse was created in 1853. The clearinghouse presently operates the Clearing House Interbank Payment System (CHIPS), which is the real time gross settlement system operating in the USA. The Federal Reserve, conversely, runs the Real Time Gross Settlement system called FedWire (James & Weiman, 2010). The settlement function provided by the Bank of England or by the Bankers' Clearing House, in fact, was not offered in an equal fashion to all banks: smaller and local banks would keep correspondent banking accounts with banks in London, which, in turn, would keep accounts with the Bank of England so that netted balances could be settled directly in the books of the Bank, hence creating the distinction between direct and indirect clearers. Direct clearers, again, would entertain correspondent accounts with indirect clearers to offer clearing services for a fee.

Institutionalist economics posits central banks as a liquidity provider of last resort in the payment system as an emergent power, endogenous to payment systems themselves and largely dictated by technical risk mitigation choices (Geva, 2018, p. 451). However, central banking is far from unproblematically endogenous to payment systems. Rather, the pyramid is the result of a process of realignment and convergence between state money and bank money, a constitutional effort that establishes a particular architecture of synchronisation, where the will of the state is just as strong, if not more, than the transaction costs and risks in the interbank payment system.

This process of synchronisation of tropic points is here defined as overcoding of lower-level monies by whereby central bank liabilities, which assume the role of a "despotic signifier", i.e., "a transcendent complete object from the signifying chain, which served as a despotic signifier on which the entire chain thereafter seemed to depend" (Deleuze & Guattari, 1983, p. 110). This overcoding of settlement through the unification of special-purpose monies around the money of account established by the state happens through the overcoding of rhythms around the frequency of netting, clearing, and settlement of open positions fixated by central-bank-operated RTGS systems. The system is kept together by a standardisation of telecommunications in terms of the address space that composes the payment system, accounting in terms of translation of the content of payment messages into updates to balances, and messaging content in terms of structure and semantics.

However, the issue of the border is not removed, it is only displaced: separate monies of accounts, separate rhythms, and separate accounting, addressing, and messaging standards remain when one considers cross-border payments or, put differently, that specific sub-set of cross-border payments that are multi-currency, i.e., that happen in the books of multiple central banks. The synchronisation of money across layers in one space simultaneously creates the problem of co-ordinating spaces together, just as the emergence of banking creates the need for correspondent banking. As a payment travels across currency boundaries, the lack of standardisation requires for both the sending and receiving banks to perform a lengthy list of steps to ensure that the transaction is successful. For example, they may have to repair and "enrich" the transactional data contained in the payment instruction, check the availability of FX funds, decide which settlement system is appropriate for that payment and currency, send advice and statements on the results of the payment, perform cash management, and then reconcile (Rambure & Nacamuli, 2008, p. 183). This lack of formal standards across borders will be delved in further depth in Chapter 7. Ripple inserted itself in this space to move towards a full axiomatics of monetary circulation, first through its trust lines, then through the XRP Ledger and lastly through the Interledger Protocol.

3.2. Rhizomes

Whilst money became organised in a pyramid-like fashion from the XVI century until now, sovereign currency spaces are not by any means the only way in which money has been shaped, nor is the pyramid of money an unalterable construct (Helleiner, 2003). Probably one of the first forms of institutionalised alternative currencies was the WIR, short for *Wirtschaftsring* (literally economic ring) (Stodder & Lietaer, 2016). WIR is a credit network denominated in a purely imaginary money established in 1934 and inspired by economic theorist Silvio Gesell (Evans, 2009). Another form of alternative monetary space is represented by Local Exchange Trading Systems or LETS, created by Michael Linton in 1983 (North, 2007). Yet another form of alternative currency is time banks, the oldest of which is Ithaca hours, first introduced in 1991 in Ithaca, New York (Grover, 2006). All these monetary forms share a conceptualisation of money as a credit-debt relationship (Amato

& Fantacci, 2018), denominated in a separate unit of account, to which each system adds its own particular features. For example, the WIR was a demurraging currency until the 1950s, i.e., the value of the money would decrease over time. LETS could use either a separate unit of account or peg the adopted currency to the official one. Time banks use labour time as unit of account to exchange goods and services. In the early 2000s, a small wave of alternative eco-currencies developed, with probably the most important example being the WAT in Japan: 1 kWh of electrical current generated by citizens' cooperatives through renewable energies, such as wind, water, sun (B. Lietaer, 2004, p. 12).

While all the aforementioned systems configure alternative economic spaces and perform, or at least try to perform different theories of value to produce alternative distributive outcomes, all these systems rely on a centralised ledger that records the relations of credit and debt, on one side, and a single unit of account across the whole network, on the other. In contrast *hawalas* and *hundis* are credit networks rooted in Islamic theology and law. These networks, albeit difficult to define and delimit, are not so much monetary spaces per se, but infrastructures for the *transfer* of claims in credit-debt relationships denominated in multiple units of account (Geva, 2011, p. 258). These systems are not only much older than any other alternative currency system already mentioned: they date back to the late IX century and they are thought to have contributed to the emergence of the bill of exchange of the XVI century (Geva, 2011, p. 253). *Fei ch'ien*, or flying cash, is also an example of such payment system, also dating back to IX century China (L. Yang, 1971). Unlike the alternative currency systems mentioned above, *hawalas* do not rely on a centralised accounting system: a transaction from a sender A to a receiver B flows through two mutually trusting intermediaries called *hawaladars*, with a code associated with the transaction being given to the sender, so that the receiver can check that they received the correct transaction (See Figure 29).

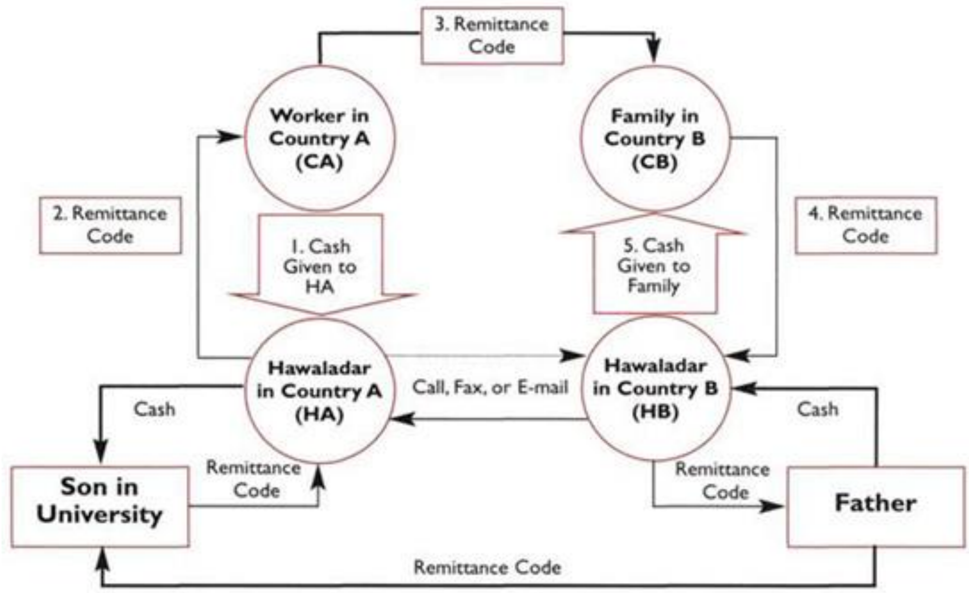

Figure 29: Hawala Transaction. Source: El Qorchi et al (2003, p. 7).

Alternative and complementary currencies are based on idea of place-bound communities, where value is produced and exchanged locally. Hence, they have, in computing parlance, both the bug and the feature of being localised and not designed for scaling up globally. Indeed, scaling and interconnecting LETS systems and time banks has been a recurring feature of the writing of heterodox economic theorists (Douthwaite, 1999; R. B. Fuller, 1981; B. A. Lietaer, 2002; B. A. Lietaer & Dunne, 2013). *Hawala*, in this respect, provides a productive infrastructure for the purpose: hawalas "were created, and continue to exist, in part to transcend the confines of a bounded territory" (Vlcek, 2010, p. 432). However, the problem of *hawalas* is the rather closed and controlled nature of the community of hawaladars.

To combine *hawalas* and alternative currencies, while offsetting the drawbacks of both, Ryan Fugger designed Ripple in 2004, and launched it in 2007. The system generalises the principle of intermediation of hawala, while combining it with the credit-based architecture of LETS systems and time banks. Each participant in the network becomes at the same time the bookkeeper, issuer, and *hawaladar* of the network. Each participant can issue money in the form of trust denominated in whichever unit of account, and she can facilitate payments by accepting claims from people she trusts. The principle of Ripple is to apply the "small world" theory behind the six degrees of separation hypothesis (Newman et al., 2006), together with an application of Internet routing to money. In short, if payer and payee do not know each other, they can employ any uninterrupted chain of mutual acquaintances to send a payment. If payer and payee use two different units of account, they can ask intermediaries to exchange a trust line denominated in a currency for another.

While the creation of money and the accounting system is fully decentralised, the *record* of the open accounts is centralised in the hands of the server that, much like an Internet Gateway or router, stores addresses and balances in traditional relational databases. Money, furthermore, is not fully programmable at will: in the specific implementation of Ripple called RipplePay, deployed in 2007 and still running to date, one can choose amongst 20 currencies. Another implementation, called Villages, only uses hours as unit of account, but it asks its participant to mentally account for these hours as an hour of decent wage in their own community. The original idea was that the system would have naturally expanded through the growing recruitment of friends and friends of friends and, from there, it would have grown to encompass entire LETS or alternative currency systems. However, this never happened, and the system remained somewhat stagnant, with isolated groups of friends sporadically using it with each other (source: informal e-mail exchanges with original Ripple users).

The original Ripple implementation represents one of the first examples of a system that takes to the extreme both a credit conceptualisation of money and a fully horizontal system of clearing and settlement. Albeit not fully developed, what is described in the few papers that Fugger wrote about Ripple describe the pure example of an "abstract machine of consistency": this machine is "singular and mutant, with multiplied connections" (Deleuze & Guattari, 1987, p. 514). This machine operates as a rhizome, in that it "ceaselessly establishes connections between semiotic chains, organisations of power, and circumstances" (Deleuze & Guattari, 1987, p. 7). In its design, it represents the most radically alternative design from the pyramid of domestic payment systems: there is no pre-determined rhythm of clearing and settlement, there is no unit of account providing a despotic signifier around which the system is organised, and there is no "liquidity provider of last resort". Conversely, the system provides, or promises, what the cross-border payment space precisely lacks: a protocological horizontal layer of standardisation of addresses, messaging standard, and conversion from one currency to another, from one unit of account to another. This is essentially rhizomatic: any point of the rhizome can be connected with any other point, and the rhizome always has multiple entry ways (Deleuze & Guattari, 1987, pp. 7 and 12; Vlcek, 2010, p. 434). A rhizome is an abstract machine of consistency because it does not produce, or it is not predicated upon homogeneity, but rather it holds together disparate elements.

However, the abstract machine cannot be dissociated from the materiality of the form that it assumes, and whilst a theoretical architecture may make some things *possible*, a specific empirical application makes some of the *possible* things *feasible* (Dourish, 2017). In specific, while the idea of close interconnection between monetary networks resonates with the theory often called "small world hypothesis" or "six degrees of separation" theory (Gurevitch, 1961), this theory is controversial in its application (Kleinfeld, 2002). While most of the pathways connecting one person to another person, *when present*, might be six steps in length or less, it is not necessarily true that any person is connected with any other person. While the abstract architecture of Ripple allowed, potentially, to set a connection between any two parties, there was neither an incentive nor an internal drive towards the inclusion of new people in the Ripple network.

3.3. Platforms

Pyramids are abstract machines produced by the layering of accounting books on top of each other forming a hierarchy that works by synchronising clearing and settlement. Rhizomes are fractal formation composed by the proliferation of bilateral accounting relationships, with no centralised synchronisation or time-keeping, with trust as their only territorialising property. Blockchains, conversely, are here used as exemplifying the third abstract machine, i.e., the platform. While, as argued in the Introduction and in Chapter 1, it is impossible to fully do justice to the wealth of scholarship on platforms (Çalışkan, 2021a, 2021b), this dissertation mainly focuses on the political economy literature that foregrounded platforms as specific and recent forms of intermediaries and capitalisation devices. Langley and Leyshon define platform intermediation as "distinctive because it attempts to make the 'connections' of multi-sited markets and to coordinate the network effects of 'connectivity'" (Langley & Leyshon, 2016, p. 13). This sub-section delves into the internal dynamics, dispositions, and contradiction of payment platforms, through the examples of Bitcoin and Ripple or, better, the XRP Ledger. The first is illustrative of the limits that blockchain technologies encounter in terms of scalability, while the latter is especially informative of the limits and contradictions encountered when using *one* specific blockchain platform to interoperate *across* blockchain platforms.

Blockchain technologies try to create a uniform book for all participants in the network: a blockchain "produces a present image of sediment, of past performances, past acts, transfigured into lasting blocks of code" (Viana, 2018). Each blockchain is a complete microcosm that simultaneously creates and manages a multi-sided market where each node can transact with each other. Blockchains are "a bookkeeper's dream" in that they afford "the ability to inspect all transactions and be sure that none have been altered" (DuPont, 2018a, p. 123) through their complete records of all present and past states of the network. Blockchain technologies are almost ideal-typical platforms because, as Viana (2018) discusses, they combine the intermediation of connection (list of coins) with the management of connectivity (map of network). As we shall see in the next chapter, this is one of the reasons that triggered enchantments with the "utility coin" as a tool for, simultaneously, investing in and monetising upon blockchain platforms.

Blockchain technologies are also platforms because, in the context of payment systems topologies listed in this chapter, they aim to *flatten* the hierarchy of monies and their rhythms onto one layer where all calculation take place. This, in turn, also has repercussions on the institutional hierarchy of monies: the hierarchical difference between central banks, banks, and non-bank financial institutions is flattened – at least on paper – and the distributed ledger becomes the only ledger that matters for all participants. This quote from an interview with a former software engineer at Ripple explains this principle quite clearly:

> Now if you're a lower level business like a remittance company, you have a bank account. You keep your money in a bank, and you are a lower tier organisation. If [an MTO] tried to help move money for banks and said, 'Oh good, you deposit money here,' banks would go 'No, no, no. That's the wrong way around. You're below us.' In the financial ecosystem, if you are a bank and you want to use XRP to send money, you need to buy it from someone, and where do you buy it from? You can't go 'Oh bank, we want you to deposit a bunch of Euros into [a cryptocurrency exchange],' that's upside down for them. But for a payment service provider like a remittance company, that's fine: they have lots of bank accounts with people. If you say, 'We'll open a bank account at [this exchange]' They'd go 'Awesome, I've got to keep my money somewhere, might as well use XRP.' (Interview, 15th May 2018)

However, blockchain platforms manifest a tension between monopoly and rent-extraction and proliferation and competition between ostensibly decentralising and disintermediating technologies (Pesch & Ishmaev, 2019; Schneider, 2019). While blockchains decentralise the process of achieving consensus within the network, each blockchain produces an independent state that cannot be altered from outside that network. The "consensus network", i.e., the set of machines running the correct software to validate transactions and update the blockchain itself, represents the ultimate boundary around any blockchain, as shown in Chapter 3, section 4.2. The limit of the world for a blockchain is the limit of what is stored in it, of the digital objects whose identities are recorded in it.

Blockchain technologies have, in addition to boundaries, *limits*. Roughly, while boundaries delimit possible and impossible things – such as Bitcoin's blockchain communicating with the outside world – limits demarcate feasible and unfeasible things, such as costs that make otherwise possible things unbearably expensive. These are not lines demarcating inside and outside, but rather degrees of internal friction and thresholds of external expansion. Both internal limits and external boundaries can be illustrated by the example of Bitcoin and Ripple. In the case of Bitcoin, these frictions produced the so-called scaling conflict: i.e., the technical and political decisions over Bitcoin's design that are required for Bitcoin to expand in reach and size. Brekke captured not only the political, but the topological stakes of these debate with great clarity when she says:

> The scaling conflict is not only about increasing block sizes on the blockchain, it is also about Bitcoin having reached such a scale that it can no longer be thought of as composed by peers. […] Unless this is worked out, and until then, this project of 'disintermediation' for those who are not peers is actually a project of reintermediation – simply swapping one set of intermediaries (the banks, politicians, and legal system) for another (developers, computer scientists and network technology), or, even worse, adding another layer of intermediation and complexity. (Brekke, 2018, pp. 60-61)

One particularly contentious area was the debate around the "block size". The maximum amount of data that can be contained in a block over the blockchain has been limited to 1MB. Increasing that size would enable faster payment processing: more available data means more transactions per block. However, that change would also increase the speed of expansion of the blockchain, with resulting increase in the costs, both in terms of hash power and in terms of memory capacity, to run a full node or a miner (Wirdum, 2016). On the 1st of August 2017, Bitcoin adopted a protocol update called Segregated Witness (SegWit for short), which de facto expands the block size to 2-4 MB (Wirdum, 2017). People who were not in favour of the content and mode of implementation of this protocol update forked Bitcoin and created Bitcoin Cash (Vigna, 2017).

Ripple, comparatively, had fewer problems in amending its code: validators oversee amendments, and they are largely run by Ripple Inc. or its clients. With this more agile design, Ripple wanted to provide a layer through which different payment systems could interoperate. However, this design did not prevent the XRP Ledger from incurring into its own scalability problems. Different payment systems would plug into the Ripple ledger through Gateways, which would issue money in trust lines in exchange for deposits in the specific currency. Gateways, however, required specific designs for them not to be attackable by hackers, on one side, and compliant with regulators, on the other. Hence the best practices proposed by Ripple Inc. to the users of the XRP Ledger started to represented Gateways as clustered addresses, as illustrated in Figure 30, so that the one that issued the money was isolated from the network if not for redeeming, and the one connected to the network (the Operational Address) could not issue funds but merely transfer those that the Standby Address devolved to it through a human-actioned transaction. This was, however, rather complex, and the gateway system ceased quite soon because of external regulatory pressures and the lack of financial viability[11].

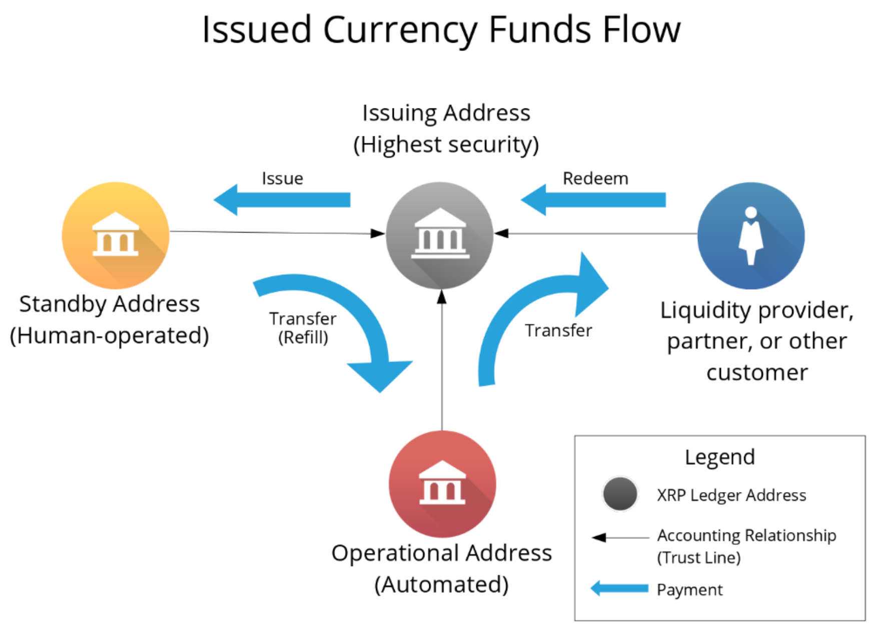

Figure 30: Clustered addresses in a Ripple Gateway. Source: XRP Developers Portal (n.d.).

Furthermore, specific Gateways required additional features that further caused an increase in complexity in the XRP Ledger's design. For example, Gold Bullion International (GBI) was the first Gateway to issue gold on the XRP Ledger. Gold custodians, however, charge custody fees. The XRP Ledger did not have, at that time, any features for fees. Ripple's software engineers, then, implemented demurrage, or negative interest rate on

[11] A Ripple employee said that, around 2015, Ripple realized that many Gateways were viable only because of funding and XRP provided by Ripple itself.

deposits (XRP Ledger Developers Portal, n.d.). However, some of the developers grew dissatisfied with the situation, with one employee describing the situation as "trying to fit a round peg into a square hole" (Interview 19th April 2019).

A more internally complex XRP Ledger also increases what that same informant defined as "attack surface", which would become "too broad" if more and more use cases were added to the same Ledger (interview 8th November 2019). Hence, in the end, that informant drew the conclusion that single-use-case Ledger, in some situations – gold, for example – are more viable that catch-all ledgers. Interoperability, then, was not a feature of individual ledgers. This conclusion was summed up by the paradox "the world will never agree on one Ledger, but XRP is a Ledger!". This image was complemented with a meme that then became a staple of Ripple presentations on interoperability (See Figure 31). As we saw in Chapter 3, section 4.3., interoperability is a limit inherent and intrinsic to the "wiring" of blockchain technologies (Easterling, 2014, p. 80), and very few of them are wired to interoperate.

Figure 31: Meme expressing the paradox of interoperability. Source: internal presentation made available by an informant. The XRP Ledger is here called RCL, or Ripple Consensus Ledger, which was the name adopted until 2015. Source: Interledger (2016, p. 13)

Platforms are practical enactments of abstract machines of stratification: as Deleuze and Guattari (1987, p. 40) have it, the abstract machines of stratification "surround the plane of consistency with another plane". The process of stratification proceeds in pairs: "A surface of stratification is a more compact plane of consistency lying between two layers. The layers are the strata. They come at least in pairs, one serving as substratum for the other." (Deleuze & Guattari, 1987, p. 40). This produces a "perpetual and violent combat between the plane of consistency […] cutting across and dismantling all of the strata, and the surfaces of stratification that block it or make it recoil" (Deleuze & Guattari, 1987, p. 159).

Hence, blockchain technologies try to collapse the computational stack onto a chain – i.e., creating a uniform register of all credit and debts, without the need for correspondent accounts. All blockchains platforms, however, are caught in a contradictory tension between creating a new layer on top of existing spaces, and ostensibly smooth space that blankets over the striated monetary spaces. Blockchain platform are caught into the double bind of either breaking up in different blockchains based on different users, or see their internal complexity grow to the point in which their horizontality, and their peculiar type of infrastructural intermediation, is jeopardised. In response to this process of horizontal proliferation and vertical complexification more and more applications are developing as additional layers on top of the layer represented by individual blockchains, to allow for cross-chain and off-chain transactions. The next, and last subsection will expand on Deleuze and Guattari's concept of axiomatics and it expands it into a fourth abstract machine that informs the interoperability stack of the Interledger Protocol.

3.4. Stacks

We have seen how sovereign monetary spaces came to assume the shape of pyramids. We then saw *hawalas* and other mutual credit networks as abstract machines of consistency that ceaselessly produce new connections. We saw blockchains platforms as examples of abstract machines of stratification, that are always caught between trying to encompass the whole plane of consistency of money, and the tendency to either lose their unity by proliferating competing platforms, or to increase internal complexity to the point of unworkability and rupture. Lastly, this sub-section investigates the development of the Stack as the abstract machine behind interoperability technologies, and the Interledger Protocol vis-à-vis other "Layer 2" and "Layer 3" technologies within the blockchain and cryptoasset industry (M. J. Casey, 2018).

As outlined in the previous sub-section, the internal tensions within platforms between scalability, monopoly tendencies, and lack of interoperability engendered the emergence of interoperability technologies. These solutions, over time, have been acquiring a distinct layered topology that more and more closely resembles the Internet Protocol stack. The earliest solution to scalability has been payment channels such as Lightning on the Bitcoin blockchain (Lightning Network, n.d.) and Plasma and Raiden on the Ethereum blockchain

(Poon & Buterin, 2017; Raiden, n.d.). Payment channels are balances between addresses on a blockchain that allow for payments to travel "off-chain" and to be settled "on-chain" at intervals and at a net basis. Two parties to a channel need to send to the blockchain only two transactions: one with which the channel is open, with each of the two contributing to its balance, and one with which the channel is closed and the open positions are settled. Hence, payment channels break the internal uniformity between messaging, clearing, and settlement within a blockchain by creating a clearing layer on top of the settlement layer that is the blockchain itself (M. J. Casey, 2018).

Payment channels solve scalability, but they do not afford interoperability. In fact, Plasma creates payment channels on Ethereum, and Lightning does so on Bitcoin, but one cannot create a multi-currency payment channel that crosses the boundary between blockchains with payment channels alone. Solutions like Polkadot and Cosmos promise to tackle the problem of interoperability by including interoperability in the "wiring" of their blockchain infrastructure. Polkadot creates "meta-blockchains" where other chains plug in if they want to provide cross-chain interoperability (Polkadot Wiki, n.d.). Cosmos provides a design template for new blockchains that allow interoperability by default (Cosmos, n.d.). Both Polkadot and Cosmos preserve stratification as interoperability principle: given two strata – i.e., two blockchain platforms – they provide a third stratum on which transactions happening in either stratum is visible by the other. In other terms, Polkadot and Cosmos want to be meta-blockchains that incorporate compatible blockchains to facilitate cross-chain transfers.

The Interledger Protocol, conversely, moved away from providing one unified "interoperability layer" to providing a layered and modular approach to interoperability itself, one that is borrowed from the Internet Protocol stack. Originally designed in 2014 by Ripple's research team, especially by Stefan Thomas and Evan Schwartz, the Interledger Protocol version 1, or ILPv1, was conceived as a Payment-versus-Payment protocol not unlike the CLS system outlined in the first sub-section (S. Thomas & Schwartz, 2015). Payments happen via synchronised bidirectional exchange of one asset – either fiat or crypto currency – for another through encrypted connections called hashed-timelock agreements (HTLA). Payments in ILPv1 were "atomic", i.e., they were either executed completely or not at all, without the present need for human intervention to reconcile lost payments. This allowed for Straight-Through-Processing (STP) – i.e., total automation of payments – and, in turn, promised the acceleration of settlement speed in cross-border payments. In particular, atomicity was especially suitable for retail interbank payments, i.e., payment big enough to represent a sustainable use case for banks, but yet too small to be managed in real-time by liquidity saving technologies like CLS or other cross-border settlement systems – see Chapter 7 on CLS. Figure 32 outlines the functioning of the original ILPv1 design.

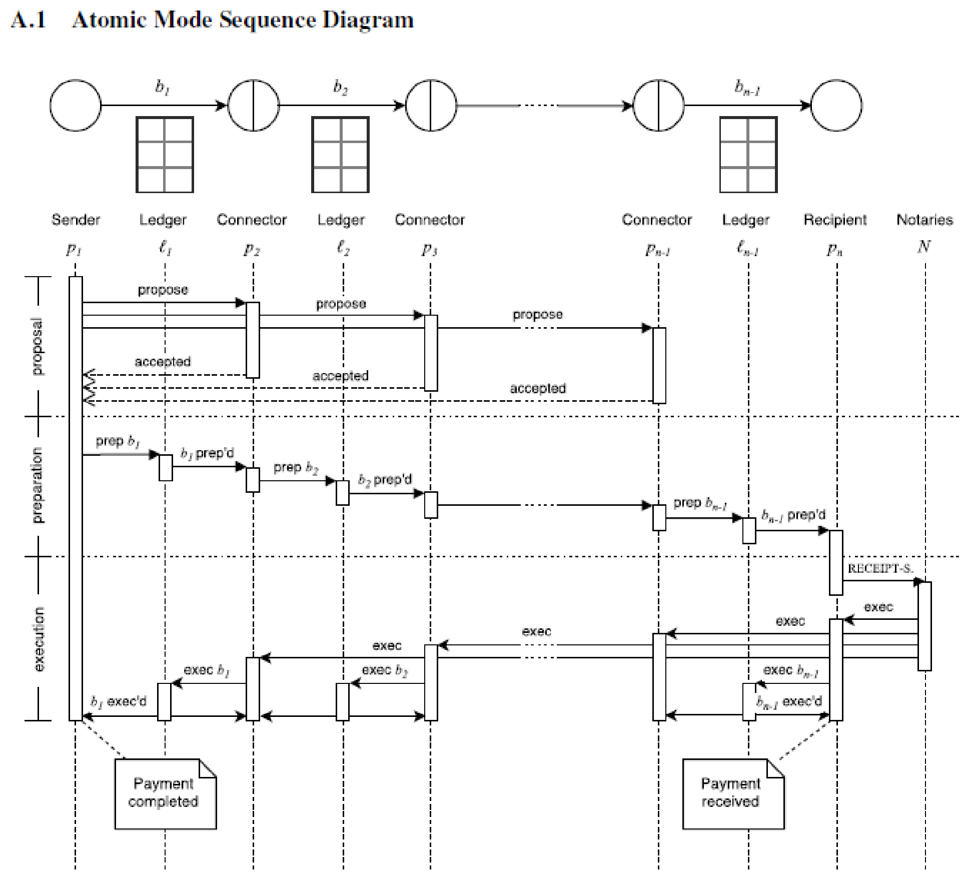

Figure 32: ILPv1 Atomic Mode. Source: Thomas and Schwartz (2015, p. 10).

Over time, ILP moved from payment-versus-payment atomicity to layered modularity and packed switching, in a process called by the community as "Interledger Enlightenment", which reached a tipping point on the ILP conference call on the 29th of November 2017 (Interledger, 2018a). This "Enlightenment" consists in a progressively literal adoption and translation of Internet Protocol language and design into ILP, starting from modularity. Modularity is "a strategy for designing the architecture of an artifact, in particular, the relationship of its function to its structure [...] that realises a one-to-one mapping between functional requirements and components, as well as decoupled interfaces between those components" (Blanchette, 2011, p. 1044). Layering, in turn, is "a specific flavour of modularity where modules are organised in a series of client-server relationships: each layer is a server to the layer above, and a client to the layer below" (Blanchette, 2011, p. 1044). In networking computers that can vary in hardware, software, and obsolescence, the guideline is to keep the internetworking and interoperability layer as simple as possible, and as much separate from the idiosyncratic components of the physical layer as possible.

The Interledger Enlightenment caused a shift in discourse and design from using the Internet as an analogy – ILP is *like* Internet Protocol for money – to metaphor and translation referent – ILP *is* the Internet Protocol for value (E. Schwartz, 2019). Partially ironically, the first version of ILP that adopted layering and packet switching was named ILPv4, i.e., the fourth iteration of the ILP concept, in a nod to IPv4, which is the most currently used version of the Internet Protocol suite (DeNardis, 2009). The layered topology that ILP adopted is taken directly from the "fifth networking truth" outlined by the designers of the Internet Protocol in the semi-ironic RFC 1925: "It is always possible to agglutinate multiple separate problems into a single complex interdependent solution. In most cases this is a bad idea" (R. Callon, 1996).

This principle was enshrined in a 2018 blog post that outlined how Interledger differed from other interoperability solutions like Polkadot, Cosmos, and even the XRP Ledger that many ILP developer worked and still work on (E. Schwartz, 2018). All these interoperability solutions, in remaining abstract machines of stratification, represent "single complex interdependent solution(s)" that agglutinates multiple separate problems. ILP, conversely maintained a strict separation between layers, and it rather proposed to be an interoperability technology that works by rearranging the relationships existing *across* layers.

ILP, then, adopts the same 5 layers of the IP protocol stack, and it applies them to money, as illustrated in Figure 33. Layer 1, the "physical layer of money", is where ledgers are: they record balances and they operate with the architecture and rhythms that they independently adopt. Let us remember, as stated in Chapter 1, that the "physical layer" of money is not the final anchor of money's materiality, but rather the asset that settles credits and debts when it is moved, and the level of abstraction where obligation are officially and permanently discharged.

Ledgers can be pyramids, rhizomes, and platforms, and the Interledger does not question their architecture, as long as the connectors between these ledgers, like gateways over the Internet, are properly configured to interoperate. Layer 2, built atop ledgers, is made of payment systems that establish "bilateral links or Local Area Networks (LANs) that allow directly connected parties or devices to communicate efficiently over the underlying network" (E. Schwartz, 2018). Layer 3 is where interoperability happens. Layer 4 would correspond to the Internet's Transport layer, corresponding to TCP, and Layer 5 to the Application layer, which corresponds to Web protocols such as HTTP.

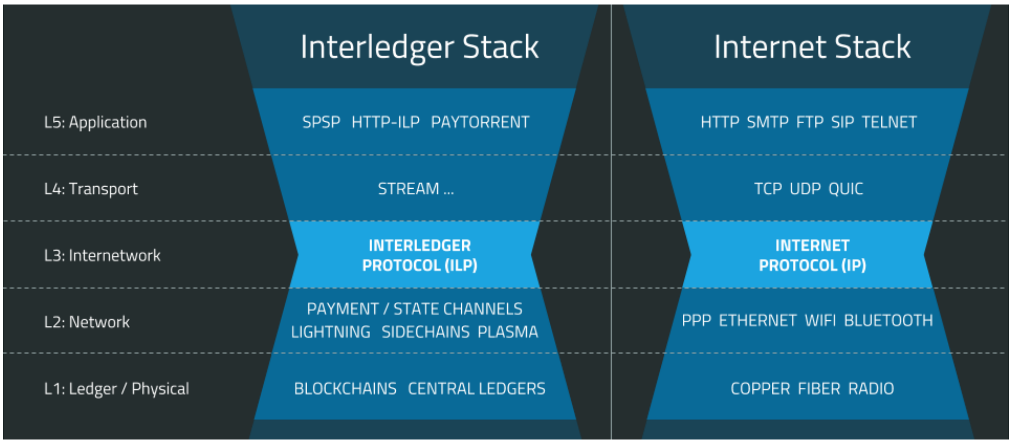

Figure 33: Comparison between the TCP-IP stack and the ILP stack. Source: (E. Schwartz, 2018).

The self-professed purpose of Layer 3, which ILP inhabits, is "to abstract away the differences between different Layer 1 and 2 technologies to connect vastly different types of networks" (E. Schwartz, 2018). This aim to "abstract away" is key to the internal functioning of the Stack as an abstract machine. ILP does not incorporate the internal complexity of the layers it wants to co-ordinate, but it rather sets a minimum set of requirements to allow for these layers to communicate with each other. This, in turn, requires parsimonious coding that sacrifices features for efficiency. ILP coders often quoted the 12th Networking Truth enshrined in IP RFC 1925: "In protocol design, perfection has been reached not when there is nothing left to add, but when there is nothing left to take away" (R. Callon, 1996).

The other borrowing from the IP protocol suite consisted in packet switching. TCP-IP packets have a standardised size called Maximum Transmission Unit, which varies between a minimum of 68 bytes to a maximum of 64 KB (Information Sciences Institute, 1981, pp. 12 and 24). TCP-IP packets also encapsulate information to make it readable across layers of the stack. By reading a packet's headers, machines can understand which protocol, hence which layer of the stack, that packet refers to (see Figure 34 below). Information can be fragmented at the origin into several packets and recomposed at the destination, based on the packet headers (Dourish, 2017).

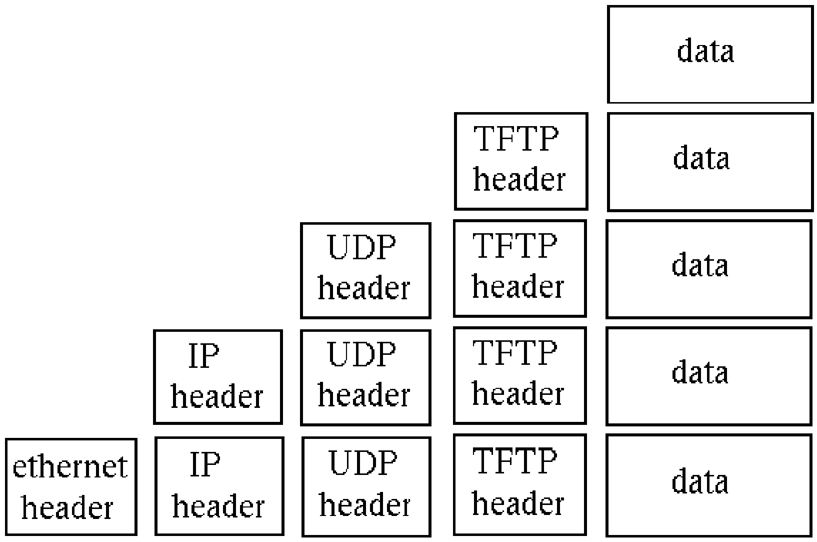

Figure 34: Data encapsulation across protocol layers. Source: Newmarch (n.d., p. 12).

Applied to payments, penny switching meant that larger payments are divided into smaller ones and sent from sender to receiver through routing tables that are kept by each connector. Based on the receiver's address, each connector can look up their routing table and see if they have a path to that address or if they have to forward the packet. The packet, furthermore, has to be as small as possible to avoid the risk of the payment being interrupted because the connectors lack "bandwidth", i.e., liquidity, to fund the payment itself.

But what could a Maximum Transmission Unit be for money when it travels from a currency to another? In other words, "When money is denominated in multiple monies of account, we have to ask what is the process, internal to moneyness, which reconciles these multiple monies of account?" (Bryan & Rafferty, 2007, p. 145). One solution originally proposed was that ILP connectors would have maintained two tables: one routing table, through which they would have figured out how to forward a packet to its destination, and liquidity curves through which one would have dynamically adjusted the maximum size of the payments it could fund by calculating exchange rate between its own accounts and the ones held by other connectors (Interledger, 2017). ILPv4 embraced so-called micropayments or streamed payments, i.e., the idea that payments had to be broken up into as small as possible. "As small as possible" is here calculated path-by-path: before starting a streaming of money, a connector sends a message similar to a "ping" in Internet parlance, and it obtains an overview of the exchange rates it encountered through the way. Based on that, it is possible to calculate how big a payment can be without it being refused at some point of the path.

In so doing, the packet works as an active technology in the same way the container does "work" in logistics: by standardising the size of the bulk being shipped, the container makes new ways of seeing, moving, and valuing things possible (Nicky Gregson et al., 2017; Klose, 2009; Levinson, 2008). The striking of the balance between this rhythm and the speed of circulation comes through the standardisation of liquidity as bandwidth: the packet size, more than the vertex of any pyramid, is the trophic point where the conversion of value happens. The Stack is the generalisation and materialisation principle of what Deleuze and Guattari call axiomatics, the universalisation of the becoming-logistics of money and payments. Interoperability deploys technologies of axiomatics, whereby

> capitalism forms with *a general axiomatic of decoded flows.* […] the worldwide axiomatic, instead of resulting from heterogeneous social formations and their relations, for the most part distributes these formations, determines their relations, while organizing an international division of labour. […] Thus, the States, in capitalism, are not canceled out but change form and take on a new meaning: models of realization for a worldwide axiomatic that exceeds them. But to exceed is not at all the same thing as doing without. (Deleuze & Guattari, 1987, pp. 453-454)

Technologies of axiomatics are primarily concerned with capital's "endless and limitless drive to go beyond its limiting barrier. Every boundary [*Grenze*] is and has to be a barrier [*Schranke*] for it. […] The barrier appears as an accident which has to be conquered" (Marx, 1993, pp. 334-335). The need for faster and faster circulation is predicated upon an inherent tendency to capitalism to cast any form of barrier, whether "natural" or "political", as friction, as a net inefficiency to be eliminated, as an interference in communication. In Deleuze and Guattari's words:

> the modern immanent machine […] consists in decoding the flows on the full body of capital-money: it has realized the immanence, it has rendered concrete the abstract as such and has naturalized the artificial, replacing the territorial codes and the despotic overcoding with an axiomatic of decoded flows, and a regulation of these flows (Deleuze & Guattari, 1983, p. 261).

It is not a coincidence, then, that other interoperability technologies tend to assume the protocological stack as their internal structure. For example, going full circle in this analysis of payment topologies, SWIFT introduced ISO 20022 in 2004 as a standard for payment messaging interoperability (ISO 20022, n.d.). ISO 20022 is also based on a layered modular approach to interoperability (S. V. Scott & Zachariadis, 2013, p. 73; SWIFT, 2010, p. 11). The business model layer defines roles and actors involved in the activity associated with the message exchanged. The middle layer is message models, which are composed of message components, in turn representing the pieces of information that are necessary to perform a specific business activity. The third layer is syntax: different standards might use different forms of syntax, i.e., different dictionaries of terms with which the same things are identified. ISO 20022 standardizes payments by defining possible message components through a syntax-agnostic dictionary and by standardizing the possible business models involved with business activities carried out through ISO20022-compatible messages. Syntaxes are left to independent standards that can map and be mapped onto ISO20022 and, through it, onto other standards. Figure 35 shows the mapping of one standard onto the other within the ISO20022 specifications.

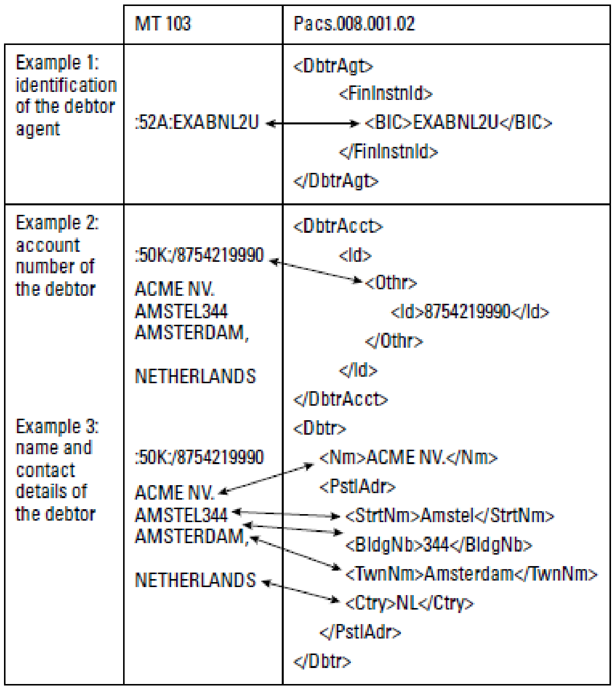

Figure 35: Mapping an MT103 to an ISO 20022 Credit Transfer. Source: SWIFT (2010, p. 29).

The platform-agnostic interoperability of the Internet Protocol and similar technologies, however, is a metaphor that obscures as much as it illuminates (Lakoff & Johnson, 2003), in that interoperability itself is far from a neutral pursuit (Guyer, 2016; Milkau & Bott, 2015; Wilmott, 2016). Indeed, as Dourish (2017) has shown, the Internet's topology and architecture is far from decentralized, and its specific topologies derive from precise design choices at each layer's level, and in the coordination across layers. The architecture of the Internet is deeply stratified not only conceptually but materially and politically, with Tier-1, -2, and -3 companies managing, respectively, continental, national, and local networks, broadly speaking. As another ironic proof of the travelling of concepts between computation and money, Tier-1 companies that manage the largest networks enter with each other into arrangements that are called “settlement-free”: any Tier-1 internet service provider can send their traffic over the network of another Tier-1 internet service provider without payment for such service (Van Der Berg, 2008). The very architecture across layers obscures aspects of the topology of the Internet that are somewhat connected with the specific way of intending this layering. The interaction between such networks are intermediated by a multinational organisation called the Packet Clearing House (PCH, n.d.).

4. Conclusions

The pyramid is the hierarchical alignment of money forms and synchronisation of settlement rhythms around a centre of truth, trust, and power. The rhizome is the lateral relation of trust between parties mutually acknowledging each other as legitimate, bridging across spaces in the absence of universal referent or central source of truth. The platform is a form of infrastructural intermediation that bridges multilateral interactions by co-ordinating truth, trust, and rhythm across potentially non-trusting counterparties. In so doing, while it bridges between decentralised networks, the platform has in itself monopolising and rentiers tendencies. The stack is the form of intermediation that ostensibly strips down money of any additional feature other than its function: being the exchange tool by definition and *par excellence* (Simmel, 1900/2011). It allows to bridge across designs without having to know and acknowledge such design: it works by interoperating *across* layers rather than by the establishment of a layer. The Stack is a pyramid with no vertex, and with one vertex for each node of the network that the Stack connects.

The stack, hence, is not a megastructure encompassing the globe through bigger and bigger platforms (Bratton, 2016), or rather it is not only that. The stack is also a microstructure of interoperability that casts any form of border like a friction and an inefficiency (Pesch & Ishmaev, 2019). This is not to say that the stack is only active at the microlevel: rather, its macro importance derives from its micro activity. The stack is rather an “infrastructural fractal” (Jensen, 2007), i.e., a technology capable of producing macro-effects through the repetition of micro-structures, and which contains no prioritised scale between micro and macro, between local and global.

As we shall see in the next Chapter, interoperability may become a source of fascination, enchantment, and desire, because interoperability is the paradoxical condition of possibility for the monetisation and assetisation of just about anything that blockchain technologies embody. Indeed, stacks and platforms are predicated upon each other: a stack is made necessary by the need for interoperability deriving from platform proliferation, but simultaneously platforms need and interoperability infrastructure for their business model to expand to reach financial viability, as the relationship between the ostensibly horizontal nature of the IP protocol and the monopolistic tendencies of digital platforms have already shown (Bratton, 2016; Langley & Leyshon, 2016; Srnicek, 2017a). However, interoperability is also a paradox, for it requires the smoothening of differences between blockchains that are the very condition of possibility for their capability of intermediating networks: platforms do not abide competition.

A proliferation of multiple platforms in the same market can easily reduce the profits of any one of them down to almost zero: this is what Pesch and Ishamev (2019) call the "fiction of frictionlessness", i.e., the paradoxical discourse that unites promises for profits together with elimination of transaction costs – including lucrative fees – and with fostering competition. Furthermore, as Tasca and Piselli (2019) remind us, blockchain technologies are not *just* payment and monetisation platforms: they are political constructs with specific design features, governance structures, and distributive outcomes. Interoperability as a technical imperative embodies a far from neutral political project that is predicated on the removal or the evening of these design features.

Chapter 6: The Enchantment Bubbles of Money Infrastructures

1. Introduction

On the 28th of September 2016, during the early stage of the explosion in interest in blockchain technologies, Andrew Hauser, Executive Director for Banking, Payments and Financial Resilience at the Bank of England, took to the stage at the SWIFT International Banking Operations Seminar (SIBOS) conference in Geneva, Switzerland. His speech, on a panel titled “Towards a single platform for all payments”, drew a comparison between payment systems and railways:

> People wanting to travel north out of London by trains are spoiled for choice. Spread along a half-mile stretch of the city’s Euston Road are no less than three major stations: Euston, King’s Cross, and St Pancras. [...] The reasons for such an apparently complex system are of course historic, dating back to the period of intense competition between train lines in Victorian Times. Euston was built in 1837 for the London and Birmingham Railway, King’s Cross in 1852 for the Great Northern Railway, and St Pancras in 1868 for the Midland Railway. Given a free hand, it is inconceivable that anyone would design such arrangements from scratch today. Yet tens of millions of passengers use each station every year: business is booming.
>
> The situation in UK payments today is rather similar. Customers wishing to make a domestic retail payment can choose between physical cash (drawn from their bank, or via the LINK system of ATMs), a paper cheque, a credit or debit card via the Visa or Mastercard systems, a real-time payment over FPS[12] or a batch payment across BACS. Wholesale payments may be made through the CHAPS high-value scheme, operated on the Bank of England’s Real-Time Gross Settlement System (RTGS) or through the embedded payment schemes CREST or LCH. Those making cross-border payments may use their correspondent bank, a direct link to an overseas RTGS system, or CLS the foreign exchange settlement service. Taken together, one can easily list 10 or 15 payments pathways without even trying. (Hauser, 2016)

This speech lays bare the relationship between materiality and imagination, between technology and enchantment, and hence between money, infrastructures, and speculation that this chapter foregrounds. The comparison between railways and payments is by no means new: in fact, it is one of the most common tropes of FinTech jargon (Rea et al., 2017). Yet, Hauser’s speech does not only define payments *as* rails metaphorically (Maurer,

[12] Faster Payments System, the retail real-time payment infrastructure active in the UK.

2012a), but it compares the practical and historical development of payment rails with that of train rails in Victorian times. Furthermore, he foregrounds rails – both literal and metaphorical payment rails – as at once material construct and as the product of intense flows of speculative investments. Infrastructure's promises (Nikhil Anand et al., 2018) and enchantments (Harvey & Knox, 2012) have as strong an effect on the performance and affordances of a technology as its wiring and plumbing. It is here worth repeating Brian Larkin's quote for what Çalışkan (2021a, p. 129) calls the intangible materialities of infrastructures:

> infrastructures also exist as forms separate from their purely technical functioning, and they need to be analysed as concrete semiotic and aesthetic vehicles [...]. They emerge out of and store within them forms of desire and fantasy and can take on fetish-like aspects that sometimes can be wholly autonomous from their technical function. (Larkin, 2013, p. 329)

This is all the truer when the infrastructure under consideration is money itself, as shown by the literature on money cultures and special-purpose monies (Dodd, 2014; Zelizer, 2011), on one side, and performativity, valuation, and capitalisation studies (M. Callon et al., 2007; D. MacKenzie, 2006, 2009; Muniesa, 2011; Muniesa et al., 2017), on the other. Beliefs, economic theories, and multiple tangible and intangible market devices help to assemble the things they supposedly merely describe and summon the processes they are supposed to explain.

This chapter, with its focus on the enchantments and ostensibly irrational investments traversing infrastructural speculation, broadly contributes to a "libidinal" understanding of political economy (Lyotard, 1993) as "a theory of the economy as a surface expression of an economy of desire, and the central concepts of capitalism as an expression of libidinal energies – or a specific organisation of flows of desire" (Gammon & Palan, 2006, p. 102). However, this chapter does not trace economic behaviours back to a psychoanalysis of the subject's repression of narcissistic impulses through market behaviours (Gammon & Wigan, 2013). Rather, it unpacks the ways in which desire is channelled through economic investments and materialised in specific infrastructural configuration and, conversely, how specific materialities can harbour and foster specific desires.

This chapter analyses the expertise (legal, financial, technological), devices (white papers, demonstrations, gadgetry), and affective and atmospheric components (logos, participants, stage design, aesthetics) used in assembling the cryptocurrency expo as a "tournament of value" (Appadurai, 1986; Moeran & Pedersen, 2011b) and a site where multiple processes of valuation happen[13]. Conference venues are here shown as the material and place-based coming together of those rules, instruments, and discourses, hence the conference is here depicted as the *loci* where the integrative practice of marketisation is actualised.

To develop such analysis, this chapter will deploy a hermeneutic strategy of comparison between the cryptoasset bubble and three past speculative manias, i.e., the 1630s Tulip Mania, the 1840s Railway Mania, and the 1990s Dot Com Bubble. This comparison uses these past examples of financial frenzy as specific configurations of materiality, imaginaries, and investment strategy. The Tulip Mania was centred on the uniqueness and individuality of the asset in question, underpinning an enchantment largely based on collection and hoarding of aesthetically pleasant objects. The Dot Com bubble represents the precursor of present-day proliferation of software platforms, and it is based on the promised capacity of software to rearticulate and monetise the relationship between a platform and its ecosystem. The Railway Mania stands for a speculative investment in technology of connectivity and logistics animated by promises to standardise time and space and organise communications and flows in an ostensibly smooth and neutral way.

The remainder of the chapter is organised as follows. The next section draws on literatures on cultures, imaginaries, and desires in speculation and investing to frame that of cryptoassets as a speculative bubble – the Crypto Bubble. Each of the three subsequent sections begins with a summary one of the past bubbles and manias in order to draw together synthetic elements about the relationships between materiality of the asset, the enchantments and desires it triggers, and the investment strategies adopted. After these summaries, in each sub-section I draw examples from my fieldwork to illustrate the specific and more-or-less discrete materiality-enchantment-investment configurations of money as infrastructure. The concluding section will summarise the argument of the chapter.

2. A Cryptoasset Bubble?

The task of this section is to ask what it means to understand blockchain technologies and cryptocurrencies as a bubble, and to ask what makes a bubble, both through reviewing extant literature on bubble and manias, and through examples from my fieldwork. Shiller (2015) conceptualises a bubble as made of largely exogenous "precipitating" factors and

[13] See also Chapter 2.

largely internal feedback loops as producing an irrational and overly-exuberant flows of investment. The precipitating factors are technological, political, and cultural, such as changes in regulation, the emergence of a new technology, changes in monetary policy, and changes in the magnitude and content of mass media coverage of investment and speculation (Cf. Chancellor, 2000, p. 126).

The analyses of the internal financial dynamics of a bubble are insightful for unpacking the relationship between price inflation, indebtedness, and subsequent implosion. However, one must look at non-financial determinants – what Shiller (2015) calls the cultural and psychological determinants – to understand why an asset or a technology comes to attract and retain so much attention. Thrift (2001, p. 414) eloquently explains that the "romance" side is an affective state that is all too often covertly associated with the financial side of business "as a material-rhetorical flourish intended to produce continuous asset price inflation [...] the passion play [...] was framed by another calculative agency with its associated metrics, which acted to both produce and discipline it" (Thrift, 2001, p. 414). Romance fits on economic interpretations of speculation such as Galbraith's, for whom "speculation [...] comes when popular imagination settles on something seemingly new in the field of commerce or finance" (Galbraith, 1993, p. 26).

The making of speculative markets entails a process of "contamination of the economic" (Stäheli, 2013, p. 239) where economic determinants and affective and cultural forces are mutually at play in producing speculation as a spectacle:

> On the stage of the stock exchange, it was possible to observe the simultaneous existence and disintegration of rational economic subjectivity. A process of abstraction was required to fashion the speculator into *homo oeconomicus.* At the same time, this process released a host of affects and intensities that brought about the destruction of an idealised economic subjectivity. The spectacle of speculation was thus to be located in the conflict between ideal economic subjectivity and the intense affective displays on the trading floor (Stäheli, 2013, pp. 71-72)

Hence, in this section it is necessary to untangle the exogenous and endogenous, economic, and affective determinants of the Crypto Bubble.

2.1. Debt

Among the economic determinants, debt and indebtedness is a crucial indicator of a bubble. Kindleberger and Amber (2005), in fact, put forward a Minskyian definition of a bubble in two stages. In the first stage, investment is sought for the income it brings under the form of interest, and, in the second stage, the asset itself is bought for the promise it holds to increase its price at the moment it will be resold. As Bagehot has it, “The first taste is for high interest, but that taste soon becomes secondary. There is a second appetite for large gains to be made by selling the principal” (Bagehot, 1999, pp. 131-132; in Kindleberger & Aliber, 2005, p. 44). The appreciation of assets and the promise of returns, in turn, produce an expansion of credit by lenders who are confident that debts will be repaid by borrowers that leverage their purchase of appreciating assets. Liquidity then becomes a “state of mind” (Nesvetailova, 2010, p. 121), a taken-for-granted condition of markets rather than a property of assets, deriving from a reduction in diversity and heterogeneity of interpretations regarding the state of the market itself by buyers and sellers (Nesvetailova, 2010, p. 126).

The cryptoasset bubble, however, seems to defy the correlation between speculation and debt that Kindleberger and Amber outline. In fact, very few licensed financial companies allow loans to purchase cryptoassets, and retail trading platforms allow only small leverage ratios. At the same time, the cryptoasset itself, and especially ICOs, are somewhat predicated on an anti-debt mentality: coins and tokens represent assets that are no-one’s liability or, as Bjerg (2016, p. 53) succinctly put it, “commodity money without gold, fiat money without a state, and credit money without debt”. They perform and promise unleveraged and non-mediated ownership of whatever a token or a coin represents.

This is not the whole story: it has been recently quantified that, through tokenisation (see below and in Chapter 4), a significant proportion of the Bitcoins in circulation are now owned through the Ethereum blockchain in tokenised form, rather than on the Bitcoin blockchain itself (Voell, 2020). While these tokenised Bitcoins are supposedly backed 1:1 with “real-world” BTC, many of these projects have opaque audit systems, which leave the door open for “fractional reserve” issuance of tokenised BTC at best, or Ponzi Schemes at worst. Furthermore, the explosion in late 2019 of so-called DeFi or Decentralised Finance platforms has seen a spike in loans contracted against holdings in crypto, without the intermediation of financial institutions. These projects account now for an aggregate US$ 4.48 billion in Total Value Locked (TVL) (DeFi Pulse, n.d.). Platforms such as Compound and MakerDAO allow for “passive income” through interest earned by depositing cryptoassets, and these deposited cryptoassets in turn become available for others to borrow for leveraged trading and investing (Leshner & Hayes, 2019; MakerDAO, n.d.).

2.2. The Making of Professional and Nonprofessional Investors

A second marker of a bubble is the production of an insider-outsider and early-latecomer divide among investors. For Rapp (2009, p. v), in fact, a bubble is a phenomenon whereby

> some event, some expectation, or some development starts the asset price rise rolling. As asset prices rise, a vacuum is generated that sucks in more investors, hungry for quick profits. The momentum so generated attracts more investors. By now, most new investors ignore the original stimulus for the boom, and are only buying with the intent of selling at a profit to 'a bigger fool' who is expected to come along soon.

What Rapp's quote encapsulates is a "first mover" versus "latecomer" dynamics whereby early investors rapidly "suck in" the ones that come when speculation is already in full swing and, in so doing, first movers and early adopters can profit from the rise in prices.

While blockchain technologies and ICOs were quickly deemed to represent new forms of democratisation of investing, hence potentially blurring the insider-outsider and professional-popular investor divide, the insider-outsider dynamics were also reinforced in multiple ways. Most of the investors or blockchain practitioners would position themselves as insiders or outsiders, depending on where the price of Bitcoin was when they first joined: savvy investors were those who held their funds from when Bitcoin was almost worthless (in May 2011 the first real-world transaction in Bitcoin totalled 10,000 BTC for two pizzas). Moreover, Bitcoin produced an insider-outsider dynamic between early adopters and newcomers through the reduction of the reward in new BTC issued to miners: each validated block used to be worth 50 BTC between 2009 and November 2012, then it halved to 25 BTC until June 2016, then it halved to 12.5 BTC until May 11th, 2020, when the reward dropped to 6.125 BTC.

As a consequence, in combination with the price dynamics of this asset, and with the dominance that Bitcoin has over other cryptocurrencies and tokens, the reduction in BTC rewards created a second heavy insider-outsider distinction between crypto "whales" on one side, and retail investors, on the other. These whales are envisioned to sit on piles of cryptoassets and that can make the crypto markets turn out of whims, and everyone else (Godlobe, 2020a, 2020b). Interestingly, the name of large crypto holders as whales resonates with the distinction between institutional and day traders by Preda:

> Traders […] are worth studying only if [they] can move markets. 'Moving markets' […] means 'being able to move the price'. […]

> Everybody likes to go whale watching, but who has ever heard of sardine watching? Majestic size is there to be enjoyed […]. Noise traders, ordinary people who put their (sometimes meagre) savings into a trading account, are no whales (Preda, 2017, p. 8).

This whale-sardine divide in price determination is especially enhanced given the relative illiquidity of these markets. As we saw in Chapter 4, one of the markers of the proliferation of cryptoassets was the increase in market capitalisation. This proxy, however, is a relatively poor tool to evaluate the actual amount of money invested and moved in and out in these markets over time. In fact, Market Capitalisation would be a measure of the actual magnitude of the market only if the market itself was perfectly liquid, i.e., one could sell any unit of a cryptoasset at market price without such market price changing. Selling, however, has effect on prices, which further reinforces oscillations in market capitalisation.

Another way in which the insider-outsider separation is reproduced is through the stages of an ICO into presale and public sale, described in Chapter 4. The staged structure of an ICO and the fact that most of the ICOs are connected to Ethereum through ERC20 smart contract creates an insider-outsider dynamic resembling a compound asset bubble (Blyth, 2008) between coins and tokens. Most of the ICO fundraising originates from BTC and ETH, i.e., one needs a wallet in those cryptocurrencies to participate. Furthermore, investors tend to "long" – or HODL, in crypto parlance (Dierksmeier, 2018; Hubrich, 2017) – cryptocurrencies, especially BTC and ETH, and "short" tokens, i.e., buying them before they are listed on exchanges, and quickly "dumping" them after they are listed (Zook & Grote, 2019). This, of course, is only possible if the smart contract allows it: to avoid investors "dumping" all coins as soon as they get listed, often the smart contract contains lock-in clauses that prevent any sale prior to a certain date. ICOs often have a "soft cap", under which the minimum viable product cannot start and often leads to refunds to investors, and a "hard cap" that is the maximum amount that the company is interested in raising. Capital, then, tends to flow in and out of BTC and ETH in combination with converse movements in and out of ICOs, based on the relative appreciation of one to the other.

2.3. Market Manipulations

The staged process of issuance of ICOs allowed multiple scams to emerge, in that the issuers have multiple opportunities throughout the ICO process to cash in the money and exit without a product. Tokencard, for example, promised to introduce a VISA-powered card that allowed holders to use Ethereum and ERC20 tokens in any place that accepts a

VISA card. The website also carried pictures of the card with the VISA logo clearly on display. After the ICO started, the company changed all documentation on their website, as well as the picture of the card, removing any reference to VISA (Kaminska, 2017a). In a more prosaic way, the start-up Prodeum launched a blockchain-powered price and provenance lookup system for fruits and vegetables. During the ICO, the company disappeared and changed their website to a blank page carrying the word "penis" and nothing else (Matsakis, 2018). This emergence of scams has also been framed as a passage from an initial "smart money" phase of "nerds with money funding nerds", to a dumb money phase of "financial money funding nerds" (Field Notes 31/10/2017).

Other examples of market alterations are "wash trading", i.e., the inflation of daily turnout and volume on cryptoasset exchanges (Çalışkan, 2021a), and the role of stablecoins in injecting "fiat money" in cryptoasset markets. Several studies, in fact, have shown trading volumes to be largely inflated: as of 2019, the actual size of Bitcoin's market volume has been estimated as low as $ 273 million, out of $ 6 billion reported, and the total volume across cryptoasset has been evaluated in $ 2.1 billion out of an official total of $ 15.9 billion (Hougan et al., 2019; Suberg, 2019b). Furthermore, the increase in market capitalisation has been often associated with the emergence of fiat currency-backed stablecoins like Tether or USDT. Tether is ostensibly 1:1 backed by reserves in US dollars, but this backing is highly controversial, as the accounts have never been independently audited. USDT is currently the fourth highest cryptocurrency by market capitalisation and between the first and the second for daily trading volume. Several studies, however disputed the veracity of the commitment to 1:1 backing in dollars (Bitfinex, 2019), and they showed a correlation between new USDT being minted and the rise in BTC price (1000x Group, 2018; Griffin & Shams, 2018; Higgins, 2018; Vigna, 2019).

The dramatic growth in capital pouring into crypto markets had spill-over effects on non-blockchain companies: famously, the small public company Long Island Ice Tea changed their name into Long Island blockchain on the 21st of December 2017, and this caused its share prices to jump by 200% on that day (Cheng, 2017). In a similar fashion, the once renown company Kodak announced its own ICO for a coin associated with the registration of the provenance and authorship of pictures for professional photographers in early 2018, sending its stock up 125% (Fiegerman, 2018). It also launched its own line of Bitcoin mining rigs. However, the lack of clarity regarding the business model associated with the ICO itself caused stern reaction from financial and technological press, and the stock prices of Kodak declined again soon after (Cellan-Jones, 2018).

2.4. Media Exposure, White Papers and Market Devices

Cryptoasset markets also show the marker of a speculative bubble in terms of the spectacularising of speculation by drawing the attention, fantasy, and fascination of professional and popular investors, and of popular and specialist press alike. In fact, the press has been throughout history a paramount force in both producing insider-outsider dynamics and in casting speculation as a spectacle. In a similar way as railway-related press proliferated in the 1830s and 40s (Preda, 2001), and as noted by Thrift (2000) in the production of managerial subjectivities in the New Economy, both specialist and popular press are important vectors in the conveyance of romance, spectacle, and desire. In fact, the Railway Mania was the first time mass media started "analysing railway capital, cost per mileage, mileage receipts, and 'working expenditures' […] traffic tables relating dividends to cost and receipts, both total and per mile" (Preda, 2001, p. 222).

A similar explosion in media coverage can be seen in the Crypto Bubble. The *Financial Times* started covering the blockchain in 2013, when it published just 4 articles on the topic. Four more articles followed in 2014, but the number jumped to 51 in 2015, 106 in 2016, 134 in 2017, 390 in 2018, and 217 in 2019. In a similar vein, *The Economist* started talking about Bitcoin in 2011 with only 1 article. This followed with 1 in 2012, 13 in 2013, 24 in 2014, 23 in 2015, 18 in 2016, 40 in 2017, 46 in 2018, and 25 in 2019 (Gale Academic OneFile, n.d.). In 2017, both *Forbes* and *Fortune* started their specialised sections on cryptocurrencies and blockchain. This explosion in interest spilled over to alternative news sources and social media, such as podcasts and videos. SoundCloud currently has 1080 channels on either Bitcoin or blockchain, YouTube returns 625 channels for blockchain and 611 for cryptocurrency. The messaging app Telegram, with more than 400 million users worldwide (M. Singh, 2020), has become another important source of news for ICOs and cryptoassets (Comm, 2018).

This spectacularising of blockchain speculation was also materialised in one specific "specialist" form of press represented by "White Papers". Glorified after the introduction of Bitcoin, white papers are a fundamental cryptoasset market device (Doganova & Muniesa, 2015) that showcase a technology, illustrate the business model this technology enables, and shows the technical and entrepreneurial backing that that technology has in terms of reliability and partnerships. As Çalışkan (2020, p. 548) argues, White Papers are documents with three essential purposes: persuade, proving, and educate investors. While at the beginning white paper resembled STEM pre-print papers such as the ones stored on the repository arXiv, they progressively became a marketing tool that was more about the glossy (literally) allure of a technology of imagination (Bear, 2020) than anything else (See Figures 36 and 37).


Bitcoin: A Peer-to-Peer Electronic Cash System

Figure 36: Bitcoin White Paper's frontispiece. Source: Nakamoto (2018).

Figure 37: Front and back of Kidcoin's white paper. Source: Author's own collection.

White papers started to become more similar to an investment prospectus than a technical overview of the technology. They gave more relevance to the timeline (green box on the left hand side picture) and the token distribution (pie charts in the right hand side picture) than to the cryptography or the consensus algorithms implemented.

The making of a market requires the construction of cognitive instruments that make the market viewable and thinkable: liquidity is a problem of sociology of knowledge (B. G. Carruthers & Stinchcombe, 1999, p. 375). All niches in the cryptocurrency market have now a dedicated calculation and valuation website. Websites like whattomine.com help miners in calculating the costs and returns of mining different cryptocurrencies based on their equipment, energy costs, and exchange rates (WhatToMine, n.d.). Websites such as Tokenmarket.net, ICObench, ICO Drops, and many others are, simultaneously, online billboards that offer information on upcoming and ongoing ICOs, and professional services that often help curating the design of the token and the marketing campaign (ICO Drops, n.d.; ICObench, n.d.; TokenMarket, n.d.). Other tools to visualise the market, as well as to participate in it, are the interfaces of trading apps and crypto exchanges, the numbers of which have become plethoric. The most important name in trading is eToro with 12 million users in its crypto trading platform and trading on Bitcoin, Ethereum, and XRP is available also on the cross-border payment app Revolut with more than 7 million users as of 2019.

Lastly, conferences, fairs, and expos quickly became a venue where the spectacle of speculation unfolded and where tournaments of value took place. In a similar way as the trade fairs in Renaissance Europe, these conferences formed itinerant networks where famous merchants, interested investors, and anonymous members of the public gathered to stand in awe of the latest in blockchain innovations. The major websites for blockchain and Crypto News also contain a list of the most important events. CoinDesk, for example, listed 14 events happening in 2014, 24 in 2015 and 2016, 39 in 2017, 80 in 2018, and 54 in 2019[14]. Figures 38 and 39 show two moments and spaces in cryptocurrency and FinTech trade fairs where this tournament of value takes place: the "pitch" stage where start-ups showcase their product in a very limited span of time, and the expo floor where one can go from stand to stand.

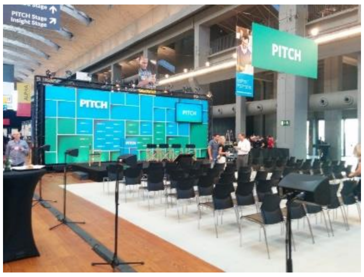

Figure 38: The "Pitch" stage of a crypto conference, where different start-ups showcase their products. Source: Author's own.

Figure 39: The expo floor, where companies are divided based on funding and production stage. Source: Author's own.

3. The Compounded Desire Bubble

In the next three sub-sections, we will delve deeper in three related and competing claims of value associated with different aspects of blockchain materialities, and the different enchantments they entail. We shall see how such enchantment tends to focus on either: (1) the token per se, making it a quasi-magical source of liquidity in sometimes paradoxical ways; (2) the token-ecosystem relationship, and on the real or potential utility the coin is supposed to leverage; or (3) the underpinning infrastructure and the capacity to knit together separate material and speculative spaces, making value realisation and flow possible.

[14] Source: https://www.coindesk.com/bitcoin-events accessed through www.archive.org at multiple points in time each year from 2014 to 2020.

3.1. Cryptotulips

Money starts as a collectible, it then becomes a store of value, and then a means of exchange

A participant to a cryptocurrency trade fair, November 2019.

This quote, which I recorded at a cryptoasset trade fair in Silicon Valley, encapsulates a vision that foregrounds the (im)materiality of the asset itself as the source of moneyness, and the fact that it evokes collecting will be of further importance in this section. The so-called Tulip Mania was the speculation frenzy on the Dutch market for tulip bulbs between 1634 and 1637. A specific virus affects tulips and causes them to "break", i.e., to change their colour pattern in unforeseen ways, while also reducing its rate of reproduction (Garber, 2000, p. 40). First planted in the Netherlands in 1562, the tulip emerged in the 1630s as a fashionable and exotic flower that appealed to the upper classes. The broken varieties were particularly desired, divided as they were according to the rarity of the colour pattern. Chancellor (2000, p. 16) reports that, in 1624, a rare Semper Augustus would be worth the price of a town house. After 1634, the appreciation of this flower grew to encompass middle class and non-professional florists (Garber, 2000, p. 25). A futures market developed whereby bulbs were purchased in advance for a given price, but the actual settlement happened only later for the difference between the price in the contract and the market price (Kindleberger & Aliber, 2005, p. 99). The development of futures contracts was also made necessary by the materiality of the tulip: since they only blossom in June, no one knew which colour the plant would have taken, albeit the weight of the bulb was a proxy of its future yield in terms of plants and future bulbs.

By 1636, the price for one bulb corresponded to "twenty-seven tons of wheat, fifty tons of rye, four fat oxen, eight fat pigs, twelve fat sheep, three tons of cheese, a bed with linen, a wardrobe of clothes, and a silver beaker" (Chancellor, 2000, p. 19). This upwards trend in the price of rare bulbs also drove up the price of common varieties, that were sold by the pound: floral arrangements with tulips used in still-life paintings became so expensive that painters had to lend each other the same flowers (Chancellor, 2000, p. 18). However, by the early months of 1637, the market crashed: the price was so high that futures contracts could not find buyers. In 1638, new regulation allowed the pending contracts to be settled for 3.5% of the original market price and, while in subsequent years the price for Semper Augustus and other rare bulbs rebounded, that of common bulbs never recovered.

Subsequently, the hyacinth bulbs followed a similar pattern of boom and bust in the 18th century (Chancellor, 2000, pp. 23-24; Garber, 2000).

The Tulip Mania represents a type of libidinal investment centred on the uniqueness and individuality of the asset, underpinning an enchantment based on collection, trading, and hoarding. What matters here is the individual token more than its underpinning infrastructure, and the potential immediate returns that can be actualised by selling the principal. The cryptoasset is also similarly ascribed intrinsic, almost magical powers. This power can derive from the asset's rarity, scarcity, and lack of fungibility. The earliest example of this kind of tokens is Rare Pepe, introduced in 2016 by the smart contract platform for Bitcoin Counterparty, which created a trump cards-style system to record individual Pepe the Frog memes and make them tradeable with each other (Leung, 2016; Rare Pepe Directory, n.d.). Decentraland creates a digital world where players buy lots of digital land and can buy improvements over them and trade (Decentraland, 2020). Dmarket offers a decentralised marketplace where blockchain-earmarked in-game items are bought and sold across games (DMarket, n.d.). In the social studies of technology and finance, attention has also been given to projects such as Monegraph (DuPont, 2017; Lotti, 2016; Zeilinger, 2018), Plantoid (De Filippi, 2017; Lotti, 2016), and Maecenas (O'Dwyer, 2019a), which in different forms and with different outcomes all tokenise unique works of art to facilitate track, tracing, and trading.

In recent times, the most famous example of non-fungible tokens is CryptoKitties. CryptoKitties is a decentralised video game built on the Ethereum blockchain, where people buy and breed digital cats, each of which with specific aesthetic characteristics. The rarer the appearance of the cat is, the more valuable it is (O'Dwyer, 2018). There are currently more than 1,8 million CryptoKitties in circulation, and the most expensive cat was sold on the 4th of September 2018 for the equivalent in ETH of $ 172,625.79 (Kittysales, n.d.). The total turnover of CryptoKitties since its inception in November 2017 has been of $ 27 million, and, at the peak of its use it accounted individually for more than 10% of the total number of transactions on Ethereum blockchain, a volume so high it created a backlog of non-CryptoKitties transactions (BBC News, 2017). However, since January 2018 the CryptoKitties traffic plummeted by 98%, also due to raised Ethereum transaction costs (Bernard, 2018; Greene, 2018). The drop in popularity of CryptoKitties spelled doom over similar pet-collection project – one of which being Aethia (Aethia.co, n.d.). Figures 40 and 41 show a specimen of CryptoKitty (left) and an arts object associated with a blockchain registry (right).

Figure 40: A specimen of CryptoKitty belonging to one of the most liked collections on the game's website. Source: CryptoKitties (CryptoKitties, n.d.).

Figure 41: A work of art ("Balloon Dog") with the associated certificate of ownership, and the QR code that allows to verify it as registered on the system run by ARTEIA. Source: Author's own.

Mass consumption of works of arts has at its centre the loss of the aura of authenticity caused by constant reproducibility: "the whole sphere of authenticity is outside technical – and, of course, not only technical – reproducibility" (W. Benjamin, 2011, p. 220). Digital objects can be seen as the pinnacle of technical reproducibility, in that they are multiple from the start (Hui, 2016). This, however, does not reduce the auratic dimension of digital objects (Lotti, 2019). Blockchain technologies applied to digital or real collectibles provide an attempt at establishing a "Economic Coordination Regime" for the valuing, pricing, and exchanging of "singularities", i.e., goods and services that are hard to price because their value is multidimensional, incommensurable, and uncertain (Dallyn, 2017; Karpik, 2010).

In so doing, these applications secure and preserve the aura either through the certification of authenticity that the blockchain itself affords, or by the aura of achieving a full collection of items of the individual object is reproduced by the aura of the systematic collection of objects. According to Benjamin, "the most profound enchantment for the collector is the locking of individual items within a magic circle in which they are fixed as the final thrill, the thrill of acquisition, passes over them" (W. Benjamin, 2011, p. 60). As Joyce Goggin puts it,

> [The collector's] self-proclaimed need 'to have them all' describes what is sometimes referred to as extension pack logic by computer gamers, or what Baudrillard called a 'system of objects'. As he explains, 'the objects of mass consumption form a repertoire' so that products are

marketed in clusters with accessories and sequel product development that induces the need in consumers to 'collect 'em all' in order to have the complete set (Goggin, 2017, p. 223).

This emotional investment is shared by collection and gambling: "in gamble-play media the fun aspects of gambling are privileged over winning or losing, and cuteness is often a key element in enabling this enjoyment" (Albarrán-Torres, 2017, p. 235). In fact, the futurity and temporality incorporated in the materiality of the tulip – the uncertainty of the aesthetics of the flower once it will bloom – brings the Tulip Mania closer to gambling and gaming. But, again, the thrill of gambling and the uncertainty of final price and actual worth of the stakes spill back into art collection. Walter Benjamin, in fact, describes the "fear of missing out", the frenzy, and the speculation that go into participating in an auction for works of art:

> to the reader of a catalogue the book itself must speak, or possibly its previous ownership if the provenance of the copy has been established. A man who wishes to participate at an auction must pay equal attention to the book and to his competitors, in addition to keeping a cool enough head to avoid being carried away in the competition (W. Benjamin, 2011, p. 63)

Readiness to pay and capacity for restrain have to be present in equal measure for the bidder not to be forced to pay higher prices due to competitive bidders. Not only are speculation and gambling not separated *a priori* (Stäheli, 2013, p. 89), but cryptocurrencies are both an object *of* gambling and a technology with the potential *for* gambling. Gambling itself, both as a subset of gaming but also as the separate economic sphere of betting, has always loomed large in all cryptocurrency expos I participated in (See Figures 42 and 43).

Figure 42: Roulette table at a blockchain conference by the crypto gambling company VARIUS. Source: Author's own.

Figure 43: Front and back of a roulette chip that is associated with an amount of Cashaa tokens, distributed for free at a blockchain event in London. Source: Author's own collection.

For Baudrillard (1968/2005, p. 91), objects have two functions: to be put to use as tool, and to be possessed as property. This is both a difference in kind – one pertaining to the practical relation to the world, the other pertaining to the abstract systems of signs underscoring property – and a difference in degree – a pure object-tool is a machine, which only exists insofar as it fulfils a function, the other is the object-collectible that only signifies ownership. This fetishisation of the aesthetics of the object used as money, and the auratic qualities ascribed to collection, betting, and gambling, make of the explosion of non-fungible, collectible tokens a perfect example of the pole "money as drug" explained by Nelms and Maurer (2014, p. 55). Yet even the money as a pure tool, as a pure means of exchange, can have its own forms of libidinal investment (Yuran, 2014).

Ripple's position in this market can be illuminating: the libidinal investment towards the cryptoasset XRP represents a variant of digital metallism (Maurer, Nelms, et al., 2013) that foregrounds XRP's liquidity. XRP is praised for its capability of automatically bridging between currencies through the distributed currency exchange built in the XRP Ledger. However, at the same time and almost paradoxically, XRP has been held as an asset that can appreciate "to the moon", mainly driven by the appreciation of the overall cryptoasset market. This type of asset-oriented enchantment is exemplified by a specific marketing strategy that presents itself as market-making and community-making at the same time. In 2018, the XRP community adopted a new logo (see Figure 44), which was launched at an invite-only community night featuring celebrities on 15 May 2018 (see Figure 45) (Ripple, 2018d). Ripple also performed large-value, highly publicised charity donations. In March 2018, Ripple donated $ 29 million worth of XRP to the charitable crowdfunding platform DonorsChoose.org, which funded all projects advertised at that moment (Elkins, 2018). Later the same year, actor and Ripple investor Ashton Kutcher donated $ 4 million worth of XRP to the comedy show host Ellen DeGeneres's Wildlife Fund (Huddleston, 2018). Hence, when considered individually, any token partially becomes a market singularity (Dallyn, 2017), in that its value becomes more distilled by its own capacity of self-appreciation and enchantment, more than for its "fundamentals" or its adoption.

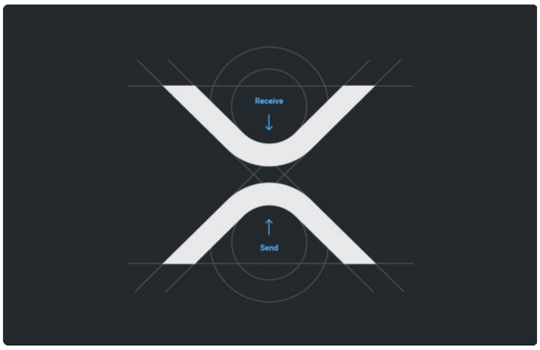

Figure 44: New XRP Logo. Source: Ripple (2020).

Figure 45: The XRP Logo pictured on a dreamy eye of a participant to the XRP community night. Source: Ripple (2018d).

3.2. Crypto.com

The Dot Com Bubble was a speculative episode that encompassed the 1990s and the early years of the 21st century, and it centred on the explosion in the number of "young, fast-growing, risk-capital backed companies which used the Internet as an integral part of their business model" (Zook, 2005, p. 6) to disrupt and disintermediate existing supply and production chains. This sustained injection of capital in technological companies and present-day platforms is facilitated and sustained by an abundance of metaphors (Feng et al., 2001). For Thrift (2001, p. 429),

> the success of the new economy arose from its ability to disclose, to bring out, a new kind of market culture as a frame in which technology could be constantly modulated and so constantly redefined – to the advantage of many stakeholders.

The Dot Com Bubble is defined by three elements: the dramatic expansion in the amount of Venture Capital made available to "New Economy" companies, the proliferation of Initial Public Offerings, and the boom-and-bust curve of the NASDAQ index.

First, the growth of venture capital was a process that began in the 1980s, from a relatively small pool of companies rooted in semiconductors and whose capital originated in extractive industries, to a much larger pool of bigger companies connected with pension funds (Zook, 2005, p. 100). Second, the number of IPOs skyrocketed in this same period, with the most iconic ones being Netscape, Yahoo, and America online (AOL). Netscape's IPO in 1995 aimed at issuing 3.5 million shares at $13 per share, and it ended up issuing 5 million shares for $28 apiece. AOL's valuation went from $70 million to $3 billion between 1992 and 1996, and when Yahoo went public, on 12 April 1996, the stock traded at $13 at the opening of the market and closed the same day at $33 (Rapp, 2009, p. 176; Zook, 2005, pp. 118 and 178). Overall, the number of IPOs went from around 50 in 1990 to more than 150 per year between 1991 and 2000, dipping below the 150 line only in 1997 and 1998 and recovering in 1999 and 2000 (Zook, 2005, p. 114).

At the peak of the bubble between 1995 and 2000, valuation tools were abandoned in favour of a direct analysis of stock prices and the oscillations of the NASDAQ index (Feng et al., 2001, p. 468). This shift in valuation models was often motivated by the impossibility of "rational" capital allocation in a technology whose use and utility was not immediately apparent (Janeway, 2012, p. 189). IPOs themselves, in this respect, became a marketing tool rather than a way of scaling up operations (Zook, 2005, p. 118). Third, the NASDAQ index of technological companies went from 600 points in 1996 to an all-time high of 5048 points in March 2000, but it started to drop from the second quarter of 2000 to the lowest point in April 2001, 68% lower than its peak (Zook, 2005, p. 124). Since the application of such technology is not immediately apparent, the valuation models used to allocate capital into this venture cannot be based on a rationally calculated projection of the expected returns of the technology itself (Janeway, 2012, p. 189).

The development that went from Dot.Com bubble to the present-day "platform economy" or "platform capitalism" (Kenney & Zysman, 2016; Langley & Leyshon, 2016; Srnicek, 2017a) is characterised by a dwindling of Initial Public Offerings (IPOs) as exit strategies for start-ups. Present-day start-ups, and the Venture Capital and Private Equity firms backing them, prefer to exit through acquisitions by larger firms, including investment and retail banks for FinTech, and incumbent Big Tech survivors of the Dot Com bubble (Langley & Leyshon, 2020). Leveraging the "winner-takes-all" monopoly tendency inherent to platform economies (Langley & Leyshon, 2016; O'Dwyer, 2019b; Rahman & Thelen, 2019), present-day platforms rely on multiple rounds of funding. This comes from venture capital funding and angel investing, for early stage companies, and private equity funding in later stages. The aim is to outlast "incumbent" firms in order to "disrupt" the existing ecosystem (Kenney & Zysman, 2016, 2019; Langley & Leyshon, 2020; Sarch et al., 2018).

While this has proliferated the number of so-called "unicorns" – i.e., companies with a valuation of more than 1 billion US$ – these companies are often not profitable for long swathes of time, sometimes all the way until acquisition, and they are dependent on "Venture Capital welfare" to survive (Srnicek, 2017b, p. 257). This concentration in Venture Capital propelled the explosion of ICOs as innovative forms of business financing that allowed the survival of companies in market niches that Venture Capital struggles to reach. According to Howell et al. (2019, p. 1), ICOs raised over $31 billion between January 2016 and August 2019. At least 20 ICOs have taken in more than $100 million each. Already in 2017, they surpassed Venture Capital funding for seed and early stage companies.

What interests us here is how the Dot Com bubble is a particular type of asset bubble, one that is based on the promises of disruption and disintermediation derived from the capability to reinvent and re-intermediate the platform-ecosystem relation through distributed computation and cryptographic software. The platform economy established by cryptoassets like coins and tokens changes fundamentally the relationship between asset, infrastructure, and ecosystem: rather than being assets used by participants in the ecosystem through the infrastructures, tokens become the way to *assetise* and, hence, capitalise on the interactions themselves. In fact, as Carruthers and Stinchcombe (1999, p. 356) have it, "Liquidity presumes assets that are knowable by a large group of potential buyers and sellers. [...] The creation of liquidity therefore becomes a problem in how to create generalised impersonal knowledge out of idiosyncratic personal knowledge".

Tokenisation, then, is a new form of assetisation: tokens render possible the "becoming asset" of just about anything because, as Muniesa et al. would have it, they are neatly delineated, i.e., they have "clear identification of perimeter, detachability from context, an attributable scope, and definite articulation of the agency that owns the asset" (Muniesa et al., 2017, p. 129). A crypto token turns the circulation of a myriad of assets, such as real estate, cars, objects of art, loyalty points, reputation, and data, in one tradeable product that can generate value through property and exchange (Birch, 2017, 2018). As one participant to a conference put it, "if Bitcoin is programmable money, then Security Tokens are programmable ownership" (field notes 25/04/2019). There is now a plethora of security tokens that are associated with fractional ownership in existing assets, especially real estate, for example Smartlands, operating on the Stellar blockchain (Smartlands, n.d.).

ERC20 tokens enable monetisation to occur at the very point of data production and consumption, or as a conference participant put it, they allow "monetising where the epicentre of value is, that is, the individual" (field notes 23/04/2018). Examples of this widespread monetisation can be retrieved in social networks such as APPICS or Steemit, which monetise the influencer economy by associating typical social network reactions such as "like" and "share" in tokens that reward the creators of the content, and at the same time gives differential weight to high-stakes influencers (APPICS, n.d.). In a similar vein but widening the scope of application, Steemit runs on top of the blockchain STEEM that is geared towards creating a rewards economy for digital content creators. The STEEM blockchain allows the creation of multiple Smart Media Tokens, that promise to "align incentives" between content creators and users by rewarding content creators with a "reward pool" distributed through tailored "competitive voting" algorithms, i.e., through processes whereby each new "like" could either provide the same reward – linear algorithm – or an additional boost – quadratic algorithm – or a system whereby likes are rewarded more intensely until the content reaches a certain amount of "virality", after which rewards diminish because the content is already popular.

One of the promises of utility tokens is the production of a symbiotic relationship between incentives, behaviour, and monetisation, and the capability of influencing the second by designing the first, in turn producing specific monetisation effects. This is at the centre of the emergence of a peculiar professional figure, that of the "token designer", i.e., entrepreneurial subjects that, according to an informant, tend to have interdisciplinary backgrounds that touch on humanities and social sciences rather than STEM, because of the "subtleties" of designing "whole civilisations or economies". Token design proceeds first by identifying whether a distributed ledger is the best technology for the use case at hand: "the challenge for token design is how you create an incentive structure that lives off a blockchain, and if you can't do that, then you might as well create digital point systems" (interview 29/05/2019).

Then, the token designer has to identify "perverse incentives" that might exist in a network. For instance, there is a perverse incentive in Ethereum whereby ETH is both a "utility coin" that is used to power the Ethereum Virtual Machine for distributed computation, and to be treated like a speculative currency. Hence, there is a trade-off between the price of ETH and its utility as a token to pay for computation. In a similar vein, the XRP Ledger created a trade-off between the versatility of the Ledger for payments and the price of XRP as an asset. To activate an account, open a trust line, and issue offers on the distributed currency exchange, everyone needs to hold reserves in XRP. This turns XRP into a battleground between competing interests. LETS supporters need XRP to be cheap to activate trust lines and to pay transaction fees. Traders want its price to be volatile to make higher margins through arbitrage. Payment providers want XRP's value to be stable, to mitigate the exchange rate risks associated with using it as bridge asset. The token designer, then, has to try and introduce ways to "tone down" these perverse incentives, such as a reputation token, or a so-called slasher protocol, where people can be paid for identify suspicious behaviours in the network (Interview 29/05/2019).

This flexibility in determining the incentive structures has not only been deployed for monetisation, but also for the management of communities and alternative currency circuits. For example, Trustlines originally did not include a token in its design, and it instead relied on an implementation of Ryan Fugger's original Ripple design, based on trust lines between users. However, they subsequently introduced two tokens, TLN and TLC, the former used within the Ethereum blockchain, where the Trustlines dApp is "homed", and the latter being used to pay transaction fees within the dApp itself (Trustlines Foundation, n.d.). In a different way yet, tokenisation has been used to paradoxically show the forms of control and commodification it entails, and to explore how tokens allow money to be structured differently: in 2017, the artist Evan Prodromou created Evancoin and essentially "ICOed himself", i.e., it issued tokens backed by his own time and sold them out, both as a "stunt" and as a way to explore how time banking and time-based currencies could work (Rosenberg, 2017).

Tokenisation has created once again the idea that standard valuation frameworks did not work to explain the growth of blockchain platforms, and the attention switched from the returns, utility, network reach, and internal security of the proposed technologies, and towards the returns and growth of cryptoassets in speculative exchanges (Feng et al., 2001). However, as the market saturated, a new niche emerged for valuation framework to get to something resembling a "fundamental value" and a "fair price" for cryptoassets. This niche tends to take either a supply-oriented or a demand-oriented approach for valuation. Supply-oriented models tend to focus on development activities, e.g., availability of the code, number of active nodes, number of commits to the code on GitHub, and transactions per second. Demand-oriented models are more geared towards user protection and user experience, which includes stability, utility, but also the legal liability behind a particular asset, e.g., if there is a company and people accountable for its operation. Real Digital Asset Index (RDA) and Flipside Crypto try to produce valuation tools based on, respectively, technology, stability, internal governance, and market sentiments around a cryptoasset in the case of RDA (Real Digital Asset Index, 2019) and User Activity, Developer Behaviour, and Market Maturity in case of Flipside Crypto (Flipside Crypto, 2020). Interestingly, RDA runs its own utility token based on precisely the data economy connected with the valuation of other tokens.

3.3. Cryptorails

Railroad scams at the end of the XVIII century were like the ICO scams today.

A presenter at a blockchain fair, 31st October 2017.

The Railway Mania was a speculative bubble that took place in Great Britain between the 1830s and the 1840s, albeit similar patterns can be found in France and Prussia in 1840s (Chancellor, 2000, p. 148) and in Ireland and in the United States in the 1870s (McNeill, 1953). Moreover, in many ways, the Railway Mania was itself a reiteration on a bigger scale of speculative tendencies shown by the canal-building effort in the second half of the 18th century (Chancellor, 2000, p. 123). The Little Railway Mania started in 1825 with the opening of the Stockton-Darlington line, picked up momentum in the 1830s, but it slowed down from 1837 until the early 1840s. After that, and especially after 1842, a second phase took hold. The bubble gained further momentum as landlords became more amenable to allowing railway lines to cross their land, and as the train started to be popularised as means of transportation. In 1844, the Parliament passed the Railway Act, and by April 1845 more than fifty companies were already registered, many touting returns in the region of 10% of initial investment. George Hudson, the first large-scale railway entrepreneur, became an MP for Sunderland in 1845, actively lobbying for the expansion of this industry.

A report on investors revealed that in 1845, 157 MPs invested more than £2,000 in railroads, one of which signed for £ 157,000. By June 1845, eight thousand miles of railways were planned, and by November the number of lines reached 1,200, with projected costs of over £ 560 million. Promised returns went as high as 500%, and interests on loans against railways shares reached 80%. But during the closing months of 1845 and at the beginning of 1846, the railway companies had to start "calling" their shares, i.e., asking the investors to immediately contribute with their resources to the costs of building the railway lines. This set in motion a spiral of railway share sales to meet the obligations in the calls. Also because of a shortage of notes and of gold bullion, the Bank of England decided to raise the discount rate in late 1846. The combination of higher interest rates and spiralling defaults on obligation caused the market to crash: by October 1846, railway scrip had declined by £60 million in value since 1845. A good grain harvest also caused prices to plummet, further spreading a crisis across the economy which forced the Bank of England to reverse its course to the point where in 1847, just three years after its introduction, the Bank Charter Act, which forbid the issuance of notes beyond a certain threshold, had to be suspended (Anson et al., 2019). By 1849, Hudson was accused of paying dividends out of capital – a mark of a quasi-Ponzi scheme – for a total of £600 million. By January 1850, railway shares declined from their 1845 peak by 85%.

The Railway Mania is here deployed as a heuristic device to flesh out a relationship between blockchain technologies and speculation centred on the infrastructural dimension of the blockchain, i.e., its capability to interconnect, standardise, and interoperate across platforms and institutions. Much in the same way as the railways per se were deemed the harbingers of time and space standardisation (Schivelbusch, 1977/2014), blockchain technologies are here invested as the infrastructural layer of an "Internet of Value" in the making (Antonopoulos et al., 2016; Antonopoulos & Hariry, 2017; Leonard, 2017). Rather than focusing on the assets per se a Railway-Mania-like libidinal investment tends to, almost paradoxically, focus its attention on the standards, protocols, and technical details that blockchains have. This is exemplified by the ubiquitous use of the definition of "agnosticism" of a host of technologies with respect of payment platforms, programming languages, currencies, and blockchains. An example of this tendency is the consortium blockchain Hyperledger, sponsored by the Linux foundation. It promises to "build the community of communities" (field notes 25/04/2019) by providing traceability and visibility across the silos of separate centralised organisations and independent blockchains.

Fascination with the purely infrastructural side of a technology is somewhat paradoxical: "one […] rather comical reason why standards may be neglected […] is that they are boring" (Star & Lampland, 2009, p. 11). "Boring" is also the way in which DuPont (2019) defines the movement of blockchain technologies to recede into the background as "middleware", i.e., as pieces of back-office software that are left ignored by practitioners and end-users alike once they are installed. As we saw in Chapter 3, interoperability is part of the "wiring" of blockchain platforms, understood as an active form that does not have immediate or obvious effects, whose import is nonetheless substantial to understand how infrastructures interface with each other. A speaker at a conference, again drawing a parallel between investment and desire, said:

> The ability to know actually where your trusted data is, and what the correct version, at what time, and where, that is a very unsexy problem to solve. We need honesty about the mess of the data inside these institutions. If you want to get funding from a board of a financial institution for something that it's sexy especially if it's front-office, the budget is always found, what nobody really wants to put their money on, is fixing something that's not pleasant, and that smells very unpleasant (field notes 26/09/2018).

Another speaker reiterated a similar point by saying: "the technology is going to be boring, like Linux that no one talks about anymore, but it's in the very fabric of the Internet [...] blockchain is going to be the same and people won't even realise that they are using it" (field notes 26/04/2019).

Despite the boredom associated with it, interoperability technologies become odd sites where imaginaries are shared and communities are built, as well as where capitalisation happens. Scott and Zachariadis show how the SWIFT International Banking Operations Seminar (SIBOS) went from an insider training session to a fully-fledged community-building networking event across the financial landscape (S. V. Scott & Zachariadis, 2013, pp. 43-47). Ripple went from being briefly mentioned in the start-up section of SIBOS called Innotribe between 2014 and 2016 (Sibos, 2015, pp. 10 and 17, 2016, p. 10; SWIFT, 2014, p. 92), to launching their own conference SWELL which featured keynote speakers like Ben Bernanke, former Federal Reserve governor, in 2017, Bill Clinton, former USA President, in 2018, and Raghuram Rajan, Former Governor of the Reserve Bank of India, in 2019.

How, then, does something boring like interoperability become the centre of a flow of desire and investment? One could be tempted to assume that infrastructure and interoperability mania is no mania at all, but a "rational bubble" (R. S. Dale et al., 2005) based on the anticipation of the profitability of selling an overpriced asset at an even higher price, rather than on "psychological factors unrelated to the asset's fundamental value" (Cheah & Fry, 2015, p. 35). After all, "here the horizons seemed truly without limit. Who could lose on what was so obviously needed?" (Galbraith, 1993, p. 64). For example, Odlyzko (2010) denies that hype or fraud played the large role normally associated with the Railway Mania. Janeway likewise described the "Little Railway Mania" of the 1820s and 1830s as one where "realisation managed to match expectations" (Janeway, 2012, p. 143).

However, interoperability is capable to capture flows of desire both as the imaginative, almost utopian effort towards frictionless connectivity, and as the very condition of possibility for the realisation of many of the investments made in the other two examples. The uniqueness-based nature of the assets exemplified by the Tulip Mania, in fact, is predicated on their illiquidity, and without interconnected payment systems there is never the possibility to "cash out". An example of such interoperability technology for non-fungible tokens is dGoods, that allows the trading of non-fungible tokens (dGoods, n.d.). The platformisation that underpins the "Dot Com" side of the cryptoasset bubble is predicated on cross-chain connectivity, otherwise each platform becomes a walled garden that can only rely on its own endogenous network expansion to thrive. Again, Chapter 3 illustrated how few blockchains are wired to sustain full-fledged interoperability. This is why, between 2018 and 2019, the attention started to focus on so-called Layer 2 technologies and interoperability: Lightning Network and Plasma, Polkadot and Cosmos, as well as Blocknet all were born and launched with the promise to scale up and interoperate. As one practitioner in this scene described it

> People have finally started to realise its importance for the development of the next level of applications that the world needs. When we started in 2014 people were actually making fun of the project saying, 'who even wants this?' and now everyone says this is the biggest issue in blockchain (informal interview 19/04/2019)

Stefan Thomas, a former Ripple employee, describing the Interledger Protocol that was designed for cross-chain and cross-currency payments, compared ILP to the open Internet where multiple networks could coexist and interoperate, while individual platforms, insofar as they remained isolated from each other, were like the now defunct America Online (AOL) network and messaging service (Jacobs, 2019).

Lana Swartz captured this tension between infrastructurality and speculation when comparing the "infrastructural mutualist" imaginary with the "digital metallist" one in the case of Bitcoin: "an act of payment for someone was an opportunity for arbitrage for someone else" (Swartz, 2018, p. 640). That example is not limited to cryptocurrencies but applies to present-day cross-border payments with their reliance on FX markets, and to any infrastructural configuration: the smoothness of flow is always predicated on more than the perfectly designed materiality of the infrastructure that manages that flow, but also on the constant capital provision fuelled by speculative and libidinal investments (Hardin & Rottinghaus, 2015).

The case of Ripple exemplifies this push perfectly, in that the company combined interoperability technologies, the XRP Ledger, and the XRP cryptoasset to promise a unified messaging standard, currencies marketplace, and a cryptoasset that, by design, is the most liquid in that marketplace and that provides "liquidity on demand". The XRP Ledger is compared to gold not as a substitute for interpersonal trust, but as the most liquid of assets in terms of speed, value, and exchangeability. The XRP Ledger is marketised for its speed, measured in 1,500 Transactions per Second (TPS) compared to Ethereum's 15 and Bitcoin's 6 (Ripple 2019). Remembering the all-time-high XRP price of $ 3.5 of late 2017, an informant said: "Ripple was worth more than all but maybe twenty banks in the planet.

And that made the phone ring!" (Interview 19/04/2019). A speaker at a conference, at some point declared "If XRP price hits 6, Ripple could buy VISA" (field notes 13/06/2018).

As shown in the previous chapter, interoperability is always in tension between unfettered competition, which would just proliferate independent walled-garden blockchains, and absolute homogeneity through the achievement of a monopoly of interoperability by one platform, which soon would trigger problems of efficiencies and cause competition, aside from de facto reinstating intermediation of financial transactions (Pesch & Ishmaev, 2019). Here, we have seen how interoperability is also the political and economic tension between scarcity, utility, and liquidity of assets that mediate ecosystems that might or might not allow for the realisation of value in speculative exchanges.

4. Conclusions

Teenagers want to experiment with sex, and so you either don't enter into the conversation and pretend that they are not going to have sex and they will not experiment, in which case watch out, or otherwise you will embrace what is inevitable, and that means that you will have to have a conversation, to understand, to immerse yourself in their world and they are facing, because it is different from the world that you want them to be. […] I think that regulators are being very naive and simplistic about the fact that digital currency and crypto and DLT and data and cloud are here to stay, these are technologies we need to embrace, to adopt them and to transform because transformation is going to happen either in a regulated world or it's going to happen in a hedge fund and private equity world where they don't actually have a hook to put their hat on, they couldn't interoperate.

Field notes 26/09/2018.

It used to be that we didn't talk about religion, we didn't talk about politics, we didn't talk about sex, we didn't talk about money. All these temples have collapsed except for money. So, I think we'll see people being a lot more open about their finances.

Field notes 11/06/2018.

As the two quotes here reported illustrate, technology and money are intrinsically connected with desire and libidinal investments. This chapter focused on the fascinations and enchantments of the blockchain and cryptocurrency bubble that started in 2009 and peaked between 2017 and the early months of 2018. It showed how money infrastructures were materially and symbolically at the forefront of the fascinations and affective and libidinal investments that traversed this industry, that is perfectly encapsulated by the two fieldwork quotes mentioned above. Fascination with the assets themselves, with the digital tokens understood as digital commodities, fuelled collecting, hoarding, gambling, and trading by inspiring a quasi-magical power of the digital object to achieve and provide liquidity. Fascination with ecosystem intermediation fuelled investments in utility and security tokens, much like the 1990s Dot Com bubble. The fascination with the underpinning infrastructure entices a fantasy of simultaneous space-time standardisation and revolutionising, a temporality of overcoming or recreating borders, and of creating the interoperability networks necessary to realise value beyond individual blockchain platforms as walled gardens.

These three bubbles are not ideal-types, nor are they conceptual distinctions between mutually separate forms of libidinal investments. Rather they are mutually interlocked in symbiotic-competitive tension with each other. Rather than being a “compounded asset bubble” (Blyth, 2008) where accumulation in one class of assets eventually results in deflation and shifting towards another class, we can speak here of a “compounded desire bubble” where different sides of the same technologies are simultaneously caught in mutually reinforcing libidinal investments. Overall, this narrative also confirms analyses that blockchain and cryptocurrencies have enhanced, more than questioned and fought against the crisis-prone outburst of exuberant speculation within capitalism (Campbell-Verduyn & Goguen, 2018).

Going back to the speech that opened this chapter, how interoperability is constructed is itself a deeply political endeavour:

> Convergence could take a number of different forms. At its most radical, it could imply a single universal payments system, run on a single platform, and handing all payment types. Or it could mean retaining separate systems, but with a common ‘backbone’, including a shared language, operating standards, and access protocols. […] An all-encompassing payments platform hosted on a single IT system has clear appeal from the point of view of simplicity and clarity of purpose [but,] just as it would be unwise to try to channel all 100m passengers a year to Euston, King’s Cross and St Pancras through a single train platform, diversity has some operational merits! Second, it would be potentially very complex to ensure that all of the different functions currently offered by the various payment systems were replicated on the single system. […] Third, someone would need to pay – and there is a good chance that such a large project might fall to the public authorities. (Hauser, 2016)

The strive towards interoperability needs to strike a balance between heterogeneity of existing rails and coordination imperatives driven by economies of scale, competition, and thirst for profit. Interoperability, then, emerges not as unification of all payment systems under one meta-infrastructure, not less because, as that speech outlines "someone would need to pay [for that universal payment infrastructure] and there is a good chance that such a large project might fall to the public authorities" (Ibid). Rather, interoperability is the condition of possibility for both profitability and competition:

> That is not the model that has developed for UK retail payments – and such a single dominant infrastructure could well have negative implications for innovation and competition. [...] In the nearer term, the UK is therefore embracing the second convergence concept – that of joining separate systems together around a common backbone, embracing so-called 'interoperability'. (Hauser, 2016)

What it left unexplored was the role of regulation in channelling and influencing the flows of desire analysed in this chapter. In fact, both in the case of railway companies in the 1840s and in the case of crypto companies nowadays, the regulatory approach in the UK has largely been the same *lasseiz faire* on the economic level, ostensibly aimed at not stifling technological innovation (Chancellor, 2000; Robb, 1992). The railway bubble changed dramatically accounting (Odlyzko, 2011), business and finance in the UK (Bryer, 1991), as well as financial crime (Marx, 1981, p. 538; Robb, 1992). The Railway Mania produced a dramatic expansion in what was considered as an "investor", being the first case of "democratisation of finance" in terms of both mass participation in the financial market (G. Campbell & Turner, 2012) and in the popularisation of finance in society at large through the proliferation of specialised press (Preda, 2001). Present-day blockchain enthusiasts are claiming, in a similar vein, that the emergence of crime, fraud, and poor business models in the blockchain sphere will bring a similar update in law and accounting: speculation drives fraud, fraud drives regulation, regulation causes standardisation, standardisation promotes efficiency.

However, there is no self-evident basis to ground the claim that unfettered competition is the only way to engender efficiency, and there is no value-free idea of what that efficiency would look like. Even during the Railway Mania, not all countries reacted in the same way:

> When a railway mania had suddenly appeared in Prussia in early 1844, the government reacted quickly by condemning speculation, banning the sale of options and settlement for differences (or futures), and refusing to sanction new lines. In France, military engineers decided on railway routes, before construction was put out to tender by private

> companies. […] The Belgian state undertook responsibility for the construction and management of the nation's railway system (Chancellor, 2000, p. 148).

Lana Swartz (2017, p. 83) said that "the blockchain is meaningful as an inventory of desire […] It is an engine of alterity: an opportunity to imagine a different world and imagine the mechanics of how that different world might be run". This chapter, conversely, argued that blockchain became an engine of desire based on its capacity, among others, of acting like an inventory, and based on its real or alleged capacity of casting any practice channelled through blockchain as alternative and revolutionary. Any form of libidinal investment in new technologies is always already a form of political investment, and the questions it raises are always already political (Papacharissi, 2015). In shaping the interior design of money, we ought to remind ourselves that, just because a technology attracts capital and fascination, there is no reason why such flows should remain unchecked and unchallenged.

Chapter 7: Blockchain Technologies, Formalisation, and Remittances

1. Introduction

This chapter furthers the overall argument of this dissertation: money is irreducibly infrastructural. It will focus on an often-overlooked infrastructure of cross-border payments and remittances, i.e., the worldwide network of Nostro-Vostro accounts that form the "correspondent banking" infrastructure for remittances. Correspondent banking is "the provision of banking services by one bank (the 'correspondent bank') to another bank (the 'respondent bank')" (FATF, 2016, p. 7). This infrastructure has been largely neglected by the literature on remittances, which has largely focused on the "point of sale" of value transfers. At the same time, this chapter will continue our infrastructural analysis of the introduction and application of blockchain technologies in cross-border payments. It will concentrate, in particular, on how blockchain technologies are presently caught up in dynamics of "co-opetition" (A. Brandenburger & Nalebuff, 1996; Leal, 2014). Emerging both at the fringe of formal finance and often in opposition to it, blockchain technologies are now experiencing a de-politicisation of their design and increased competition between business implementations. Corporate co-optation of blockchain technologies leads to ambiguous dynamics in the payment space, caught in between interoperability and enclosure, disintermediation and re-intermediation, disruption, and rent extraction (O'Dwyer, 2012, 2015a).

The chapter's infrastructural account of current developments leads, then, to a somewhat different understanding of the introduction and application of blockchain technologies remittances. The core argument of this chapter is that concerns about risks and efficiencies in correspondent banking arrangements – in addition to financial inclusion agendas – are driving the application of blockchain and DLTs in remittances. As a consequence of the Global Financial Crisis, CBRs are presently undergoing "de-risking," i.e., a reduction in the number of active bilateral arrangements ("corridors") between currency areas, and a concentration in the number of banks managing correspondent relationships (World Bank, 2015a, p. 1). Furthermore, for many financial institutions, correspondent banking accounts are increasingly understood to represent costly and inefficient "dead capital" and "idle liquidity". The result of de-risking is that some banks and even entire countries might be completely cut off from transnational remittance corridors. Hence, customers may find themselves incapable of sending and receiving remittance payments, or they might incur dramatically higher fees (World Bank, 2015b, p. 31). De-risking is particularly detrimental for remittances, in that it disproportionately affects Money Transfer Operators (MTOs), NGOs, and local banks in the Global South (Eckert et al., 2017; FATF, 2014a, 2014c).

Ripple, as it will be shown in this chapter, is again a particularly valuable "revelatory case" of broader tendencies in correspondent banking, financial inclusion, and formalisation (Fletcher & Plakoyiannaki, 2010). Ripple will demonstrate, first, how blockchain is being applied to correspondent banking and remittances. Second, it will show how such applications are caught up in the dynamics of co-opetition (A. Brandenburger & Nalebuff, 1996; Leal, 2014) that are animating FinTech applications of blockchain. Third, the chapter will elaborate on the centrality of interoperability in these applications to money and payments. To respond to de-risking, international organisations and global private entities have recently been arguing for the introduction of interoperability solutions that, by enabling end-to-end transaction traceability and real-time settlement, would make correspondent banking obsolete. Ripple has been frequently cited as an example of such interoperable solutions, and it represents a specific FinTech market niche that taps into the "financial inclusion" drive from the back-office and infrastructural point of view, rather than at the point of sale and user experience side.

Cross-border payments have been one of the earliest and most promising applications of blockchain technologies (D. Mills et al., 2016). Chapter 5 showed how correspondent banking is an inherent feature of money as a "double entry book operation" (S. Bell, 2001; Minsky, 2008). In fact, as money is issued by recording credits and debts on one's book, correspondent accounts are needed to allow money to move *across* books. Domestic payment spaces have largely – albeit not completely – lost the need for correspondent banking through the overcoding of clearing and settlement through centralised infrastructures. However, cross-border payments still require these arrangements, due to their lack of synchronisation.

This, in turn, engendered the need for interoperability devices and infrastructures that will be explored later in the chapter, such as SWIFT and CLS, which we will expand on in section 2.1. As we saw in Chapter 5, this de-politicisation is behind the drive towards cross-payment interoperability that was conceptualised as axiomatics, following Deleuze and Guattari (1987). Chapter 6 detailed how this lack of interoperability is also one of the drivers behind the enchantment and libidinal investment in blockchain technologies as railways. Key to the attention, desires, and speculation on and around blockchain and interoperability technologies is their promise for instant clearing and settlement, and immutable and transparent recording of transactions across and through space (Ali et al., 2014; Godfrey-Welch et al., 2018; Morini, 2016).

This chapter mobilises the concept of formalisation to zoom in on interoperability in its political economic aspects, to further illustrate how interoperability is a far from a neutral dynamic. Rather, interoperability *qua* formalisation entails the incorporation into market dynamics of social relations that were hitherto left outside of it, with an eye to freeing idle assets and capitalising on them (T. Mitchell, 2007). In the case in point for this chapter, the idle asset is money itself, represented by "trapped liquidity" in Nostro-Vostro correspondent banking accounts. If, as shown in Chapter 5, interoperability is represented by an axiomatics of money, then formalisation is the dynamic process of "becoming axiomatics" of payment systems. While blockchain technologies provide strong impetus towards interoperability, they also represent and entail specific obstacles to that dynamic.

The move from interoperability via platforms to generalised interoperability represents conceptual and material specificities that need to be unpacked. In particular, this chapter argues that platform interoperability and generalised interoperability entail two different articulations of the relationship between money and memory, between value and money of account (Maurer, 2017a). Further, Chapter 5 showed how axiomatics forms part and parcel of the process of grammatisation (Stiegler, 2010). This chapter builds on those reflections and, through the idea of formalisation, it shows how interoperability aims at producing the space of monetary circulation as a new "smooth space" (Deleuze & Guattari, 1987, p. 475) of universal translation and "portability" of memory.

While informal value transfers flow through localised memory-storing practices, domestic payment systems entail the layering of memory in different tiers of currency space pyramids. blockchain technologies, by performing platformisation of interoperability, produce portable memory through the production of permanent and visible archiving of credit, debts, and assets. Conversely, generalised interoperability produces fully portable memory, disembedded from the concrete and localised ties that created bonds of credit and debt, which can freely float against other credit and debt claims and flow across multiple monetary circuits and spaces.

This chapter comprises five parts. Section 2 will provide an overview of the literature on remittances and its relative neglect of payment infrastructures. Section 3 will unpack correspondent banking and its present transformation. Moreover, it will illustrate the application of blockchain technologies for payments and remittances through the case study of Ripple. Section 3 will also illustrate the limitations and ambiguities inherent to the interoperability promises that blockchain technologies purport. Section 4 will expand reflections on the technical and conceptual specificities inherent to interoperability of money, connected to the nature of money as mnemonic technology. The conclusions will further summarise and elaborate on the contribution of this chapter to the thesis.

2. The Remittance Industry from the Point of Sale to Cross-Border Payment Infrastructures

Remittances are "household income from foreign economies arising mainly from the temporary or permanent movement of people to those economies" (IMF, 2009, p. 272). These transfers happen through a variety of formal or informal channels. Informal arrangements comprise physical transportation of cash and *hawala* (M. Martin, 2009; Rusten Wang, 2011; E. A. Thompson, 2008). At the formal end of the spectrum, meanwhile, Remittance Service Providers (RSPs) include banks, post offices, and credit unions and non-bank financial intermediaries (NBFIs) of which Money Transfer Operators (MTOs) are the most important (Deloitte, 2017b; Orozco, 2004; UPU, 2013). The focus here is on the tensions and conflicts around blockchain technologies as applied to the "formalisation" (T. Mitchell, 2007) of hitherto informal value transfers, such as remittances (IMF, 2017; Silverberg et al., 2015; World Bank, 2017).

Remittances grew from US$2 billion in 1970 to US$31.2 billion in 1990, to more than US$400 billion in 2016 (Datta, 2017, p. 539). In this period, remittances overtook overseas development assistance (ODA), coming second to foreign direct investment (FDI) in many developing countries (D. Hudson, 2015; IDB, 2006; Ratha, 2003; Wills et al., 2010). This impressive growth caused remittances to attract attention from researchers and practitioners. Development economics frames remittances as "aid that reaches its destination" (Bracking & Sachikonye, 2010, p. 218), and assesses their economic impact in terms of net gains and losses, efficiencies, and market failures (Heilmann, 2006; D. Yang, 2011). This literature focused on measuring the "migration-development nexus," whereby remittances ostensibly transfer resources in a way that is beneficial for both the global South and North (Datta, 2012, p. 141). Remittances are also praised as counter-cyclical, informal welfare systems that serve to lift families out of poverty, and that benefit the originating countries' balance of payments (Barham & Boucher, 1998; Brown, 2006; De Haas, 2005; D. Hudson, 2008; Mazzucato, 2009). Hence, economic literature casts remittances as an untapped market of informal value transfer (Bailey, 2005; Davies, 2007; Durand et al., 1996; Faist, 2008) that could explode in magnitude if more people had access to formalised financial services and mobile and digital technologies (Cf. Kleine & Unwin, 2009; Mader, 2018; Roy, 2010, 2015).

However, critical scholarship has questioned the emancipatory and transformative potential of remittances by highlighting its distributive asymmetries and hierarchies, illuminating how inclusion entails a dynamic of "adverse incorporation" (Aitken, 2010). According to this critical scholarship, remittances are part of a "financial inclusion assemblage" (Schwittay, 2011) that comprises public agencies, NGOs, IGOs, private actors, and consortia, striving toward inclusion, and, more recently, digitalisation. Remittances are traversed by a "mission drift from poverty alleviation to profit maximisation" (Roy, 2010, p. 386). The constellation of actors that push for the formalisation of remittances is critically understood as "poverty capital" (Roy, 2010), or the "financial inclusion assemblage" (Schwittay, 2011, 2014).

According to the "migration-development nexus," remittance formalisation fosters development through financial inclusion, freeing the untapped markets and idle assets that compose the "fortune at the bottom of the pyramid" (Collins et al., 2009; Prahalad, 2005). But, understood more critically, the poor constitute a frontiers market (Aitken, 2015; T. Mitchell, 2007): they are the "missing billions to be discovered, accounted for, channelled and harnessed for development" (Kunz, 2011, p. 49). In short, poor people "do not only possess assets but are assets" (Roy, 2010, p. 64).

Within the poverty capital business, the expansion of retail payment technologies has fostered the emergence of "poverty payment," i.e., "the idea that the design of digital platforms for the transfer of value, agnostic as to what value is being transited or what it is being used for, has positive spill over effects that ultimately benefit poor people" (Maurer, 2015a, p. 128). This proliferation of mobile technologies and the political and industry-led effort toward cashless transactions led to the emergence of a "fintech-philanthropy-development complex" (Donovan, 2012; Ojong, 2016; Omwansa & Sullivan, 2012). For Datta (2017), we can understand this move toward inclusion and digitalisation as an effort toward the formalisation and mainstreaming of alternative and informal remittance flows. Domestic remittances are also increasingly targeted as sites for formalisation and standardisation of their infrastructural materiality through the actions of an "ecology of cashlessness" (Small, 2020) that, as this dissertation illustrated multiple times, is obsessed with interoperability.

Mitchell (2007) argues that markets have boundaries and limits, and there is a frontier region that lies between "market" and "nonmarket" relations. This frontier separates the formal economy, where asset ownership is recorded and fixed, and where everything can be traded for a price, from informal economic relations, where ownership regimes and freedom of exchange are more flexible. All processes of formalisation happen against the backdrop of hitherto "informal", often considered illicit property relations or lack thereof. "The capitalist economy" Mitchell summarises "is surrounded by a boundary, outside which stands the non-capitalist, nonmarket world" (T. Mitchell, 2007, p. 247). Much like Aitken described the process of financial expansion as a process of incorporation of multiple "fringe markets" into financial loops and circuits (Aitken, 2015), the expansions of markets in general happen through the expansion and incorporation of informal property relations into formalised ones. Assets that lie beyond capitalist markets are defined as "dead capital" (Soto, 2000, pp. 5-6) because it cannot be used to leverage investments through credit.

Once markets recognise their "other", then this outside can be cast as lacking something – formalised property relations and price mechanisms – hence "misrepresenting" market dynamics. Much like "abnormal" market outcomes – such as pollution – are often cast as the product of "externalities" engendered by the *lack* of pricing mechanisms for particular individual or social costs, here the informality of non-capitalist markets are cast as lacking what Mitchell (2007, p. 248) calls "technologies of representation". As Mitchell (2007, p. 249) shows, representation "transforms [assets'] value into abstract forms, which can live an 'invisible, parallel life' alongside their physical existence".

Technologies of representation, then, are "techniques of control, which make it possible to manage assets at a distance" (T. Mitchell, 2007, p. 266). They do not just represent what was previously unrepresented, but they "try to reorganise the circulation and control of representations" (Ibid). Technologies of representation allow for these "dead capital" to become "live capital" by assigning them a new, abstract form of reality besides the material one they already possessed. Applied to remittances, formalisation allows capitalisation through transaction fees, monetising users' data, and leveraging these payment streams into more sophisticated financial products (Gabor & Brooks, 2017; D. Hudson, 2008). Much like double-entry bookkeeping represented a technology to spread the rationalisation of accounting which, in turn, facilitated valuation and capitalisation (B. G. Carruthers & Espeland, 1991, p. 61), technologies of representation represent technologies for the spread of formalisation, allowing to transform hitherto informal property relations into tradeable assets.

The existing literature on remittances has productively unpacked the "point of sale" of remittances (Maurer, Taylor, et al., 2013; Tooker & Maurer, 2016), their affective economies (D. Hudson, 2015, p. 246), their cultural content (Carling, 2014; Isaakyan & Triandafyllidou, 2017), and the motives of senders and of recipients (Lacroix et al., 2016; Levitt, 1998; Levitt & Lamba-Nieves, 2011; Vari-Lavoisier, 2016). More broadly, it has also pointed toward the place of remittances and digital payments in the business of poverty capital, or what (Maurer, 2015a) aptly terms "poverty payment." However, comparatively less attention has been given to payment infrastructures that allow and measure the value transfer from payer to payee (A. Lindley, 2009; Anna Lindley, 2009; Pollard et al., 2016; Rea et al., 2017; Siegel & Fransen, 2013).

The infrastructural approach to money allows to fill the first gap by foregrounding the cross-border payment infrastructures constituted by the network of Nostro-Vostro accounts that banks maintain with each other. Furthermore, in the context of correspondent banking, this chapter argues that the application of DLTs within existing correspondent banking arrangements aims to reduce costs and fees, and to mobilise the idle liquidity "locked up" in Nostro and Vostro accounts (Maurer, 2016). This is the aim of the next section.

2.1. Remittances in Infrastructural Context: SWIFT, CLS and Correspondent Banking

While banks themselves tend to take a back-seat position when it comes to providing *direct* remittance services, formal remittance services often rely *indirectly* on a network of cross-border Correspondent Banking Relationships (CBRs) (Erbenová et al., 2016, p. 17). Correspondent Banking is a continuous arrangement between financial institutions that enable banks to provide services in countries where they do not directly operate. It covers cash management, international wire transfers, check clearing, payable-through accounts, and foreign exchange (FX) services (The Wolfsberg Group, 2014). Correspondent Banking Relationships (CBRs) encompass so-called "Nostro and Vostro" accounts. Nostro is the account of the respondent bank held by the correspondent bank.

Vostro is the account on the books of the correspondent bank, conducted on behalf of the respondent bank (World Bank, 2015b, p. 13). Correspondent banking can be either limited to one respondent-correspondent relation, or “nested” or “downstream,” when one correspondent bank serves several respondent financial institutions simultaneously (BCBS, 2017, p. 24).

Correspondent banking is a distinctive feature of cross-border payments, due to the lack of a worldwide infrastructure of clearing and settlement (Rambure & Nacamuli, 2008). As we saw in Chapter 5, in domestic payments, messaging, clearing, and settlement happen through Automated Clearing Houses (ACH) and central bank Deferred Net Settlement (DNS) retail payment systems (BIS, 2013). In cross-border payments, however, no such worldwide clearinghouse exists, and transactions must pass through CBRs. Partial exceptions are card payments, which are cleared by the card provider, e.g., Visa or MasterCard, and some large transnational MTOs like Western Union, which might manage independent end-to-end payment services depending on jurisdiction-specific conditions (CPMI, 2014; CPSS, 2003).

Interbank messaging flows mainly through the Society for Worldwide Interbank Financial Telecommunications (SWIFT) (Dörry et al., 2018; S. V. Scott & Zachariadis, 2013). SWIFT is a member-owned, cooperative society comprising more than 11,000 financial institutions across more than 200 countries and territories (SWIFT, 2019). SWIFT’s network spans the globe and it interfaces with a multiplicity of financial market infrastructures, including securities clearing, foreign exchange, and more than 70 RTGS systems around the world (S. V. Scott & Zachariadis, 2013, p. 36). SWIFT connects together monetary spaces by standardising *addressing* spaces, message *syntax* and *semantics,* and by providing a *protocol* that allows an information to be translated to and from different syntax and semantics (SWIFT, 2010, 2019, p. 191).

SWIFT, however, does not move funds: while payment messages flow across borders between one bank and its correspondent, each bank changes the balances in correspondent accounts denominated in their own currency (Dörry et al., 2018). Conversely, the flow of funds happens in the Foreign Exchange markets, on which separate offices of the same banks draw to balance their foreign currency positions based on the payments they committed themselves to. Partial fixes to these risks and costs are the introduction of the Continuous Linked Settlement (CLS) bank in 2002 (CLS Group, 2019b), and some voluntary schemes in place in specific corridors, such as the one between US and Mexico (Orozco, 2004, p. 24).

CLS Bank was created in 2002 as a response to the so-called Herstatt or settlement risk. On 26th of June 1974, 4:30 pm Berlin time, the I.W. Herstatt Bankhaus, a small German bank that was heavily exposed on the then burgeoning FX market, was forced into bankruptcy and liquidation by the German financial regulator. At the time of bankruptcy, Herstatt was short $ 840 million, against assets worth $ 380 million. At 10:30 am New York time, the FX market was already open, and Herstatt had already accepted claims, which was now unable to deliver on. The New York correspondents of Herstatt had then paid Herstatt, but they were not going to receive the payment from their counterparty. This, together with the collapse of the Franklin National Bank (FNB) caused the American regulator to suspend the activities of the US's Real Time Gross Settlement System CHIPS (CPSS, 2005).

CLS is incorporated in the USA, and it provides a proto-clearing house for cross-border payments. It composed of 72 direct or settlement members, 2 user members that need the sponsorship of an existing settlement member, 18 RTGS systems in the currencies in which CLS provides settlement (CLS Group, 2019c). CLS is a peculiar, part-time clearing house that matches payment instructions between currencies and settles them by simultaneously debiting and crediting both counterparties' accounts at CLS Bank. This simultaneity is achieved by synchronising the RTGS systems of the central banks that adhere to this scheme. Its rhythm, hence, is based on the deposit of collaterals for payments waiting to be settled, called pay-ins, and it calculates pay-outs throughout the day. Pay-ins to CLS begin at 7 a.m. Central European Time. Settlement begins at the same time and is normally complete by 9 a.m. CET, but pay-outs (and additional pay-ins) may continue until 10 a.m. CET for Asian currencies, and noon CET for all other currencies. Starting from Chapter 5's pyramidal diagram describing domestic payment spaces (Figure 27), Figure 46 represents a schematic overview of the flow of messaging and funds as payments travel across borders.

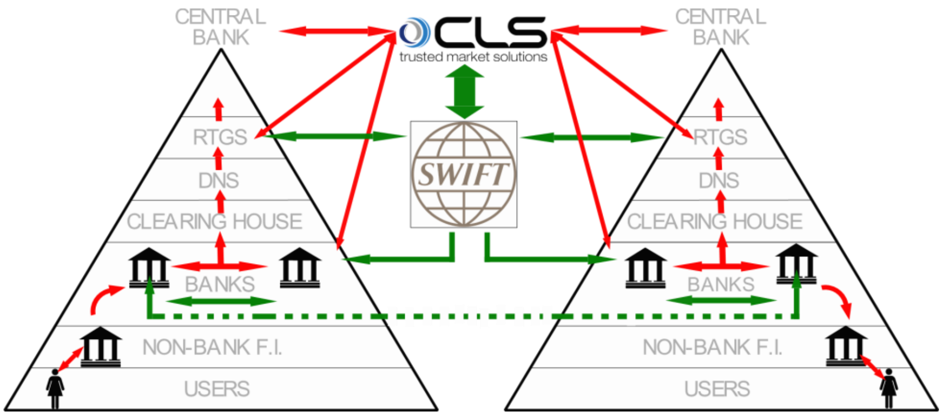

Figure 46: Flow of funds (red) and flow of messages (green) associated with cross-border interbank payments. The dotted arrow represent an optional MT103 message directly from sender to receiver. Source: Author's own, based on an adaptation of Dörry et al (2018, p. 8).

In the past 10 years, the number of CBRs has decreased, and it was concentrated in the hands of fewer financial institutions. First, CBR reduction and concentration is a consequence of de-risking, i.e., risk and cost reduction strategies, based on regulatory compliance costs-e.g., Know-Your-Customer (KYC) Anti-Money Laundering (AML) and Combating of the Financing of Terrorism (CFT)-and real or perceived risk profiles of partnering financial institutions (FSB, 2015). Second, revenues typically associated with cross-border payments have been shrinking, such as transaction fees, FX margins, interest on Nostro-Vostro accounts, and float. Float is money "in flight" between sender and receiver of a payment, and it is hence briefly counted on both accounting books (Federal Reserve Bank of New York, 2007). In 2015, cross-border payments accounted for 20% of the volume, but 40% of the revenues associated with payments, for a total of US$ 300 billion, and remittances accounted for US$ 25 billion (McKinsey, 2016, p. 14). The growth in revenues from cross border payments decreased from 4% in 2011 to 2% in 2015, and revenue margins declined 2% on average between 2011 and 2015 (Ibid). Furthermore, the drop in interest rates made the liquidity stored in Nostro and Vostro account less profitable (Bansal et al., 2016).

In 2015, the World Bank (2015a) found that 80% of responding financial institutions reported CBR reduction and consolidation, and 55% of local and regional banks reported spill-over effects onto remittance-related companies. The Association of Supervisors of Banks in the Americas (ASBA) confirmed that, in 60% of responses, remittances were affected by CBR reduction (Erbenová et al., 2016, p. 12). While this reduction does not seem to impact on the volume and value of remittances, it shows to have a severe impact on their costs (IMF, 2017, p. 19). The number of active correspondent accounts worldwide fell from more than 520.000 to 480.000 (CPMI, 2016a, p. 15). Another study by the World Bank (2015b) found that half of the respondents directly experienced a decline in correspondent banking relationships. Most of the large banks declared that they actively reduced the number of their correspondent banking relations in the 2012-15 period. The Financial Stability Board estimated that, between 2011 and 2016, the number of active corridors decreased by 6.3% (from 13,072 to 12,242), and the number of active correspondents decreased by 6%. For the corridors to and from the Dollar and the Euro, that jointly represent more than 80% of the value of SWIFT payment messages, the decrease was by 15% (FSB, 2017, p. 1).

These trends are uneven geographically, bearing disproportionately on the Global South. While Europe and South and Central Asia have seen a somewhat consistent reduction in transaction costs between 2011, East Asia, Pacific, Middle East, and both North and Sub-Saharan Africa have seen an increase in transaction fees after 2014 (IMF, 2017, p. 20). In the Middle East and North Africa, 40% of banks reported higher costs related to compliance and fees associated with remittances. Palestinian banks are under increased pressure and fears of CBR terminations that would impact on a financial system already in dire straits due to the relevance of the shekel in the Palestinian economy (IMF, 2017, p. 17). In Sub-Saharan Africa, Liberia saw the termination of almost 50% of its CBRs (36 out of 75) between 2013 and 2016 (Erbenová et al., 2016, p. 15).

Sub-Saharan Africa, the Caribbean, and the Pacific are especially affected geographies. Angola has been highlighted as particularly severely hit by Correspondent Banking reduction and concentration. Just one correspondent bank was serving six Angolan banks for foreign exchange services, and it was providing US Dollar notes to 10 financial institutions in total. In 2015, all those relations ceased. Hence Angolan banks had to resort to downstream and nested correspondent banking relationships with subsidiaries of Angolan banks in EU, Africa, and Asia (World Bank, 2018, p. 15). The case of Angola is emblematic of some commonalities across Africa, such as the heavy reliance on correspondent banking and foreign currency (mainly US dollar) to fund international trade, such as the Sino-Africa trade (IMF, 2017, p. 18; Sy & Wang, 2016). In the Caribbean, the Bahamas-Haiti corridor is another critical example: 75% of remittances are same-day settlement payments, which means that de-risking could have close-to-immediate effects on Haitian economy through remittance reduction (CPMI, 2015, p. 10). The Pacific is considered a problematic region for the relationship between correspondent banking and remittances: the decrease of CBRs and the closure of remittance providers brought to a halt. In the case of Samoa, furthermore, remittances compose 18% of the GDP, with 80% flowing through Money Transfer Operators that rely on the correspondent banking infrastructure (IMF, 2017, p. 17).

These trends also affect MTOs and charities disproportionately, due to their real or perceived higher risk profile and lower profitability as clients of correspondent banks. Between 2010 the number of MTOs that had at least one bank account closed, resulting in an impediment to conduct cross-border business grew from 26 to 54%, while the amount of MTOs that did not have any account closed each year decreased from 67 to 42% (World Bank, 2015a, p. 7). As the World Bank (2018, p. 13) argues, "remittances are a volume business, and for small states, in particular, volumes are by definition small." Hence, a price increase and a reduction of channels through which to send payments affect smaller countries more than bigger ones, local banks more than transnational ones, and Money Transfer Operators more than banks.

De-risking is particularly detrimental for remittances because it affects the Global South and MTOs more acutely. Furthermore, CBR reduction and concentration could push back a sizeable amount of remittance forms back into informality (IFC, 2017, p. 49) potentially also making AML and CFT screenings less effective (de Goede, 2003; Vlcek, 2010). To offset these consequences, the IMF and the World Bank investigated blockchain technologies as potential alternatives to Nostro and Vostro accounts. Blockchain technologies promise to introduce shared ledgers without the need to establish centralised clearinghouses, making Nostro and Vostro accounts redundant (IMF, 2017; World Bank, 2018). The next section, hence, will focus on the relationship between Correspondent Banking, blockchain technologies, and formalisation.

2.2. The Application of Blockchain Technologies to Correspondent Banking

The application of blockchain technologies in correspondent banking centres on interoperability, i.e., with the mutual visibility of ledgers, standards, payment infrastructures, and of individual customers and transactions. For the CPMI, the merits of interoperability can be summarised thusly:

> Interoperable payment systems enable the seamless interaction of two or more proprietary acceptance and processing platforms, and possibly even of different payment products, thereby promoting competition, reducing fixed costs, enabling economies of scale that help in ensuring

> the financial viability of the service, and at the same time enhancing convenience for users of payment services. The consequences of low interoperability are overlapping or limited coverage, sunken investment costs, and inefficiency. (CPMI, 2016b, p. 34)

Blockchain technologies are a particular form of technologies of representation that allow interoperability and seamlessness of transactions between the members of the network. In fact, technologies of representation echo DuPont's conceptualisation of notational technologies as "systems for establishing the identity of some digital object […] and then maintaining the technical and social infrastructure for managing and controlling that identity" (DuPont, 2017, p. 651). These identities perform and reinforce the "invisible, parallel life" of the abstract form of assets' value mentioned previously by Mitchell. For Garrod (2019), property and its codification are fundamental for the development of specific forms of capitalism and accumulation regimes, and blockchain holds the potential to be inscribed and form the infrastructural layer of new property relations. For Ishmaev (2017), blockchain technologies represent a new institution of property because they provide "a system of universal access to the knowledge about property rights of all […] owners" (2017, p. 681). This, in turn, guarantees exclusivity and separability of property, i.e., the capability by the owner to exclude all non-owners from the enjoyment of the possession, and the capability by the owner to transfer the ownership of the possession.

Maurer (2017a) showed how blockchain technologies can be and are being used to formalise post-trade settlement and mortgage papers, so that the traded asset can sit "idle" for as short a time as possible. In remittances, the realm of application is similar, but the idle asset is money itself, in the form of Nostro-Vostro liquidity. Blockchain technologies promise interoperability through shared ledgers held by all banks operating cross-border remittances. In 2017, the IMF outlined some of the potential use cases of blockchain technologies in correspondent banking, focusing on risk management, cost reduction, and real-time settlement (IMF, 2017, pp. 35-36). The World Bank further summarised distributed ledgers' potential as that of

> creating a distributed network for cross-currency funds settlement that replaces the correspondent banking network […] lowering settlement costs and increasing efficiency […]. DLT can also allow for new approaches to correspondent banking, which can potentially be part of a solution for addressing de-risking. (World Bank, 2017, p. 23)

While analysing several use cases of blockchain technologies in cross-border payments, the World Bank also mentioned Ripple as providing "commercial cross-border and inter-bank payments combined with cross-currency funds settlement [which] allows for a move away from establishing upfront correspondent banking relationships" (World Bank, 2017, p. 23, see also at p. 37, 2018, p. 29). The next section, hence, will delve in more detail into the Ripple case.

3. Ripple: Formalisation of Remittances and Correspondent Banking

As we saw in Chapters 3 and 4, Ripple is older than Bitcoin itself, since it emerged in 2004. The primary use case for Ripple was to provide an infrastructure for scaling up LETS and other alternative currencies (Fugger, 2004). Between 2012 and 2013, Ripple morphed into a distributed ledger technology-the XRP Ledger-that combines the mutual credit network with the cryptoasset XRP and a distributed currency exchange (XRP Ledger Project, 2019). While Ripple still owns a significant amount of the cryptoasset XRP, the XRP Ledger remains an open distributed ledger, that is not under the direct control of the company Ripple. Since 2015, the company Ripple focused primarily on interbank payments, aiming to become a competitor to SWIFT, and it currently counts 200 customers in 40 countries.

The XRP Ledger, as shown in Chapter 3, allows users to create entirely new currencies and to program their behaviour. If a direct trust line connects them, people can pay each other by changing the balances on that trust line. Otherwise, they can send payments across mutual acquaintances. Payments "ripple" through trust lines between payer and payee if there is an uninterrupted chain of trust lines. Alternatively, they can send each other XRP, which can be sent from any user to any other without the need for trust lines. If the payment requires a currency exchange, the amount flows through offers on the distributed exchange, which works like a digital FX marketplace. People post offers on the Ledger, and the system matches outgoing payments with open offers to exchange one currency with another and finds the most suitable option. The offers included in the calculation do not only include direct exchanges between one currency and another, but also offers to exchange the outgoing currency with XRP, and XRP to the destination currency. This feature is called autobridging, and it uses XRP as a bridge asset in exotic or illiquid currency pairs (Birla, 2018). Furthermore, XRP promises to provide "on-demand liquidity" (Ripple, 2019b): rather than relying on batched payments as in the case of foreign exchange payments routed through major international currencies, the XRP ledger sources liquidity on a payment-by-payment basis.

From the beginning, Ripple marketed itself as a "new and better Bitcoin" for the unbanked and underbanked (Bullington, 2014; Detmering, 2014a, 2014b; Long, 2014b). Bitcoin promised a cheap and fast means for value transfer, but its high transaction fees and slow transaction processing prevented Bitcoin from delivering on that promise (D. Schwartz et al., 2014). Ripple, conversely, promised higher speed, and lower fees and by providing an interoperability layer between payment systems. Ripple promises to be the Internet Protocol for a new Internet of Value in the making (Leonard, 2017). A 2014 post perfectly encapsulates this turn of blockchain technologies into a new frontier of capital expansion: "Far from its misunderstood characterisation as an ideological revolution to usurp institutions or a subversive vehicle for the dark arts, the cryptocurrency movement is about advancing the frontier" (A. Liu, 2014).

Ripple's proposition for the poor focuses primarily on new opportunities for profits and market expansion for financial institutions: "In addition to allowing poor customers to become a profitable market segment, open protocols and distributed architectures can enable entirely new and novel offerings" (Aranda & Zagone, 2015). To allow the poor to become a profitable market segment, hence advancing the frontier, Ripple's interoperability protocols promise to unlock the pools of liquidity "trapped" in Nostro and Vostro accounts, that Ripple estimated between US$ 1.6 to 5 trillion (Ripple, 2018b; Zagone, 2016). Here is a statement of one of Ripple's software developers:

> We found in our research that the biggest cost was the cost of capital. So, banks had a huge amount of money sitting in Nostro and Vostro accounts all over the world to be able to facilitate payments. So, you have two options: I can either offer you, my customer, an immediate payment, or I can make you wait. If I want to provide you with instant payments, I need to have liquidity sitting in the destination country where you want to send to, all the time. (Interview, 25th May 2018)

As said before, this liquidity pressure is particularly hard, especially in low-value payments, for MTOs rather than banks. Here is a comment from a Brazilian remittance company, part of RippleNet:

> So, the client would pay in our account, and we would have to send these transactions to a partner bank's account for them to be able to send it abroad. If we had, let's say, 100 transactions a day, we would send 100 SWIFT messages. And that, of course, brings up the cost of the transactions, because it depends on the corridor, but it's 20 reais to send a SWIFT [...]. The euro is worth more than four times more than reais, so when I am increasing the volumes that I settle in euros, I actually send a lot of reais abroad. That means that I have less liquidity in Brazil, and at the end of the day it's really hard for a small company to operate at high volumes if you actually have to pre-fund an account. (Interview, 5th December 2018)

MTOs are more vulnerable to de-risking because of the inherently hierarchical design of payment systems. As said in Chapter 5, payment systems are layered, resembling a pyramid, with central banks at the top, hosting commercial banks' accounts, which in turn host MTOs' and individuals' accounts (CPSS, 2003, p. 3). On the XRP Ledger, conversely, any account can issue liabilities in the form of a trust line, and all issuers are treated equally by the Ledger. The promise of levelling the payment system hierarchy is mirrored by another interviewee, this time about the relationship between banks and countries in the Global South:

> In Thailand, they are quite keen [to use crypto], because their credit score is already comparatively lower than advanced economies [...]. In Mexico, again, because the country's score is quite low, they are quite happy to use cryptocurrencies. You sell USD, buy XRP, you sell XRP and buy Mexican peso. The thing is that those two separate transactions happen precisely at the same time, so a bank would never have to hold XRP, would never have a position, being exposed if the value might go down. Because that's a significant risk, right? (Interview 10th October 2017)

Originally, Ripple's business proposition was to substitute CBRs and SWIFT with the XRP Ledger. Financial institutions and MTOs would have been gateways, i.e., accounts on the XRP Ledgers that accept deposits off-ledger and issue trust lines on the ledger to represent those deposits. Messaging, clearing, and settlement of cross-border payments would have happened by rippling on trust lines from payers to payees through the gateways. FX market makers and liquidity providers would have issued exchange offers and provided the liquidity necessary to fund cross-currency payments.

However, regulatory uncertainties and reluctance from financial institutions – especially banks – made Ripple develop the Interledger Protocol or ILP (S. Thomas & Schwartz, 2015). ILP does not send payments over a blockchain: instead, it synchronises the ledgers of all financial institutions in the Ripple network (RippleNet). This ensures that both legs of cross-border transactions happen simultaneously, and they either both succeed or they both fail. In transaction-processing software jargon, this property is called atomicity and, together with consistency, isolation, and durability, constitutes the so-called ACID test of transaction processing. As Amsterdam (2001; Cf. IBM, 2019b) succinctly puts it,

> An activity is atomic if it either happens in its entirety or does not happen at all. Atomicity is crucial for writing correct software in many applications; for example, a bank's software may implement a transfer from account A to account B as a withdrawal from A followed by a

> deposit to B. If the first action happens, then the second had better happen as well.

The promise of mobilising idle assets by synchronising circulation performs an imaginary of money as liquidity and lubricant of the engine of the economy. At the same time, it fulfils the promise of the seamlessness of exchanges and frictionlessness of flows typical of logistics (Maurer, 2012a; Plantin & Punathambekar, 2019).

Much as just-in-time logistics promised to make the warehouse obsolete, so instant payments promise to make Nostro and Vostro accounts outdated, or so the belief goes (Nicky Gregson et al., 2017). Standardisation of messaging, clearing, and settlement work like the size of the railway gauge, the standardised dimensions of the shipping container, and the open telecommunication protocols of Ethernet, SMTP, and TCP-IP in making flows seamless and reserves and warehouses redundant (A. Liu, 2015a; Rossiter, 2016). The space defined by SWIFT and CLS is essentially a logistical space, where logistics represents "the art of accommodating [multiple lines of friction] and creating competitive advantage through making interruptions, discontinuities or seams in the spaces of flow […] through different temporal logics" (Nicky Gregson et al., 2017, p. 381). Money is moved like goods in containers but, in so doing, money itself is transformed in the process: constantly translated from one accounting and messaging standard to another, from a currency into another, from one programming language into another, divided up and reassembled based on payment size and liquidity availability.

On top of cutting transaction costs, Ripple also promises to tackle another source of correspondent banking de-risking, namely KYC-AML compliance costs. In multiple hearings and public consultations, Ripple pledged to provide stronger visibility of funds transfers than what SWIFT can deliver. As a response to the UK Payment System regulator, Ripple articulated the visibility of transactions on the XRP Ledger in this way: "Unlike payments sent through correspondent banking today, which are opaque at best, Ripple Ledger provides complete end-to-end transaction traceability" (Gifford, 2015, p. 13). This is a sharp change from the concern with anonymity and privacy that heralded the very emergence of blockchain technologies and cryptocurrencies (Swartz, 2018, p. 632).

In at least one case an MTO reported that the integration in Ripple was a success, saying:

> We have since seen very good results: we were able to bring down the prices of the operations, we don't charge a SWIFT fee to our clients anymore. Previously we were charging a cost of 20 Brazilian reais, which is about 7 dollars. (Interview 5th December 2018)

However, Ripple's website only rarely provides assessments of the direct savings for intermediaries and end-users. Furthermore, it is too early to tell whether there is uniformity in the benefits across the Ripple network. Rather than assessing Ripple's successes and failures, this chapter illustrates the changing landscape of actors, interests, and promises surrounding new payment technologies.

While payments powered by the Interledger Protocol are now live in many corridors, payments using the cryptocurrency XRP are being rolled out only recently. Ripple announced that xRapid, their corporate product that uses XRP as a bridge asset, was being used in the US-Mexico corridor on the 1st of October 2018. On the 17th of June 2019, Ripple entered an agreement with MoneyGram. This company is the world's second-largest MTO after Western Union (Meola, 2016), with a market capitalisation of US$ 148 million (Nasdaq, 2019) and an average revenue per quarter of US$ 300 million (MoneyGram, 2019). According to this agreement, Ripple will provide up to US$ 50 million in exchange for equity in MoneyGram over 2 years, and the two companies will jointly work on XRP-enabled payments (Ripple, 2019c). After signing this agreement, MoneyGram's stock increased by 155% in valuation (Easton & Bloomberg, 2019).

The application of Ripple to correspondent banking entailed a change both of its money cultures and the political economy of its actual use. From a *hawala* credit network geared toward Local Exchange Trading System (LETS), Ripple became more oriented toward profit maximisation. A senior Ripple employee synthesised Ripple's morphing thusly:

> You can still use the XRP Ledger as a distributed exchange, as a LETS system, as a *hawala*-like community credit and lending. And now, we kind of said 'what is the product-market fit for this Ledger? What's the market that we can target with it?' And most of the use cases that we were most interested in the early days like community credits and the LETS feature and the issued asset feature, there just wasn't really a market for it, we didn't see a way that we as Ripple as a company could target. That does not mean that if another company wanted to use the XRP Ledger to target community credit market, that would be wonderful, but Ripple had to focus on something. (Interview 30th May 2019)

Ripple raised a total of US$ 93.6 million in Venture Capital (VC) funding across eight funding rounds between 2012 and 2016. The company also holds a sizeable amount of the cryptoasset XRP, which brought its valuation at US$ 20 billion in January 2019, given the market price of XRP in cryptocurrency exchanges (CoinMarketCap, 2021; Rooney, 2019a). The MTO TransferGo, presenting at a public Ripple event, described the aim of the partnership in enabling its business to grow: "how do you get from 1 to 10 to 100 million users?" (Ripple, 2018f minute 5:45). The Siam Commercial Bank (SCB), furthermore, recently launched a Japan-Thailand remittance product based on Ripple's technologies (Marquer, 2017). As SCB's Chief Technology Officer reported, the partnership with Ripple and the focus on remittances aim toward an "aggressive ambition and expansion" of SCB (Ripple, 2018e minute 7:00).

The move of Ripple's solutions toward profit maximisation entails and implies Ripple's incorporation in existing regulatory structures. Ripple was the second blockchain company to obtain a New York bitcoin license in July 2016 (NYS – DFS, 2016). Ben Lawsky, the author of the BitLicense, went on to join Ripple's board of directors (Ripple, 2019a). Ripple has also been a member of payment improvements working groups of established by the Automated Clearing House and the Federal Reserve in the US, and it collaborated on Real-Time Gross Settlement (RTSG) improvement efforts in the UK and Saudi Arabia (Bank of England, 2017; Ripple, 2018a).

Blockchain technologies are the latest development in network technologies promising "frictionless capitalism" (Pesch & Ishmaev, 2019, p. 267) in the form of low transaction costs and disintermediation. However, as these technologies gain traction, new forms of expertise, specialisation, and institutionalisation create new frictions and costs. While blockchain technologies disintermediate internally, they re-intermediate, albeit in a decentralised way, between each other. As Nelms et al (2018) have it, blockchain disintermediation coexists with walled gardens and "siloed" networks that cannot interoperate with each other. The frontier of disintermediation and transaction fee reduction is moving to the so-called "Layer 2" and "Layer 3" technologies, such as payment channels, decentralised exchanges, and open interoperability protocols, as shown in Chapters 5 and 6 (M. J. Casey, 2018; Herlihy, 2018; Poon & Dryja, 2016). The Interledger Protocol or ILP is one such technology. However, by making Ripple potentially interoperable with other payment systems, the ILP simultaneously puts Ripple in danger of seeing its margins eroded by the competition fostered by its technology (Bloomberg, 2019; Coppola, 2019; Sloane, 2019).

As the struggle for interoperability moves away from immediate end-users, blockchain technologies tend to disappear from view. This eclipse is inherent to technologies becoming infrastructural: they become taken for granted, and they reappear only when they break down (Star, 1999). In fact, an MTO employee said that the application of Ripple's technologies to their remittance platform was not associated with co-branding or with major changes in the user interface and experience. However, this disappearance can never be full, lest it becomes unworkable and economically unviable for the actors deploying and running it. Rather than leading to the vanishing of *any* geographical articulation, these media entail specific geographies of calculation (DuPont, 2019, p. 189). The tensions between “fictions and frictions” (Pesch & Ishmaev, 2019) that propel blockchain technologies’ expansion in the payment space is not accidental, but inherent to the economic theories, models, and assumptions that these technologies perform.

4. Formalisation and the portability of memory.

As said before, the existent literature on blockchain has so far underscored the affordances of these new technologies for *property* (Garrod, 2019; Ishmaev, 2017). With a flank move on this literature, Maurer argues that the Cambrian Explosion and the emergence of blockchain are uncovering the connection between money and memory:

> Despite most Bitcoin proponents’ claims that the currency is completely fungible, it provides this alternative account by constraining fungibility: no one bitcoin is truly the same as another, as each contains the history of its transactions along the way. Each is always earmarked already. Money of account, in Bitcoin, contains within it its individual, socioeconomic history. (Maurer, 2017a, p. 226)

This represents a flank move because the concern is not immediately with property, but with memory of that property: “it is not that [an asset] cannot be separated from its owner, but rather that it cannot be separated from its history” (Ibid). Assets become mobile because the memory underpinning those assets has been rendered immobile. The formalisation of payments through the ostensible interoperability of blockchain applications, then, is the fixation of memory in technical artefacts to allow for the recorded assets to flow freely in market exchanges. Money represented on a blockchain is the maximum degree of liquidity – understood in this case as speed of turnover – deriving from the maximum degree of fixity of memory.

From this discussion, however, a difference emerges between interoperability through blockchain technologies and generalised interoperability, or formalisation through stratification and formalisation through axiomatics. To put it in other terms, the formalisation of payments and remittances is not only a linear movement from less to more materialised memory, but a difference in the articulation of that memory. Rhizomatic and informal payment systems are based on fully localised memory. Networks like *hawala* can truly be global from their very inception precisely because of the localised articulation of memory they entail: the payer and the *hawaladar* know each other, two *hawaladar* across borders know each other and have accounts with each other, and a *hawaladar* in the receiving destination knows and has records with the payee. In smooth spaces like informal value transfer networks, "one never sees from a distance in a space of this kind, nor does one see it from a distance" (Deleuze & Guattari, 1987, p. 493).

Domestic payment systems are predicated on isolated books and on selective "tropic points" (Guyer, 2012, 2016) where, through correspondent accounts, one is able to move money either from one level of the pyramid to the one above, or from one pyramid to another. Hence, memory in these systems is localised, but transferred through institutionalised bilateral translators. SWIFT and CLS afford such tropic points for messaging and settlement of multi-currency transactions. Blockchain technologies do away with these tropic points and, instead, allow for unhindered *internal* circulation of claims through permanent and universal recording of the network state. The interoperability *through* platformisation promised by the XRP Ledger promised the creation of a meta-book where all the books would be hosted, where all the localised relations of credit and debt could be made visible and liquid across the network. This entails a formalisation of memory which is still localised, albeit within a larger range of vision: the XRP Ledger promised to record all accounts across all participants across the globe, while also affording instant messaging, clearing, and settlement.

Generalised interoperability, understood in Chapter 5 as layered modularity in the exchange of value across layers through computational stacks, entails the production of "portable memory". Let us recall two of the "software primitives" that animate the Interledger Protocol suite. First, the Interledger protocol borrows – not unproblematically, as seen in Chapter 5 – the layered modularity of the Internet Protocol. This means that there is a functional hierarchy based on different levels of abstraction proceeding from the physical layer of cables and electric impulses (for the Internet) or settlement (the ILP), all the way up to the user-facing application layer. This architecture is predicated upon two principles: each protocol layer only needs to "know" how to translate messaging coming from the layer below, without necessarily knowing how the layer itself is internally built, and each layer works by abstracting away as much complexity as possible. Within this architecture, money-as-memory exists at the "physical layer" of the ILP stack, i.e., it lies in ledgers that the Interledger layer does not need to know in their internal complexity. Interoperability through Interledger connections is secured by abstracting away memory from the material conditions where it emerged, and by keeping the complexity that that memory represents in the individual ledgers, who will take care of settlement through their own internal rules.

The second element of is packet switching. Over the Internet, any piece of information is "sliced" into standard-sized packets and sent over multiple routes based on the speed of the connection, geographical proximity, and other criteria, according to the "routing tables" stored by any router connected to the Internet. While malicious and law enforcement actors alike might be interested in intercepting these flows of information, in principle a neutral connector and router does not need to know which kind of information it is relaying, but only from which node that information is coming and to which node it must be forwarded. The destination node, then, will collate together all packets connected through their headers, and reconstruct the piece of information in its entirety – a picture, a PDF file, etc. Over Interledger, this means that payments are similarly fragmented into bite-sized chunks and sent over chains of connectors who put their liquidity-bandwidth at the disposal of other people who want to pay.

Packet switching for payments, however, differs in one fundamental way from information: a router relaying information only needs to make available computing power and connection speed, but an Interledger connector needs to make available liquidity, in the form of social relations of credit and debt materialised in memory. In the original RipplePay system, payments *rippled* through trust lines connecting participants: if I owe money to a friend B who already owes money to another friend C, I can pay C instead of B to shorten the settlement time of both transactions. At the same time, if I want to pay D, whom I don't know, I can pay E if that person is friend of, or already in business with D. Interledger generalises this topology by sending one payment, fragmented in multiple packets, across lines of credit and promises to pay between multiple actors and hosted in multiple ledgers. The receiving node only needs to know the receiving sums and the payment headers that allow her to recognise all micro-payments as parts of the larger sum that she was expecting.

Memory becomes fully portable both because it is abstracted away from the layer in which a transaction happens, and because that memory becomes cut and reassembled as it crosses ledger boundaries. As we saw in Chapter 4, Ripple promised to create "the universal calculator that Hayek dreamed of" (Ripple, 2013). As we saw in Chapter 5, this calculator was provided by the Interledger Protocol, rather than the XRP Ledger, not as a world-sized megastructure and megamachine (Bratton, 2016; Mumford, 1967), but as an "infrastructural fractal" (Jensen, 2007) that provides macro effects through micro structures. There is no universal, centralised, or ubiquitous calculation of exchange rates, liquidity-bandwidth constraints, and pre-existing credit-debit relations, and yet the system is designed to allow for universal capability to transact across whichever currency and accounting space.

5. Conclusions

On the 27th of August 2020, the name of the original RipplePay project was changed into "RumplePay", to "avoid any possible confusion as [Ripple Inc.] continue growing their new version of Ripple" (email exchange 27th August 2020). The original RipplePay project is now known as RumplePay (RumplePay, 2020). While this symbolic act was not immediately perceived by those involved as traumatic or invasive, this severing of ties is nonetheless of import here for what this chapter discussed about formalisation. In fact, as stated earlier, a dynamic of co-opetition has traversed distributed ledger and interoperability technologies that has cast the deployment of innovations as a matter of formalisation, efficiency gains and of mobilisation of hitherto idle assets. This process, in turn, seems to have resulted in a formalisation *of* blockchain and interoperability technologies themselves, so clearly encapsulated by this change of name request. Ripple's website, up until 2014 used to refer to Ryan Fugger and the original RipplePay project as an example of how Ripple was older than Bitcoin, based on different conceptions of money, and more capable than Bitcoin to really create the "Internet of Value" (Long, 2014a). Now the references to the original RipplePay become unnecessary sources of confusion vis-à-vis Ripple's marketing, branding, and communication strategies.

This chapter analysed remittances by foregrounding the infrastructure that makes these payments possible, i.e., correspondent banking. Correspondent banking is depicted by blockchain technologists as "lacking" synchronisation, standardisation, and interoperability, in a similar way as informal property relations are painted as missing the pricing and rights allocation necessary for assets such as land to become fully "living capital" (T. Mitchell, 2007). Blockchain technologies do not represent a rupture in the tendency towards formalisation. Instead, by promising interoperability and frictionless payments, blockchain technologies aim to free idle capital, democratise liquidity and flatten the existing "pyramid" of monies encompassing MTOs, correspondent banking accounts, clearinghouses, and central bank settlement systems (Caytas, 2016; Wandhöfer, 2017). Simultaneously, the use of blockchain technologies to expand the frontier of market relations turns blockchain technologies themselves into a new market frontier through their incorporation in legacy infrastructures, business solutions, and public and private regulation. Furthermore, the original stress and focus on anonymity is attenuated by harnessing the capacity of blockchain technologies to better track transactions.

Frictionless circulation and transaction cost annihilation, however, have their own inherent limits. While a blockchain can provide interoperability and simultaneity of clearing and settlement, each blockchain is a separate network, following its own rules and following different accounting standards. As more and more blockchain technologies emerge, this creates more, not fewer intermediaries, with the result of reproducing the transaction costs that were meant to disappear. Hence, blockchain interoperability moves the competition from the cross-border to cross-chain payments, as testified by the emergence of "Layer 2" interoperability solutions. Despite the flamboyance of blockchain marketing, its most important applications will impact on less flashy and more "boring" sectors of banking and payments, such as middleware (DuPont, 2019, p. 172) and back-office reporting and interoperability (Fanning & Centers, 2016).

Hence, the "inherent" tendency of blockchain technologies toward disintermediation is not unambiguous (Campbell-Verduyn & Goguen, 2018). As existing and incumbent financial players are flocking toward blockchain technologies for clearing and settlement of payments, existing power structures can be challenged but also reinvented and reinforced. Maurer (2015c) rightly pointed out that the ownership, design, and access to payment infrastructures are deeply political problems that refer to the nature of money as a social institution. Blockchain research, based on the novelty and unruly origins of the technology, has produced a wealth of literature both on its technical aspects and inner workings, on the alternative imaginaries that inform this design, and on the economic practices that it can enable. The increased corporate co-optation and competition, comparatively, received far less scrutiny. This chapter, hence, tried to show the process of co-optation and formalisation without giving analytical primacy to either existing infrastructures or emergent technologies.

Cost-benefit analyses are particularly hard in this field, due to its ever-changing transformations (Caytas, 2016; Godfrey-Welch et al., 2018). Again, the interviews I conducted seem to point toward a general appreciation of the improvements brought by

Ripple, but more research is needed in the lived experience of the payers and payees in this case. This chapter pointed out that there is a gap in the literature on the “rails and pipelines” that underpin remittance transfers, and that most of the research tends to concentrate on the point of sale. This chapter’s limitation is the flip-side of the latter: by foregrounding remittance infrastructure, this chapter has comparatively overlooked the individual end-users.

Blockchain literature has been beneficial in foregrounding and in making “transparent” this technology (DuPont, 2019). However, it has somehow obscured and forgotten the broader social processes in which it is inscribed and deployed. The adoption of these technologies is often narrated as a process of actualisation of inherent positive or negative tendencies and potentialities, rather than a process of mutual shaping, dependent on enabling and disabling factors. This literature needs to reconcile with previous scholarship on money and finance to understand not only how the new technology impacts on existing hierarchies, but how both existing and emerging technologies influence one another. Blockchain technologies are neither embryonic forms of radically different societies and monetary systems, nor business as usual. Instead, they “productively engage in and perform a plurality [of modes of finance], thus blurring the line between alternative and dominant, formal, and informal, embedded and disembedded” (Maurer, 2012b, p. 415). The study of digital money needs to foreground competition, conflict, and redistribution of resources, beyond both solutionism (Morozov, 2013) and dystopian cynicism (Bogost, 2017; Garrod, 2016; Golumbia, 2016).

Lastly, the application of blockchain technologies and, subsequently, Interledger interoperability technologies to payments produces a change in the articulation of memory that underpins all money forms. While informal systems allow for truly global and cross-border networks to be established out of localised memory of credit and debt relations, formalised payment spaces are based on hierarchies and layers of memories, which are made exchangeable with each other through institutionalised tropic points. Blockchain technologies, conversely, allow to produce fully liquid claims by recording fully fixed memories and records of asset ownership. Interledger interoperability technologies, lastly, produce fully “portable memory” by abstracting away the record of promises, credits, debts, and assets away into different ledgers, and by fragmenting and recomposing memories as they traverse multiple networks and borders. If Layer 2 and Layer 3 technologies will gain traction in the years to come, then this new and emergent articulation of the “money of account” needs to be attended to. Such rearticulation will again interrogate the relationship between money, power, and space through a rearticulation of the act of exchange of currencies against each other, of the act of paying across borders, and the act of using multiple formal, informal, legitimate, or illegitimate intermediaries to carry out transactions.

Conclusions

If infrastructures become so when they recede from view, a focus on the power, control, and distributive effects of infrastructures are necessary to prevent these forms of power and exclusion from becoming a repressed "technological unconscious" of money (Thrift, 2004). This thesis, then, has illustrated how a conceptual move called "infrastructural inversion" (Bowker & Star, 2000, p. 34) enables us to understand the material conditions of digital money which is ostensibly immaterial and virtual. As we saw in the Introduction, the past decades have seen an explosion in the number of companies, platforms and "pipelines" through which payment and value is moved within and across borders. This, in turn, poses some empirical and, indeed political opportunities: as Brekke (2018, p. 61) put it, "the doors of the money press have been flung open". The wiring, plumbing, and engine of money as a socio-technical infrastructure are, for a short moment, on display, and capturing money conceptually is as essential as seizing it politically. This concluding chapter will then summarise the content and core arguments of the dissertation, before further expanding on its wider contributions, as well as on the areas left unstudied or underexplored, which might prove as fruitful avenues for future research.

Chapter 1 reconstructed a theoretical and conceptual toolbox to conceptualise money *as* infrastructure. This allowed to go beyond the dichotomy between money as commodity and money as credit, money as object and abstract money of account, to apprehend the infrastructural materiality of money as a memory machine. Through such conceptualisation, we can see that money digitalisation – underpinning the present Cambrian Explosion in money and payments – is far from being the demise of money's materiality. Both money and digital objects, in fact, retain an irreducible materiality constituted by the infrastructures of money circulation. If money is a memory bank (Hart, 2000), then memory works, after Stiegler (2010) and Hui (2016), through three degrees of retention, culminating in the externalisation of memory itself and in its crystallisation into technical artifacts. The Cambrian Explosion of payments is regarded by this thesis, then, as an expansion of money's internal complexity – a process described by Stiegler, via Derrida, as "grammatisation" (Stiegler, 2010). This infrastructural approach to money also creates a theoretical "trading zone" between science and technology studies and social and political economy theories of money, such that concerns with the agential capacity of materiality and value extraction and accumulation can be held together and foregrounded.

If money is an infrastructure, as Chapter 1 argued, then we need a conceptual vocabulary that is capable to apprehend the manifold ways in which an infrastructure asserts its agency, and to translate and adapt that vocabulary to money. Keller Easterling's (2014) concepts of active forms and dispositions provided the tools to unpack the wires, pipelines and standards composing the materiality of each specific infrastructure. Susan Leigh Star's (1995b) concept of ecology, as currently expanded upon by new materialist scholars in STS (Hörl & Burton, 2017; Hui, 2020), provides a way to apprehend intangible materialities of technological systems and their capacity to influence dispositions. Indeed, as it has been developed here, the concept of ecology also opens up for exploration the deep relationality of infrastructures by acknowledging how they co-evolve with their surrounding *milieu* of other infrastructures, institutions, imaginaries, regulation, and political economies. Like the Stieglerian and Simondonian concept of technicity (Kinsley, 2014; Simondon, 2016; Stiegler, 1998), ecology recognises that a technology and its milieu are born together and constantly co-evolving (Kinsley, 2014; Simondon, 2016; Stiegler, 2010).

Chapter 1, moreover, identified three sets of analytical concerns that follow from this theorisation of money as infrastructure, namely topology, enchantment and desire, and formalisation. These concerns were also, of course, each further developed and addressed, in turn, in Chapters 5, 6, and 7. A concern with topology enables us to understand the spatialities of money infrastructures beyond the cartography of bounded currency areas. Once money was shown to be a mnemonic infrastructural technology, concerns with topology also illustrated how money and computation share a layered internal spatiality made by a "stack" of computational instructions or credits and debts accumulating over time (Chun, 2008b; Solomon, 2013). Concerns with enchantment and desire, meanwhile, encourage consideration of how infrastructures are maintained, changed, and propelled by libidinal and economic investments (Harvey & Knox, 2012; Larkin, 2013, 2018). Lastly, analytical concerns with formalisation centre on how the interoperability of infrastructure is far from being a neutral endeavour, and is instead a power-ridden act that, at once, allows platform-enabled forms of value extraction and accumulation, and the reduction of frictions and the mobilisation of "dead" and idle pools of capital (Datta, 2017; T. Mitchell, 2007).

Chapter 2 developed a research design and methodology befitting a study of money as an ecology of infrastructures, one capable of "situating money in time and place" (Gilbert, 2005). Starting from geographical reflections on the challenges to "following" money and its trajectories (Christophers, 2011a, 2011b; Gilbert, 2011; R. Martin & Pollard, 2017), on the "taking place" of cultural economies and cultural economic practices (Hall, 2011), and on the layered (in)visibilities of digital infrastructures (Furlong, 2020), Chapter 2 developed a radically multi-sited approach to fieldwork. First, deriving from the ecological and deeply relational approach to money infrastructures, the Chapter devised a specific form of case selection that configured Ripple as a "case within a case within a case", i.e., a revelatory case (A. J. Mills et al., 2010) that, by virtue of occupying both the space of blockchain technologies and of cross-border payments, is capable of making visible hitherto unnoticed connections and dynamics.

Chapter 2 also elaborated how a radically multi-sited approach to the field became necessary as a response to the specific "trials of access" (M. F. A. Dos Santos, 2018) that research in finance and technoscience entails. The difficulties to go beyond hyper-visibility of actors on the public scene and to achieve access to often secretive institutions and to "parse through" widespread self-promotional and public relations jargon requires a different fieldworker subjectivity – a "scavenger", as defined by Seaver (2017) – and a different research ethics. However, access is not the only reason why a multi-sited approach to the field is required: as Hart and Ortiz put it, money is by definition embedded in the world system, hence it requires a methodology that is capable to bridge "between ethnography and world history" (Hart & Ortiz, 2014). Chapter 2 thereby drew upon existing ethnographic reflections regarding multi-sited and networked approaches to the field (Burrell, 2009; Preda, 2017), and developed these for a research design that included an 18-month combination of participant observation of eight cryptoassets industry fairs, seventeen in-depth interviews, documentary analysis of reports spanning from cryptoasset white papers to central bank and regulatory reports on payment systems, and online ethnography through participant and nonparticipant observation of online forums and collective zoom calls. The field, then, becomes a rhizome, it "has no beginning or end; it is always in the middle, between things, interbeing, intermezzo" (Deleuze & Guattari, 1987, p. 25). Chapter 2 concluded with some reflections on the problematic temporalities of multi-sited and hybrid fieldwork.

Informed by the theoretical, conceptual, and methodological work of Part I, Part II of this thesis developed an analysis of money infrastructures in light of empirical developments stemming from the Cambrian Explosion in payments and, in particular, the proliferation of blockchain technologies and DLTs. Chapter 3 began from an analysis of Ripple's technologies "under the hood". It moved on to develop a minimum infrastructural terminology that was capable, at once, of being accurate enough to illustrate the main areas of blockchain development and, simultaneously, of being open-ended enough to capture how terminology itself and its standardisation are not neutral endeavours, and how research needs to keep the tension open between fixity of meaning and fluidity of matter (Barad, 2003). This included taking stock of the multiple taxonomies that have been developed to capture developments in blockchain and converted them into the analytical vocabulary of active forms and dispositions provided by Keller Easterling (2010, 2014). In so doing, Chapter 3 stressed how the differences in blockchain design are visibly political, and how the agency they afford to the overarching infrastructural space becomes textured, complex, and always capable of unforeseen uses and adaptations.

In particular, five active forms were isolated as crucial to blockchain money infrastructures: multipliers, switches, governors, wiring, and topologies. These active forms are not separate and operating in isolation: in fact, Chapter 3 identified four combinations in which they operate within blockchain applications. Consensus algorithms operate as governors but they also define the internal topology. The software code and its affordances – open or closed source, Turing completeness, and so on – act as the wiring of the infrastructure. Coin and tokens, furthermore, are both switches and multipliers at once, in that they can enable and disable specific affordances, they can make some things possible and others impossible, or making some possible things feasible or unfeasible in economic, energetic, or computational terms (Cf. Dourish, 2017).

Chapter 4 developed the concept of ecology to understand the process of co-evolution of blockchain infrastructures in the decade following Bitcoin. The chapter foregrounded the imaginaries, stories, and cultures that animate this infrastructural space, to place blockchain in the wider context of FinTech revolution and Cambrian Explosion of payments. Moreover, the chapter reconstructed the evolution of Ripple from a mutual credit network to a global interbank cross-border payment infrastructure. This change was brought about by a combination of factors, such as the 2015 lawsuits and the split with Stellar, which in turn made it easier and more remunerating to turn to banks, rather than individuals, as "customers". Furthermore, the appreciation of XRP priced out most of the alternative uses of the XRP Ledger, turning that infrastructure from a multi-currency credit network into a largely speculative space populated by cryptoasset market makers and exchanges. It then shows how a set of cultures and imaginaries at the crossroad between Keynesian and Hayekian theories of money were purported as being synthesised by the "neutral" design of the XRP Ledger, but that was far from what happened.

Part III unpicked specific analytical dimensions, namely topology, enchantment, and formalisation. Focused on topology and drawing on Till Straube (2016) and Paul Dourish (2017), Chapter 5 argued that the materiality of infrastructures engenders specific spatialities. Similarly, to how active forms combine to determine dispositions, material components of infrastructures produce different topologies based on the diagram and abstract machines that inform them. In specific, four topological constructs were deployed: pyramids, rhizomes, platforms, and stacks.

First, pyramids have historically been the topology of domestic payment infrastructures centred around central bank-operated Real Time Gross Settlement systems and overcoded by the sovereign money of account acting as a "despotic signifier" (Deleuze & Guattari, 1987, p. 117). In comparing the Westphalian order with the present-day Stack as the new topology of planetary computation, Bratton defines the former as a "partitioning of planar geography, separating, and containing sovereign domains as discrete, adjacent units among a linear and horizontal surface. […] a specific and durable compositional lamination of territorial and governmental layers into one" (Bratton, 2016, p. 5). However, the "lamination of territorial and governmental layers" needs more explanation: it is precisely through the vertical layering inherent to money that the state's territory can be constructed as a two-dimensional entity. It is because it centralises the synchronisation of clearing and settlement, as well as it standardises note issuance and money of account, that the state can be seen first and foremost as an enclosed institution exerting sovereignty over a territory.

Rhizomes, second, are the abstract machines used throughout history to facilitate exchanges across borders, based on interpersonal trust (de Goede, 2003; M. Martin, 2009; Vlcek, 2010): *hawala* and *hundi* are the oldest examples of this diagram, and Ripple tried to generalise their functioning across any border by allowing anyone to create – and destroy – money. Platforms, third, are the abstract machines informing blockchain technology as a particularly extreme version of the platform business model (Langley & Leyshon, 2016, 2020; Srnicek, 2017a), and they are based on the idea of subsuming all pre-existing intermediaries into an all-encompassing stratum laid over and intermediating within a specific social field (O'Dwyer, 2019b; Westermeier, 2020). Finally, protocological stacks are the abstract machines of axiomatics that enable universal and ostensibly "agnostic" and value-free interoperability (Pesch & Ishmaev, 2019; Tasca & Piselli, 2019). Through layered modularity (Blanchette, 2011; Dourish, 2017), these machines, exemplified by the Interledger Protocol, allows universal translation of forms of value into each other but, in so doing they engender new political economies and produce imperatives that reverberates on the original designs of money infrastructures with deeply political effects.

Even in the stack, in fact, form and function, metaphor and materiality remain in tension: "money as an abstract quantity cannot be divorced from a becoming-concrete without which it would not become capital and it would not appropriate production" (Deleuze & Guattari, 1987, p. 249). Like any metaphor, the stack at the same time works to prevent us from seeing other aspects of the same concept (Lakoff & Johnson, 2003), and any form of design that takes inspiration from a specific form of stack and a specific form of Internet also obscures potential *other*nets, and the politics and topology inherent in choosing specific designs (Blanchette, 2011; Dourish, 2017). Ostensibly trivial and technical questions like bandwidth, packet size, and address space deeply political (DeNardis, 2009).

Chapter 6 shifted the focus of the thesis from materiality and space to materiality and desire, and it sought to illustrate how the active forms and dispositions populating blockchain infrastructures have been caught in a "compound desire bubble" (Cf. Blyth, 2008) triggered by the different affordances they provided. In particular, Chapter 6 illustrated the different articulations between materiality and desire with a historical comparison with three previous bubbles: the Tulip Mania, the Dot Com bubble, and the Railway Mania. These three historical comparisons respectively foreground the cryptoassets as singularities (Dallyn, 2017; Karpik, 2010), the blockchain platform for the rent extraction they afford (Langley & Leyshon, 2020; Westermeier, 2020), and interoperability as the condition of possibility to realise the returns produced by assets and platforms. There is, in short, a relationship between the materiality of the technology that is the object of investment and the act of investing, a relationship forged through more-than-rational and more-than-calculative promises and expectations. What is normally deemed invisible, taken-for-granted, and boring like payment and data infrastructure became the object of speculation and frenzy that invested professional and popular investors alike.

The infatuation with the materiality and even the aesthetics of blockchain technologies and cryptocurrencies is particularly surprising given the obscureness and exoteric nature ascribed to that same materiality. The British-American comedian John Oliver, in the "Last Week Tonight" episode aired on the 11th of March 2018, summarised blockchain technologies with the punchline "everything you don't know about money, combined with everything you don't know about computers". The Daily Show's contributor Ronnie Chang, curating a short clip on cryptocurrencies, mocked the complexity of the topic by, first, re-enacting the scene from the movie "The Big Short" where Margot Robbie explains the functioning of a derivative from within a bathtub. Then, Chang is seen trying to create his own cryptocurrency with his voiceover despairing on how complex it must be to create this new money. The voice is immediately cut short after a few seconds: "done!" A now triumphant Ronnie Chang goes out and tries to convince hot-dog sellers and taxi drivers to accept Chang-coins for payments and blaming their stupidity for not accepting an asset that will redefine finance forever.

Chapter 6, then, showed how complexity, obscurity, and to some extent boredom that are so often associated with money and payments could become object not only of ideological debate, but of speculative frenzy. It also tried to zoom into the specificities of this enchantments, on what enchantment focuses on, and which kind of force it exerts on the materiality of payment infrastructures. Chapter 6 argued that any form of libidinal investment in new technologies is always already a form of political investment, and the questions it raises are always already political (Papacharissi, 2015). In shaping the interior and infrastructural design of money, we ought to remind ourselves that, just because a technology attract capital and fascination, there is no reason why such flows should remain unchecked and unchallenged.

The three bubbles described in Chapter 6, however, are not static and frozen in time, nor are they exhaustive of all the dynamics traversing the cryptoasset space. In fact, lately, the saturation of the ICO market has hampered the ease and speed with which ICOs are launched and profits realised. As an informant described it,

> At the start, in May [2017] I contributed one or two ETH, at that time worth 140$ each, I left my flat, I went to see some family for dinner, and within that time the token called ANT hit an exchange, it had already been listed on the exchange, so I went on there and I sold half the token for a small profit. But now everything is saturated, so if you try to make 5X on your initial investment you're not going to be able to do it, unless you find a very solid company, those days are gone now. Everyone is fighting for attention from investors, and investors are tired of that now. White papers are now light papers, they do two pages, because people don't have time to go through all the pages (interview 4th December 2017 minute 18:00 – 20:00).

As the market changed, and with an increased attention from regulators, what is often called "the wild west" has been somehow receding. As an informant put it,

> The challenge for someone wanting to design a utility token is how you make sure it's not a security, and for a security token is how you don't go to jail, because there is a lot more legal risk associated with tokenisation, and that is why you see less project in that space because it's less of a wild west anymore (Interview 29/05/2019).

In fact, some crypto companies sometimes actively tried to distance themselves from the ICO craze as an active marketing strategy. A representative of a blockchain platform for international development and aid said: "we don't want to get into the ICO charade, there's too much pressure on delivering something fast" (field notes 31/10/2017). Another company that uses blockchain technologies for storing and sharing sensitive data, put it rather bluntly during a start-up pitch during a conference: "we are not a crypto company, we don't have a token, and our ICO is scheduled for never: we solve real world problems" (field notes 11/06/2018).

Chapter 7 focused on the analytical theme of formalisation in remittances and of interoperability in money infrastructures. Leveraging Timothy Mitchell's concept of "formalisation" and of "technologies of representation", Chapter 7 showed that interoperability is the driver towards the mobilisation of "idle assets" and "dead capital" in the form of Nostro-Vostro accounts in correspondent banking. While existing literature tends to focus on the formalisation achieved at the point of sale in remittances, this chapter took a step back and looked and the often-ignored infrastructural network of correspondent accounts that banks have been maintaining with each other for centuries to send payments across borders. This infrastructure is instrumental to most of the existing point-of-sale remittance solutions amply studied in the literature, like Money Transfer Operators (MTO) that work through nested bank accounts.

The introduction of interoperability technologies such as the XRP Ledger and the Interledger Protocol were investigated as providing an ostensible technological fix to a political-economic trend towards "de-risking", wherein Nostro-Vostro accounts are being closed because either considered too risky and too expensive, or because the "parked" liquidity in those accounts is considered as "idle" and "dead". Interoperability, then, was shown to work as a technology of representation that makes payment systems visible to each other and capable of being synchronised, making correspondent banking redundant. However, this impetus towards formalisation *through* infrastructural blockchain technologies was also shown to produce a trend of the formalisation *of* blockchain technologies, as "alternative" and "informal" uses become caught into a dynamic of "co-opetition" between corporate applications.

Moreover, and developing in further depth the theme of money as mnemonic technology, Chapter 7 shown how the political economy of interoperability is enabled through and by a transformation of memory and its relationship with space, time, and value. Domestic payments are predicated on a hierarchically-arranged memory that also corresponds to different degrees of value and liquidity: central bank liabilities, though being a very exclusive asset, are the most valuable and liquid within a payment system, and they enable the final settlement for all obligations emerging within a payment space. Rhizomatic payment systems are based on localised memory enabling the transfer of value across borders: their inherently translocal character is only made possible by the local nature of the ties that *hawala*, *hundi,* and mutual credit networks leverage. Platforms produce memory as universal through distribution and repetition: memory about the state of the network is considered universally true and immutable through the dispersion of multiple, mutually consistent records across distributed networks. Interoperability stacks produce "portable memory", fully detached from the context in which that memory emerged, because they abstract away the concreteness of that memory through layered modularity. Memory is only stored within a ledger, and interconnection makes memory portable by the fragmenting of that memory into "value packets".

1. Further Reflections on Wider Contributions

1.1. Between the Old Materialism and the New: Technological Fetishism

Running beneath and through this thesis's infrastructural approach to money, there is a meta-theoretical effort to conjugate historical materialism with new materialism. As Anand and colleagues pointed out (2018), infrastructure itself and its conceptualisation is somewhat indebted and genealogically connected with Marxism-inflected understanding of infrastructure as determinants of forms of life. The combination of new and historical materialisms provides the kind of post-Cartesian demystification of technological fetishism that Hornborg (2014) argues for. This enables us to go beyond traditional "progressive" accounts of technology as outright empowering, but also beyond the insufficient attention to politics, political economy, and exploitation that can characterise STS (Christophers, 2014; Winner, 1993). However, contradictions and tensions remain between new materialist onto-epistemologies (Coole & Frost, 2010; Dolphijn & Tuin, 2012) and historical materialism (J. Edwards, 2010):

> If materialism is a doctrine that holds that material reality determines or shapes social reality, then Marx is *not* a materialist. In a way, focusing our attention on physical objects that play the role of social objects may mislead us because they conflate physical with social objectivity. Doing so hides the crucial question of how something assumes the place of a social object regardless of its materiality (Yuran, 2014, p. 61 emphasis in the original).

Despite this ostensible division, the new materialist understanding of infrastructures share an uncanny similarity with the characteristics of commodities in historical materialist accounts of production. Just as a commodity, in becoming a commodity, obliterates and obscures its underpinning social relations, so infrastructures retract from view and become taken for granted.

This thesis, then, combined the new materialist interests with the "entanglement of matter and meaning" (Barad, 2007) with "old" materialist concerns of political economy. For Edwards (2010, p. 282) historical materialism is

> An ongoing analysis of the current social and political conditions of contemporary capitalist society in light of their historical development, their embedded institutions and practices, and the contingent circumstances that serve to reproduce them – or that threaten their reproduction – over time.

According to this definition, casting the difference between "old" and "new" materialisms as an irreconcilable ontological cleavage seems to derive more from dogmatic understandings of either one or the other body of literature.

As this thesis has shown, an alliance between old and new materialism can also provide a fresh perspective on the intangible and libidinal content of money and digital infrastructures, not least by leveraging Marxian and post-Marxian understandings of desire in capitalism and reflections on desire and fetishism in STS. Brian Larkin, in an already-mentioned definition of infrastructure, shows how infrastructures can entice "fetish-like" desires (Larkin, 2013, p. 329). As Chun (2008a) shows, the concept of the "fetish", when applied to technology, is not only that which obscures the complex ecology of social and material relations that make that technology possible, but also a fetish in terms of the investments of desire and imagination that are associated with that. Speculatively, Noam Yuran (2014, 2017) showed how desire shapes and is shaped by capitalist monetary relations in a way that goes beyond the trope – reiterated also by Marx – that money homogenises values and creates unproblematic universal equivalence. Viana analysed

High-Frequency Trading (HFT) in a way that lies somehow in between Chun and Yuran and that draws them together:

> The shaping of the market occurs when an enormous amount of bidding teaches the algorithm how the data, *the particles of desire (supply and demand)*, are distributed, allowing the computer to decide how to act upon this overarching representation. It is a representation of the market at a certain instant, a nearly immediate cartography of the market: a real-time map of supply and demand. Yet one must notice that the trader herself cannot see the map that results from the cartography operated by the algorithm. Only the machine itself has direct access to this level of organised data. (Viana, 2018, p. 93 added emphasis)

This thesis shows that, applied to new, burgeoning, and hyped technologies such as blockchain and DLT, demystification of infrastructural fetishism also means to recentre and make visible again the plethora of intermediaries that these new technologies purport to overcome once and for all, while they most often just make them less visible. Kaika and Swyngedow (2000) reconstructed the shifting patterns of fetishism of urban networks and showed the present moment as one where "The new urban fetish, then, lay in the apparent aesthetic disconnection from all the old, dirty unsafe and 'ugly' networks" (Ibid, p. 135). Nelms et al. (2018) show how, in performing disruption and displacement of legacy infrastructures and existing intermediaries, blockchain platforms rely on an imaginary of "just us" that casts the techno-financial landscape as empty, up for grabs. In contrast to the often openly political stance of payment disruptors, then, this "just us" mentality "evacuates the nitty-gritty of politics" (Ibid, p. 28). Casting all regulation and intermediation as "friction" also means obscuring the often old reasons why those intermediaries are there (DuPont, 2019) and it obscures the problems with retro-fitting (Howe et al., 2016) and with the obduracy of the materialities and institutions that constitute "legacy" payment infrastructures.

All in all, then, the approach to money as infrastructure developed in this thesis allows for the demystification of the infrastructural fetish that is allied to the demystification of the commodity fetish while rejecting both the dogmatism of both potentially depoliticising flat ontologies and of dogmatically structuralist accounts of materiality and agency. This effort invests all the components of infrastructures and money that this thesis listed. At the material level, infrastructures can be "read" in the immediate politics inscribed in their materiality. At the same time, this acknowledgement of infrastructures' "thing power" (Bennett, 2010) does not result, as Yuran (2014) would have it, in a fetishisation of technology, but rather in an enrichment of the "deep relationality" (Coeckelbergh, 2013) that characterises technology.

The disposition of an infrastructure is both that which results from the social use of a piece of technology, and the emergent properties of that piece of technology deriving from its materiality, which is also one of the reasons why that technology was socially adopted in the first place. Furthermore, at an intangible level, infrastructures' relationality is articulated through a study of the cultural, semiotic, and more or less rational elements through which technology is apprehended – like discourses, stories, and cultures – and the pre-personal, pre-verbal, affective forces that drive adoption and change – like enchantments and desires. In so doing, demystification of infrastructural fetishes becomes much more than opening a black box, but rather showing that there was no box to begin with, but rather to trace, connect, and acknowledge the "material relations between persons and social relations between things" (Marx, 1867/1982, p. 166) that infrastructures are.

1.2. Between STS and Political Economy: Platformisation and Interoperability

Read together and underpinned by the wider analysis and arguments advanced across this thesis, Chapters 5, 6 and 7 can be understood as a contribution to the reconstruction of a political economy of blockchain applications as caught between platformisation and interoperability. Put another way, the chapters show how frictionless interconnectivity and the "neo-feudal" (Fairfield, 2017) walled gardens of platform capitalism are not at odds with each other, but rather are actually predicated upon each other. If blockchain technologies afford a renewed degree of freedom to capitalise on platform-ecosystem intermediation through the simultaneous monetisation that tokens afford, this capitalisation would never actualise itself without interoperability. At the same time, interoperability would never emerge as a need without the existence of untapped pools of liquidity and opportunities for arbitrage.

Here again, then, the wider contribution of thesis follows from the productive tension between two ostensibly oppositional literatures. While the political economy of platformed money infrastructures is primarily fleshed out in Chapter 7, the motivation to combining science and technology studies of infrastructures with political economic approaches is a thread that runs through the whole thesis. Platformisation, in fact, is also dealt with in

Chapters 5 and 6, as a powerful drive between tokenisation and the affordances it provides for widespread assetisation (Birch & Muniesa, 2020; Lotti, 2019). Interoperability, on the other hand, was addressed in Chapter 3 as a particular active form pertaining to the "wiring" of a blockchain (Easterling, 2014, p. 80), Chapter 5 as a drive towards capitalist axiomatics, and in Chapter 6 as a form of fascination and enchantment with the seamlessness of transactions and with the immediacy of "cashing out", as well as with powerful imaginative connections with ostensibly seamless connectivity and horizontality that powered the "Internet imaginary". While explicitly addressed in Chapter 7, then, themes of platformisation and interoperability are analysed in that chapters across Part III as mutually necessary poles of a political economy centred on formalisation, i.e., on the specification and tradeability of property rights. And, as Chapter 7 draw out more explicitly, formalisation entails the reduction and removal of alternative uses of money infrastructures, hence rendering blockchain technologies a formal sector of investment and capitalisation at the same time as they are deployed to formalise existing socio-economic relations.

In his interpretation of payment interchange, as well as in his analysis of the historical evolution of the USA's payment system infrastructure, Maurer (2012a) seems to point to a critique of "payment capital" as a way to monetise on an act that, in Marxist theory, should be free, smooth, and free from opportunities for rent, fees, and capital extraction. Chapter 7 argued, in effect, that such smoothness is impossible, as any payment infrastructure is as much a terrain of platformed speculation as it is of exchange. However, Chapter 7 concurred with Maurer on the political reflection of what *ought* to be the flow of capital that goes in and out of payment infrastructures. After all, clearing of payments *at par* – i.e., without fees – is the economic reflex of a political commitment to the provision of money as a public good, rather than a private, pay-as-you-go service (Maurer, 2015b).

If a form of technology triggers imagination and desires about futurity and society, the conversation should open up about the type of society that is envisioned. In Chapter 6 we saw how Andrew Hauser (2016) framed the design of UK's payment systems as resembling that of the UK's railway network. The chapter problematised this by showing how both payments and railways are designed in a way that foregrounds speculation and economic and libidinal investments. When designing money infrastructures, we are not limited between the plethora of train stations that populate UK cities, or the perfection that railways would have if they were to be designed from scratch today. Rather, the point is to understand that both designs, as well as all other alternative forms, are political, economic, and affective machines. The spectacle, speculation, and enchantment that fuel infrastructures have to be understood as a political weapon in a battle to define the very essence of money and the way it acts in the world through the definition of the materiality of money infrastructures.

It is important that flat ontology does not immediately and unproblematically translate into a flat politics that "posits the accelerating tendencies of capital as an ontological inevitability" (Sutherland, 2013). Being immersed in socio-technical assemblages then does also warrant and require a political stance that goes beyond accepting or resisting a given technology. Rather, this stance should encompass questioning the political, economic, and cultural foundation on which a technology is based, that counters the political economies that technology performs, and potentially attacks the implementations of that technology itself, if necessary. As Nelms et al (2018, p. 28) have it "we must continue to ask: What kind of money, what kind of public, what kind of society, do we want?"

The subsequent, and arguably more important question regarding interoperability is: which kind of interoperability, *if any*, do we want and need? Is an alternative Stack possible (Terranova, 2017), or is the abstract machine of the stack that which has to be countered? As Lépinay argued for derivatives,

> At stake are the accounting rules that one should adopt to assess the impact of these goods and markets. As they cross existing markets and hybridize existing processes, parasitic goods disrupt the normative ground upon which their worth is based and call for a political discussion on whether or not and under which conditions we want to live in the wake of their rhythms. (Lépinay, 2007, p. 281)

An infrastructural approach to money, then, enables us to see both the materiality of infrastructures and the enchantments and desires that propel infrastructures themselves as two different sets of political tools to achieve different societal outcomes. As the height of the Long Island bridges examined by Winner (1980) showed that spaces were classed according to who was allowed to pass and was not, here we saw that different material elements enabled and disabled specific behaviours and distributional outcomes. At the same time, like the Railway Mania – together with the bargaining power of landlord over railway constructors – developed a cartography of winding railway lines and proliferation of company-specific train stations, the cryptoasset bubble, in its different articulations, changed the affordances of the technology itself. This is an example of intangible force being able to "buckle concrete and bend steel" (Easterling, 2014, p. 93).

1.3. Between Economic and Digital Geography: neomaterialist monetary spaces

The third contribution of this thesis is towards the "more sophisticated understanding of the spatialities of money and finance" that Martin and Pollard (2017, p. 1) argue for. Furthermore, this thesis contributed to Martin and Pollard's agenda by adding materiality to the properties that contribute to shape monetary spaces. Such an approach goes beyond schematic models like optimal currency areas (Goodhart, 1998; Mundell, 1961) and the Westphalian cartography of sovereign monetary spaces defined by monies of account (Ingham, 2004). It further allows to apprehend money as plural and composed of "special monies" (Zelizer, 1989, 1999), while being attentive of "how particular monies articulate with other particular monies across space and time" (Bryan & Rafferty, 2007, p. 153).

As outlined in Chapters 1 and 2, then, this thesis contributed to the effort towards situating and following money in and across time and space (Christophers, 2011b, 2011a; Gilbert, 2005, 2011). Chapter 3 added nuance to the appreciation of the role of materiality in shaping monetary spaces, and Chapter 4 deployed ecology as a more effective alternative to network in understanding the effects of money infrastructures. The discussion in Chapter 5, then, allowed for the apprehension of the "special monies" that compose the layers of a pyramid of domestic payments, and the tropic points (Guyer, 2012, 2016) – clearing houses, correspondent accounts, SWIFT and CLS – that allow special monies to interact and exchange with each other. It also showed how this type of interaction and exchange is differently articulated in other monetary spaces, like credit networks, blockchain platforms, and interoperability protocols. Chapter 6 added yet and additional analytical dimension in the understanding of monetary spaces: that of desire and the capability it exerts, through libidinal and speculative investments, over the morphology of monetary spaces. Chapter 7 further expanded on the effort that goes into interoperating and interconnecting monetary spaces by smoothening and abstracting away their internal differences.

Altogether, the contributions of this thesis amount to a neomaterialist understanding of monetary spaces that combines together materiality, cultures, desires in determining ecological co-evolutionary trajectories, topologies, and political economies. Monetary spaces emerge, through Chapters 4 and 6, as, at once, defined by political will, material technological agency and desire. If, with Sloterdijk, the globalised and interconnected world is “the last orb” (Sloterdijk, 2013), that orb is both a bubble and an infrastructure at the same time. Like a Geodesic Sphere, it is kept together by connections, and held in its spherical shape by endogenous counterbalancing tensions and energies. This also dispels the practical, and even ontological tenability of a separation, under capitalism, of “payment money” and “finance money” (Deleuze & Guattari, 1983, pp. 228-229; Dodd, 2014, p. 234): no act of payment is untethered from speculation, arbitrage, desire for profit, and concerns with return on investment.

Moreover, the troubles of cross-border transacting, transferring, and translating value expose the problematics of monetary spaces without the existence of a money of account. As Bryan and Rafferty (2007, p. 145) argue, “When money is denominated in multiple monies of account, we have to ask what is the process, internal to moneyness, which reconciles these multiple monies of account?”. Generalised interoperability, means, in money, to provide this internal process of reconciliation that allows for multiple monies to become exchangeable with each other. Much like derivatives in Bryan and Rafferty’s case, interoperability, and formalisation “show that a general theory of money does not need to deny the particular forms of money, or the particular effects that money has in different times and places” (Bryan & Rafferty, 2007, p. 152). As observed in the Introduction of this thesis, the “incomputability of exchange” (Lotti, 2018, p. 46) renders the value of money the product of recursive and self-referential computation. Computation without a universal unit of account becomes “as a performative process in which […] traders use all sorts of information, perceptions and preconceptions to put a price on different forms of money” (Bryan & Rafferty, 2007, p. 153).

Even if this thesis does not articulate the performativity of exchange directly, then, the “portability of memory” discussed in Chapter 7 gestures towards another property of monetary spaces: that of being assemblages of enunciation (Deleuze & Guattari, 1987, p. 23; Morris, 2016), which then casts cross-border payments as acts of translations from one assemblage of enunciation to another. And, indeed, cross-border payments and interoperability are replete with translation metaphors. Ripple’s website, in 2013, featured an explanatory blog post that read “If a global currency is like the universal language Esperanto, then Ripple is like the ‘Babel fish,’ the universal translator of science-fiction, and, more recently, Google” (Ripple, 2013). Likewise, the ISO20022 handbook frames this standard as translation more than as a universal language:

> As long as the world does not speak a single language, multiple languages will coexist. The same holds true for the financial industry as long as it uses multiple message standards. […] For centuries, people dreamt of a common language (for example, Esperanto) to breach the communication gap. However, this dream never materialised. […] As a consequence, coexistence is not a short term situation and the challenge becomes one of interoperability between different standards (SWIFT, 2010, p. 27).

With Donna Haraway, however, we can see translation as

> a problem of coding, a search for a common language in which all resistance to instrumental control disappears and all heterogeneity can be submitted to disassembly, reassembly, investment, and exchange […] The world is subdivided by boundaries differentially permeable to information. Information is just that kind of quantifiable element […] that allows universal translation, and so unhindered instrumental power (Haraway, 2016, p. 34).

Hence, cross-border payments are not only multi-currency or international payments: they are always complex acts of translation across programming and human languages, technical standards, regulatory spaces, and units of account. Seen in this light, cross-border payments are a special instance – again, an extreme case – of a more general tendency towards interoperability in digital payment infrastructures. Money's universality is constructed, maintained, and negotiated through multiple material and discursive devices and practices and chains of reference and translation.

2. Avenues for Future Research

A first important avenue for future research is thus to consider the type of subjectivities that populate the space of blockchain's infrastructural technologies and cryptoassets. This project, in fact, was at its inception a study of the making and remaking of the subject through networked financial technologies (crowdfunding, personal finance apps, payment apps, cryptocurrencies). Over time, however, the infrastructural substratum of money moved from the background to the centre of the stage, at the price of a discussion on the type of subjectivities that are summoned by different infrastructures, and the strategies available to subjects to subvert those pre-attributed positions (Amin, 2014; Berlant, 2016). This shift enabled analytical moves that would not have been possible otherwise: for example, the ecological understanding of infrastructural change, a full appreciation of the different topologies of monetary spaces, and the foregrounding of long-overlooked correspondent banking relationships spanning the globe. Furthermore, a theory of subjectivity is, at least to some extent, implicit in the neomaterialist theories that this thesis mobilised, often indebted to Simondonian understandings of technicity and individuation. In these approaches, the individual is always the product of processes of subjectification and individuation, which however are not predetermined in advance: the individual has infrastructures as its associated *milieu*, and infrastructures have users as theirs associated *milieu* (Simondon, 2006).

While co-constitution of agency, subjectivity, self, and personhood in infrastructural contexts will remain a task for another day (Kockelman, 2013), Chapter 6 and its focus on desires and libidinal investments in the cryptoasset bubble already gestures towards a set of subjectivities that deserve further investigations, similar to Brekke's (2020) work on hacker-engineers. One such example is the "token designer" who, by leveraging an often interdisciplinary background in economics, IT engineering, and social sciences, shapes the internal functioning and incentive structure of a blockchain platform and a token. Another such subjectivity is the day trader: the proliferation of cryptocurrencies and the explosion of mobile technologies has allowed for a dramatic expansion of the array of devices that can be used for spot trading of cryptoassets, stocks, bonds, and currencies. The platforms named in Chapter 6 such as Plus500, eToro, Trading 212, and Revolut all leverage payment capabilities and social network to greatly enhance the repertoire of imaginaries and affects mobilised to produce the trader as a subject (Preda, 2017; Swartz, 2020). Furthermore, Chapter 7 highlighted how payers and payees in MTOs using Ripple's interoperability solutions might be a fruitful area of study where infrastructural changes and subjectivities meet and interact.

A second area for future research expands on the property of monetary spaces as assemblages of enunciation discussed above. The idea that money can work as language by conveying and structuring meaning and value is not new (Rotman, 1987; Shell, 1993). However, the work of Pip Thornton (2018) has moved forward this metaphor by showing how language is increasingly treated as money, and how Google effectively leverages the semantic liquidity of language as a capitalisation tool through advertisement. As shown earlier in this conclusion, what this thesis uncovered was a broader analogy between money and language in the similarity between the act of cross-border payment and of cross-language translation. Hence, Thornton's work could be mobilised to contribute to future research into the working of cross-border payments and FX markets that uncovers similarities and differences with translation platforms like Google Translate and Deepl. For example, FX transactions and automatised translation are unified by the use of "bridges" when converting between "exotic" pairs: cross-border transactions between two currencies that are rarely exchanged with each other are often bridged through the Pound Sterling, the Yen, the Euro or, most often, the Dollar. An interesting question could be whether automated translation software uses similar kinds of "bridges", for example, by using English to bridge between "illiquid" language pairs.

A third area that this dissertation touched upon which could be expanded for future research is how bandwidth plays a role in determining money and its internal architecture. Bandwidth is defined in computing as the maximum rate of data transfer across a given path, and it is determined by packet size and by the speed afforded by routers and cables. These mundane sides of materiality are fundamentally important in determining the macro-morphology of large technical systems. For example, the move from punched cards to hard disk memory storage made climate-data analysis feasible, because information that would have weighted thirty-five tons and occupied entire warehouses in punch-card form, was now digitalised (Dourish, 2017; Paul N. Edwards, 2010).

In cryptocurrencies, there are interesting analogues for bandwidth in determining the internal architecture of blockchain infrastructures. In Chapters 3 and 5, for example, we saw that Bitcoin had a scalability problem connected with the maximum 1MB block size. As Brekke and others have noticed, changes in such size cause storage requirement changes for nodes and miners, which in turn might contribute to centralise or decentralise Bitcoin's network (Brekke, 2018; Wirdum, 2016). A similar problem was encountered by the Interledger Protocol developers: a "payment packet" could only be reliably sent across a network if the size of that payment were as small as possible, but the lack of a universal unit of account prevented ILP from developing a Maximum Transmission Unit (MTU) size like the Internet Protocol did in RFC 791 (Postel, 1981). However, one informant noticed that, given the layered architecture adopted and other architectural choices, "there is a close analogy between liquidity and bandwidth, effectively" (Interledger, 2018b). At a macro level, the size of "payment packets" is what allows them to be routed through retail channels, like Faster Payments in the UK, or through RTGS channels. The size of these payments and the speed of settlement also matter in determining the materiality and economic impact of high-frequency trading data centres (Leander, 2015; D. MacKenzie, 2017a).

Money's bandwidth clearly matters, then, but future research would need to provide a more fine-grained analysis of exactly how, and under which conditions, money can be treated as bandwidth. This apparently niche area of research can provide fruitful contributions to political economic approach to information and digital economies (Castells, 2010), as well as into imaginaries of money circulation in addition to already-studies metaphors (Langley, 2017), such as water (Swade, 1995), mercury (Clark, 2005), blood (Mann, 2010), electricity (Mayhew, 2011), and poison (Peckham, 2013).

Lastly, the methodological and theoretical toolbox provided by this thesis can be put to use to analyse larger, older, or more geopolitically strategic infrastructures of payments. The cross-border payment giant SWIFT has lately started to gain the attention that it deserves (de Goede, 2012; Dörry et al., 2018; Romaniello, 2013; S. V. Scott & Zachariadis, 2013), while for decades its infrastructural operations have largely been ignored by the social sciences (Polillo, 2012). Another very promising candidate for this type of inquiry is CLS. This little-known institution, as seen in Chapters 5 and 7, is a part-time clearing and settlement house for the largest financial market on the planet (i.e., FX). Moreover, while being a private bank incorporated in the US jurisdiction, it actively has central banks and their RTGS systems as their clients.

The articles of incorporation and international rules, in fact, set standards and procedures that central banks have to abide by to join its network (CLS Group, 2019c). The amount of money this institution facilitates to settle is eye-watering, with an average of 5.9 and a peak of 12.8 US$ trillion settled daily (CLS Group, 2019a, p. 9). Hence, CLS is an example of an institution of axiomatics superimposed over pyramidal institutions of overcoding of money – i.e., central banks – and it also shows how quasi-central bank powers are partially emergent from an infrastructured market, as hinted at in Chapter 5. Future research in this vein would also recentre FX in the social scientific research agenda: attention has somewhat faded after the global financial crisis, and recent literature on FX tends to focus on high frequency and day trading (D. MacKenzie, 2017b, 2018a; D. MacKenzie et al., 2012; Viana, 2018), without a view of connecting such gargantuan market to the rest of the economy and society (Cf. Wójcik et al., 2016).

Appendices

Appendix A: Glossary

Byzantine Dilemma: The Byzantine Generals Dilemma is a dilemma in Game Theory and Network Theory, whereby a decentralised network cannot reach consensus in the presence of malfunctioning or fraudulent nodes. A Byzantine Fault Tolerant algorithm is one that, under given conditions, assures that all nonfraudulent nodes can achieve consensus.

Cryptographic function: Cryptography is the set of techniques to secure communication in presence of adversaries. The aim of cryptography is to secure that the content of a message can only be viewed by the intended parties and not by adversaries. To do that, cryptography uses mathematic formulae that are one-way and collision-free. A one-way formula is one that is easy to calculate in one direction but close to impossible to reverse: in this way, one cannot access data after they are encrypted. A collision-free formula is one that, given two different inputs, always provides two different outputs. Symmetric cryptography means that one key is used both to encrypt and decipher a message. Asymmetric cryptography, such as public key cryptography used in Bitcoin, uses a private key, and derives from it a public key. When a sender A wants to send a secure message to receiver B, it uses B's public key to encrypt the message, and B will be able to decipher it using B's own private key. Bitcoin uses multiple cryptographic functions, such as Secure Hashing Algorithm SHA256 for mining.

Cryptoasset: A digital representation of value underpinned by a distributed ledger of transactions validated following cryptographic functions. While cryptocurrency represents a cryptoasset that is used as a means of payment, store of value, and unit of account, cryptoasset is more and more often used to represent blockchain digital assets, in that many of them are not used as currencies, but rather as investments.

Double spend: Any digital payment system must prevent the same sum of money to be spent twice, by either duplicating files or by sending multiple payment messages and revoking them after receiving the goods. Blockchain technologies prevent double spending in the absence of centralised authorities by recording all transactions that happen in the network. Furthermore, nodes in a blockchain network follow a set of instruction to verify that the transactions they are including in a new block do not imply double spend. Bitcoin, for instance, keeps a record called the Unspent Transaction Outputs (UTXO) that records the sums not yet spent at any given time, and only these amounts can be used to perform a successful transaction.

Fork, hard: A hard fork is a change in the underlying code of a blockchain that is not backward compatible and that is not adopted uniformly across the network. The result is that nodes running the outdated and updated code start validating different transactions, and the network splits into two, developing two ledgers, two cryptocurrencies, two histories. Famous hard forks are the split between Bitcoin and Bitcoin Cash in 2017, and the fork between Ethereum and Ethereum Classic after the DAO attack in 2016.

Fork, soft: A soft fork happens when a change in a blockchain is so-called backward-compatible, i.e., the blockchain's software is updated so that only the nodes running the updated software can append new blocks to the record, but the nodes running the outdated software still recognise the new blocks as valid.

Hashing: Hashing is a cryptographic function that takes an alphanumeric string of arbitrary length as an input and returns a string of finite predetermined length as an output. This function is (almost) collision-free, i.e., two different inputs do not result in the same hash. Hashing is easy to calculate but hard to reverse. This means that, given an input, it is easy to calculate the hash. Conversely, the process of retrieving an input given a hash cannot be easier than hashing all possible inputs until one finds the correct value.

Initial Coin Offering (ICO): An ICO, also called token sale, is a form of business finance for cryptoasset start-ups. A firm launching an app with an associated cryptoasset, either built on an existing blockchain or running a separate blockchain, would sell the asset on the open market in exchange for fiat money or other cryptocurrencies, usually Bitcoin or Ether.

KYC, AML, and CFT: Know Your Customer (KYC) is the regulatory requirement to ascertain that all customers exist, and certify their identity, contacts, address, and history. KYC is essential in banking and finance for Anti-Money Laundering (AML) and Combating the Financing of Terrorism (CFT).

Ledger: A ledger is a register, a physical or digital book where the accounts, balances, identities, properties, addresses, and, sometimes, locations are stored. It records the state of an economy, and it must possess clarity and consistency in its content.

Market capitalisation: The total value of a cryptoasset, defined as the circulating supply multiplied by its unitary price. In case a currency has only a part of its total supply in circulation (for example, because the company or foundation issuing it retains a quota), only the circulating supply counts toward the asset's market capitalisation.

Node: A machine running the appropriate software protocols to be visible to, and communicate with the other nodes in the network, initiate, and verify transactions. In Bitcoin, nodes can be differentiated in mining nodes or miners, full nodes, and lightweight nodes. Mining nodes validate transactions, add them to blocks, and add these blocks to the blockchain. Full nodes are machines that store a full, updated version of the entire blockchain. Lightweight nodes, or Simplified Payment Verification nodes, store a synthetic version of the blockchain for reason connected with memory capacity and ease of calculation.

Ponzi Scheme: A Ponzi Scheme is a financial fraud whereby an entrepreneur asks people to invest in a business, but the returns do not come from the company's profits, rather from quotas given by later investors. The scheme, hence, can only sustain itself if the number of investors keeps growing, and as long as all the investors do not withdraw their quotas at once.

Proof-of-Stake (PoS): A family of consensus algorithms that share the principle that gives owners of a cryptocurrency the right to validate new blocks based on the stake they have, i.e., the quantity of the cryptocurrency they already own. Each node is randomly selected to validate a new block and obtain newly generated coins. The probability of a node being selected for validation might depend on the size of the stake and coin age, i.e., the period of time that the node has owned that stake. This consensus algorithm aims to incentivise honest behaviour by rewarding loyalty, represented by coin age, and capital at risk, represented by the stake. PoS cryptocurrencies, hence, behave similarly to interest-bearing deposits, in that the owner is rewarded with new currency based on their existing stake, every time a new block is added to the blockchain.

Proof-of-Work (PoW): Proof-of-Work is the family of consensus algorithms that includes Bitcoin's mining. In PoW blockchains, nodes, often called miners, have to perform computing work in order to add blocks to the blockchain. This is to ensure that an attacker who wants to change a block in the blockchain cannot do so without doing the necessary calculations. Calculations for PoW algorithms are designed to be difficult to execute but easy to verify. This means that it is time- and energy-consuming for a miner to calculate a value that satisfies the requirements of the algorithm but, once a value is calculated, other nodes can easily verify that the result is legitimate. It might be the case that multiple legitimate blocks are mined simultaneously, with the possibility for the blockchain to fork.

In Bitcoin, miners automatically accept the chain containing the highest number of blocks, in that it contains the greatest PoW effort invested in it.

Wallet: A physical or digital way of storing the Public and Private Keys associated with a blockchain address. A paper wallet is a paper-printed encryption of the keys, e.g., a QR code. A hardware wallet incorporates the public and private keys in an ad-hoc device, often with its own passwords for access. When a wallet is stored on a device that is connected to the Internet, and that can be accessed remotely, this is called a hot wallet, while a disconnected wallet that can only be accessed in person is called a cold wallet.

White paper: Originally, a technical document outlining the cryptographic features, consensus algorithms, and other details of the data structure and software architecture of a cryptocurrency. Lately, these documents tend to resemble marketing materials, and they might include the business model, profit estimates, corporate governance, prestigious endorsers, and other business-related information.

Appendix B: Cryptocurrency regulation around the world.

Source: Law Library of Congress (2018) unless elsewhere stated.

Country	Legal Status	Ontological Status and Taxes	CBDC
Albania	Unclear	Largely unregulated	No
Algeria	Outright ban	Cryptocurrencies and their purchase, sale, and exchange are illegal and punished by law.	No
Argentina	Unclear	Goods	No
Armenia	Implicit ban	In 2018, Armenia rejected the adoption of crypto legislation, saying that worldwide authorities are inviting people to refrain from getting involved in crypto.	No
Australia	Unclear	Crypto payments are considered barter. Consumers are encouraged to keep record of the transactions they perform. Capital gain taxes are lifted below 10,000 AUD. Bitcoins are added to the income in their AUD fair market value, and the sale can be subject to capital gain tax. Goods and Sales Tax (GST) apply only to purchases and sales carried out by businesses related to digital currencies. ICOs are judged on a case by case basis between three categories: managed investment schemes, shares or derivatives and noncash payment (NCP) facilities (Avan-Nomayo, 2019). Crypto exchanges need to be licensed if they list tokens considered as financial products.	No

Country	Legal Status	Ontological Status and Taxes	CBDC
		It has devised a test for categorising ICOs as financial instruments or not (ASIC, 2019). Issuers of non-financial ICOs, such as utility tokens, need to justify why their token is not a financial product. DLT providers are subject to specific regulations relating to ensure, for example, that self-executability of smart contracts encounters law-compatible limits (ASIC, 2017).	
Austria	Allowed	The Austrian Ministry of Finance (Bundesministerium der Finanzen, BMF) does not qualify cryptocurrencies as legal tender or as financial instruments. Instead, it classifies them as other (intangible) commodities. It stated that cryptocurrencies are treated like other business assets for income tax purposes. Mining is not subject to VAT, because there is no identifiable recipient.	No
Azerbaijan	Unclear	Largely regulated through warnings.	No
Bangladesh	Ban	Crypto transactions are considered illegal under foreign exchange and money laundering regulation.	No
Belarus	Allowed	A March 2018 Decree allows buying, selling, exchanging, and mining, and the establishment of ICO companies within the special economic zone called High Technologies Park. Crypto-related income is taxation-free until 2023. ICO are largely self-regulated. The exchange of cryptocurrency for fiat money must be approved by the National Bank.	No

Country	Legal Status	Ontological Status and Taxes	CBDC
		Operators of cryptocurrency exchanges will be treated as high-risk clients similar to operators of lottery games and casinos. Businesses operating in the Park are exempt from taxes and only have to pay 1% of their turnover to the government. This arrangement is guaranteed by the government to last until 2049.	
Belize	Unclear	None	No
Bermuda	Allowed	Utility Tokens are not Securities if there is no promise of future value.	No
Bolivia	Banned	None	No
Bosnia	Implicit ban	It is impossible to exchange crypto for fiat currency, but there is no ban in exchanging and trading between cryptoassets.	No
Brazil	Unclear	None	No
British Virgin Islands	Unclear	None	No
Brunei	Unclear	Regulated mainly through warnings	No
Bulgaria	Allowed	In 2015 a Bulgarian court reportedly concluded that activities associated with buying, selling, and paying with cryptocurrencies are not subject to licensing requirements.	
Cambodia	Unclear	While Cambodian authorities have stated that cryptocurrencies are not illegal, they were also deemed as not allowed for payments.	Unclear: the National Bank of Cambodia entered an agreement with a Japanese firm for what seemed to be a blockchain-based clearing and settlement system, but no updates were given since 2018 (Spiess, 2018).

Country	Legal Status	Ontological Status and Taxes	CBDC
Canada	Allowed	Subject to Income Tax. Canada Revenue Agency classifies them as commodities and crypto transactions as barter. goods purchased using digital currency must be included in the seller's income for tax purposes. GST/HST also applies on the fair market value of any goods or services you buy using digital currency. virtual currencies, including Bitcoin, are treated as "money service businesses" for the purposes of the anti-money laundering law.	Yes: Project Jasper (Bank of Canada, 2017) is probably the second most advanced project after Singapore's Ubin. It follows the steps of Ubin in many respects: first, central bank-issued receipts of deposited funds (Payments Canada et al., 2017), then wholesale interbank payments (Chapman et al., 2017), then delivery versus payments (Hendry et al., 2018), then cross-border payment versus payment (Bank of Canada et al., 2018; Bank of Canada & Monetary Authority of Singapore, 2019).
Cayman Islands	Unclear	On January 29, 2018, Cayman Islands' Premier, Alden McLaughlin, reportedly spoke at a leading blockchain conference called "d10e" where he encouraged blockchain companies to establish themselves at Cayman Enterprise City, a "special economic zone that caters to tech-related entities." (Law Library of Congress, 2018, pp. 24-25).	No
Chile	Unclear	None	No
China	Explicit ban	Cryptocurrencies are not recognised as a legitimate means of payment. In 2017, the People's Bank of China (PBOC) blanket-banned ICOs (Chen & Lee, 2017; PBOC, 2017). In 2018, China banned crypto exchanges completely (Yu, 2018). Also in 2018, China limited energy supply to cryptocurrency miners in an attempt to curb their operations (Yujian et al.,	Yes, China has been working on a central bank digital currency since 2018, although and official deadline is not established yet (Suberg, 2019c).

Country	Legal Status	Ontological Status and Taxes	CBDC
		2018). Despite this, in 2019, China accounted for circa 75% of worldwide energy consumption associated with crypto mining (Cambridge Centre for Alternative Finance, 2020). Financial and payment institutions are prohibited from using bitcoin pricing for products or services or buying or selling bitcoins, nor can they provide direct or indirect bitcoin-related services, including registering, trading, settling, clearing, or other services; accept bitcoins or use bitcoins as a clearing tool; or trade bitcoins with Chinese yuan or foreign currencies (Law Library of Congress, 2018, p. 107). In October 2019, China passed its own Crypto Law, which is largely focused on passwords and encryption but which has been seen as an acceleration towards regulation of the field ahead of the introduction of China's CBDC (Zmudzinski, 2019b).	
Colombia	Implicit Ban	None	No
Costa Rica	Unclear	None	No
Czechia	Allowed	Crypto are commodities and not currencies.	No
Denmark	Allowed	In 2017 the Financial Supervisory Authority released a report on ICOs (Initial Coin Offerings) in which it stated that cryptocurrencies that are solely used as a means of payment continue to not be regulated by the Authority.	The Danish Central Bank has made it clear that it is not in favour of the creation of an official Danish e-currency (issued by the Central Bank), unlike neighbouring Sweden.

Country	Legal Status	Ontological Status and Taxes	CBDC
		ICOs may be conducted in such a way as to fall under the purview of the Authority and thus would be subject to Danish regulation.	
Dominican Republic	Implicit ban	Virtual currencies are not backed by the government, and financial institutions cannot engage in transactions involving crypto.	No
Eastern Caribbean Central Bank (ECCB)	Allowed, different national legislation applies	On the 7th of May 2018, the Anguillan government issued the Anguilla Utility Token Offering Act (AUTO Act) (Anguilla Utility Token Offering Act, 2018). Under this act, some tokens are classified as securities. Utility tokens are non-security tokens when they do not provide property rights over assets, companies, or income streams, but when they have one or more utility features. ICOs are taxed at 1.5% of the total amount raised, and ICOs must pass technical and KYC-AML checks before issuance. Antigua and Barbuda does not have legislation on the matter. Bahamas equates virtual currencies with electronic money and applies exchange control regulations to transactions in and out of the Bahamian currency. It issued DARE crypto bill. Barbados does not have any specific law on crypto and its taxation, although a plan was reported for the digitalisation of the Barbados dollar (Acheson, 2017). Dominica has no legislation on the matter, although it participates in the ECCB scheme.	Yes: On March 9, 2018, the ECCB signed a memorandum of understanding with the Barbados-based financial technology company Bitt Inc. agreeing to participate in a pilot program that will enable it to issue a digital currency. Antigua and Barbuda ostensibly issued the Antigua and Barbuda Development Coin on Ethereum. Bahamas have issued a digitalised Bahamian Dollar that will be rolled out in late 2020 (Partz, 2020a).

Country	Legal Status	Ontological Status and Taxes	CBDC
		Grenada has no legislation, although it signed up to the ECCB scheme. Monserrat has no legislation, although it signed up to the ECCB scheme. Saint Kittis and Nevis has no legislation, although it signed up to the ECCB scheme. Saint Lucia has no legislation, although it signed up to the ECCB scheme. Saint Vincent and the Grenadines has no legislation, although it signed up to the ECCB scheme.	
Ecuador	Allowed	None	No
Egypt	Implicit ban	Egypt's Central Bank only authorizes the use of the sovereign currency for commerce. Cryptocurrencies have been pronounced *haram*, i.e., prohibited under Islamic law.	No
El Salvador	Partial Ban	Fundraising using digital currencies is prohibited	No
Estonia	Allowed	Virtual currency service providers are required to have a license.	Estonia launched estcoin in August 2017 (Canepa, 2017). It was later rejected by ECB governor Mario Draghi because it infringed on the cession of monetary sovereignty entailed by the introduction of the Euro (Canepa & Chopra, 2017).
European Union	Unclear but permissive	In 2019, the European Commission (2019) published a Consultation Document "On an EU framework for markets in crypto-assets", with which inputs are gathered by March 2020.	No

Country	Legal Status	Ontological Status and Taxes	CBDC
		On the 19th of April 2018, the European Parliament adopted the amendments to the Anti Money Laundering Directive (AMLD), which also defines virtual currencies as "a digital representation of value that is neither issued by a central bank or a public authority, nor necessarily attached to a fiat currency, but is accepted by natural or legal persons as a means of payment and can be transferred, stored or traded electronically." (Law Library of Congress, 2018, p. 28) The European Commission launched a FinTech Action Plan which includes an EU blockchain Observatory and Forum. On February 12, 2018, the European Supervisory Authorities for securities (ESMA), banking (EBA), and insurance and pensions (EIOPA) jointly issued a warning to consumers regarding virtual currencies, stating that they are "highly risky and unregulated products and are unsuitable as investment, savings or retirement planning products." In December 2016, the ECB, and the Bank of Japan (BOJ) launched a joint research project named "Stella," which looks at the possible use of distributed ledger technology for financial market infrastructures. However, the ECB remains critical of CBDC, and it has barred the Estonian government from adopting a state-backed ICO with the estcoin (McClean, 2017). The European Court of Justice, on 22nd October 2015, in the case C-264/14 *Skatteverket v David Hedqvist* (hereafter	

Country	Legal Status	Ontological Status and Taxes	CBDC
		Hedqvist), ruled that purchases and sales of Bitcoin are exempt from VAT taxation (*Case C-264/14, Skatteverket v. David Hedqvist*, 2015).	
Finland	Unclear, rather restrictive	When the currency is used as a form of payment for goods and services it is treated as a trade and the increase in value that the currency might have gained after it was obtained is taxable. The exchange rate is determined at the time of realisation of the bitcoin (i.e., when it becomes cash), and that cryptocurrency records should be kept for six years. Sales of bitcoins have reportedly resulted in millions in revenue for the Finnish Tax Authority. The Tax Authority has monitored both those who trade and those who use cryptocurrencies. Seized bitcoins from drug crimes are auctioned off (Palmer, 2018).	No
France	Unclear	In 2016 the French government allowed blockchain for the issuance of mini-bonds. The prudential regulator ACPR stated, in 2014, that crypto exchanges must be licensed as payment service providers. In 2017, ACPR and the financial market authority AMF stated that purchase and sale of crypto is beyond any regulated market. In 2019, a new French regulation lifted taxation on crypto-to-crypto transactions, while capital gains are charged on	Yes: the *Banque de France* has confirmed that it is piloting a CBDC for interbank clearing and settlement, at least partially in reaction to the introduction of Libra by Facebook (Partz, 2019c). It should be launched in late 2020.

Country	Legal Status	Ontological Status and Taxes	CBDC
		crypto-to-fiat transactions. VAT is only charged when cryptocurrencies are used to purchase goods (R. Mitchell, 2019; Zmudzinski, 2019a).	
Georgia	Unclear	Mainly regulated through warnings.	No
Germany	Unclear	Crypto were classified in 2011 as unit of account and therefore financial instruments (Henkelmann & Dahmen, 2020). However, they do not automatically count as securities. Exchanges normally have to be licensed with the BaFin. ICOs are regulated on a case by case basis. Payments in crypto are just payments and are beyond VAT Mining is not taxed. If wallets are offered for a fee, they are taxed if the wallet provider is based in Germany. IT technical processing is not exempt from VAT, but crypto brokerage is (Gesley, 2018). Non-crypto virtual money (e.g., Fortnite's V-Bucks) are not VAT-exempt, because they are not a means of payment within the VAT law.	No
Ghana	Unclear	Mainly regulated through warnings	No
Gibraltar	Unclear but permissive	Passed regulation in 2017, in force since 2018. Exchanges and other crypto businesses must apply for licenses. A bill on token sales was drafted in 2018, but it seems not having been followed through (GFSC, n.d.).	No

Country	Legal Status	Ontological Status and Taxes	CBDC
Greece	Unclear	Warnings in 2014 and 2018.	No
Guatemala	Allowed	None	No
Guernsey	Unclear but restrictive	In 2014, the financial regulator of Guernsey issued a warning that discouraged the use of crypto and threatened to withdraw licenses to institutions handling crypto (GFSC, 2014).	No
Honduras	Unclear	None	No
Hong Kong	Partial Ban	In 2018, Hong Kong imposed licensing to cryptocurrency exchanges, as well as to ICOs that qualify as securities (SFC, 2018). In 2019, however, regulation has relaxed somewhat, stating that the SFC could start regulating exchanges (John, 2019).	No
Hungary	Unclear	Warnings in 2014, 2015, and 2016.	No
Iceland	Implicit ban	In 2014, the Central Bank implicitly banned all cryptocurrencies in that Iceland had, at that time, extremely strict capital, and currency controls, which forbade foreign exchange transactions and any form of purchase and sale of Icelandic krona to and from any other currency. Cryptocurrency holdings are taxed as "other asset" at the prevailing exchange rate on December 31st of the year in which taxes are filed.	In 2014, a programmer under the pseudonym of Baldur Friggjar Odinsson launched the cryptocurrency Auroracoin and, given the public availability of the Icelandic social security number registry, s/he distributed an amount of Auroracoin to every Icelander in that registry. For this reason, Auroracoin has often been considered a Central Bank Digital Currency. However, this is far from true, and the Central Bank's notice of 2014 came shortly after Odinsson's announcement (Hofverberg, 2014).

Country	Legal Status	Ontological Status and Taxes	CBDC
India	Unclear	Crypto are not legal tender. The Reserve Bank of India barred financial institutions from getting involved in crypto at any capacity. This ban was lifted by the Indian supreme court in a landmark case in March 2020 (Huillet, 2020). However, there were plans for enacting a parliament-sanctioned ban. They have not been followed through yet (Partz, 2019b).	An unverified version of a bill banning cryptocurrencies reported the introduction of a "Digital Rupee" (Huillet, 2019a).
Indonesia	Implicit ban	Cryptocurrencies are not allowed as means of payment in Indonesia. Trading, however, is not banned, and a number of exchanges are based in Indonesia. In 2019, Indonesia has introduced high minimum capital requirements for futures traders in crypto, which have been said to curb adoption of trading (Diela, 2019).	No
Iran	Outright ban	Financial institutions and currency exchanges are barred from handling cryptocurrencies, apparently in an attempt to regain complying status within the FATF. Recently, however, Iran has significantly relaxed its regulation by authorising industrial cryptocurrency mining (Huillet, 2019b).	Iran was said to be working on a CBDC as recently as January 2019, but no announcement has been given since then (Suberg, 2019a).
Iraq	Outright ban	Cryptocurrencies transactions are punished under AML regulations.	No
Ireland	Unclear	No laws	Apparently, there is an IrishCoin aimed at the tourism industry, but it looks more like Auroracoin for Iceland

Country	Legal Status	Ontological Status and Taxes	CBDC
		ICOs judged on a case by case basis, if they are deemed a transferrable security, then securities exchange laws apply.	which, despite being considered a CBDC, it is a private cryptocurrency (IrishCoin, n.d.).
Isle of Man	Allowed	Crypto businesses are subject to all KYC and AML regulation typical of other financial institutions. For ICOs, the Isle of Man's authorities will not register an applicant if the ICO provides tokens that do not offer any benefit to the purchaser other than the token itself. Crypto-based gambling businesses are legal in the Isle of Man.	No, but the registry of the companies that operate cryptocurrencies is itself stored on the blockchain, ostensibly the first case in the world.
Israel	Allowed	Crypto businesses require licensing. The tax authorities consider currencies as "means of virtual payment" and are taxed as an asset under capital gain taxation. Records of crypto transactions must be kept for auditing purposes.	No
Italy	Unclear	VAT does not apply, but cryptocurrencies are taxed as corporate income or loss. Holding bitcoins for non-commercial purposes is not taxed. D.Lgs. no 90/2017 subjects crypto providers to the same legislation as money exchange businesses.	No
Jamaica	Unclear	No legislation, and the government issued a warning press release on risks associated with crypto transactions on the 5th of February 2018. However, the Jamaican Stock Exchange entered into an agreement with the Canadian fintech Blockstation to trade	No

Country	Legal Status	Ontological Status and Taxes	CBDC
		digital assets, including security tokens, over the Ethereum blockchain (Khatri, 2019).	
Japan	Allowed and regulated	To operate in Japan, exchanges need to be regulated and resident in Japan, or being regulated in their own domestic country in a way that is comparable to the level of compliance that domestic companies are subject to, according to the Payment Services Act. ICO are not automatically regulated as securities, and instead they are regulated on a case by case basis. Cryptocurrencies are subject to inheritance tax, and capital gains must be disclosed under "miscellaneous income". However, VAT and consumption tax do not apply (Awataguchi & Nagase, 2020). Exchanges are subject to AML, KYC, and CFT due diligence.	No
Jersey	Permissive	Since 2016, KYC-AML-CFT laws apply to crypto businesses. Virtual currencies are considered currencies and not commodities.	No
Jordan	Unclear	Regulated mainly through warnings.	No
Kazakhstan	Ban	The Kazakh national bank has issued very strict measures banning crypto exchanging and mining.	No
Kenya	Unclear	Mainly regulated through warnings	No
Kosovo	Unclear	Mainly regulated through warnings. In 2018, the central bank established a virtual money advisory group.	No

Country	Legal Status	Ontological Status and Taxes	CBDC
Kuwait	Implicit ban	Cryptocurrencies are not considered accepted means of payment. Financial institutions are barred from partaking in crypto transactions or providing financial services to crypto businesses.	In January 2018, the central bank of Kuwait announced an e-currency, but no news were given since December of the same year (Peyton, 2018).
Kyrgyzstan	Allowed	The monetary and tax authorities issued warnings, but also declared they were not planning to ban crypto.	No
Latvia	Unclear	Crypto are largely unregulated In 2017, AML and KYC legislation has been introduced or adapted to cryptocurrency businesses.	No
Lebanon	Unclear	In 2013, authorities warned against cryptocurrencies. Recent unrest has spurred a proliferation of bitcoin users and informal financial networks such as hawala (Azhari, 2020; DiCamillo & Cuen, 2020).	In 2017, the central bank of Lebanon announced the introduction of a CBDC, which has not thus far been followed through.
Lesotho	Unclear	The promotion of investment in cryptocurrencies is banned.	No
Liechtenstein	Allowed	Virtual currencies and exchanges are under the same due diligence regulation as other financial institutions. Licensing may apply, but the regulation on this is unclear. ICOs are assessed on a case by case basis.	No
Lithuania	Unclear	Financial institutions cannot partake in crypto activities. ICOs are judged on a case by case basis and the relevant regulation (e.g., about crowdfunding, collective investment, investment services) must be extended to ICOs.	Yes, in 2018 the Bank of Lithuania (2018) announced the launch of the first collector coin based on blockchain. However, as it is stated in the name, it is not a means of payment but a digital collectible.

Country	Legal Status	Ontological Status and Taxes	CBDC
Luxembourg	Unclear but permissive	In 2018 it warned against the volatility of crypto and the risks of ICOs but acknowledged the merits of the technology.	No
Macau	Explicit ban	Mainly regulated through warnings, in September 2017 the Macau Monetary Authority issued a ban to domestic banks from getting involved in activities connected with cryptocurrencies (GCS, 2017).	No
Macedonia	Unclear	Mainly regulated through warnings.	No
Malaysia	Allowed	Based on court cases, it seems that Malaysia treats cryptocurrencies as income for tax purposes, but they are not subject to capital gain tax. The line so far has been to warn customers and formally and informally foster transparency, but not banning or regulating directly. A 2019 statement aims to bring ICOs within the remit of securities regulation (Buchanan, 2019). Tokens with payment functions must abide by payments regulations, and all coins and token providers need to abide by AML, KYC, and CFT regulation. The Capital Markets And Services Order states that no ICO are allowed without the license of the Malaysian Securities Commission (SC) (Capital Markets And Services Order 2019, 2019). In March, SC launched a public consultation on its proposed regulatory approach to ICOs, which would require an ICO	No

Country	Legal Status	Ontological Status and Taxes	CBDC
		issuer to host the ICO and assess the whitepaper. The paper also lists the required information to be enclosed in a whitepaper, as well as the capital and regulatory requirements for companies to be allowed to start the process of an ICO, and it outlines the requirements needed for anyone to be able to assess ICOs and whitepapers.	
Malta	Unclear but permissive	Published a Discussion Paper on ICO and related services on the 30th of November 2017 (MFSA, 2017). In October 2017 it started a consultation on the regulation of crypto and, in January 2018, it published the T&C for crypto businesses. In July 2018, Malta introduced the Malta Digital Innovation Authority (MDIA) (MDIA Act, 2018). In the same month, it passed the Innovative Technological Arrangements and Services (ITAS) Act (ITAS Act, 2018). In conjunction with the Legal Notice 355 (LN-355, 2018), the ITAS act establishes fees and procedures to acquire licensed status as a DLT and crypto business. Virtual Financial Assets (VFA) are defined as "any form of digital medium recordation that is used as a digital medium of exchange, unit of account or store of value, and that is not electronic money, a financial instrument or a virtual token" (Gauci et al., 2019). Security tokens fall within the purview of existing financial services legislation. Hence, a prospectus must be drafted	No

Country	Legal Status	Ontological Status and Taxes	CBDC
		and registered. They can also only be exchanged in existing financial products exchanges. In November 2020 it passed the Virtual Financial Assets Act (VFA Act, 2018). Under these, ICOs that are securities or e-money can be regulated by the existing laws for those sectors rather than by the VFA Act. It requires previous submission of white papers before the ICO (or IVFAO). It sets standards in transparency and content for whitepapers, and it attributes responsibilities and liabilities.	
Marshall Islands	Allowed	In 2018, the Marshall Islands have officially adopted and act announcing the issuance of a CBDC, called Sovereign or SOV (Declaration and Issuance of the Sovereign Currency Act 2018, 2018). It will circulate as legal tender alongside the US Dollar.	Yes
Mexico	Allowed	virtual assets as representations of value electronically registered and utilised by the public as a means of payment for all types of legal transactions, which may only be transferred electronically. Mexico's Central Bank is granted broad powers to specify those virtual assets that financial companies can operate, and to authorise financial companies to perform transactions with virtual assets. Financial companies that carry out transactions with virtual assets must disclose to their clients the risks applicable to these assets.	No

Country	Legal Status	Ontological Status and Taxes	CBDC
Moldova	Unclear	Mainly regulated through warnings. The breakaway republic of Transnistria passed permissive legislation and tax provisions specifically aimed at crypto businesses.	No
Montenegro	Unclear	Mainly regulated through warnings.	No
Morocco	Implicit ban	Cryptocurrency transactions are considered in breach of exchange regulation.	No
Mozambique	Unclear	Mainly regulated through warnings.	No
Namibia	Unclear	Mainly regulated through warnings.	No
Nepal	Ban	All transactions related to crypto are illegal in Nepal.	No
Netherlands	Unclear but permissive	The Central Bank does not plan to ban crypto, but it says it does not constitute money nor it impacts on monetary policy. The AFM assesses on a case-by-case basis whether the tokens in an ICO qualify as a security or a unit in a collective investment scheme as defined in the Financial Supervision Act and are therefore subject to authorisation by the AFM.	As a pilot study, the De Nederlandsche Bank (DNB) created a DNBCoin for internal uses only (Berndsen, 2016).
New Zealand	Unclear	No official regulation. ICO are judged on a case by case basis and, if necessary, traditional financial regulations for financial products and payment services apply. Cryptocurrencies are treated as property, and there is no specific taxation aimed only at them. Sales that realise capital gains are taxed accordingly as per the gains realised at the time of sale.	No

Country	Legal Status	Ontological Status and Taxes	CBDC
Norway	Unclear	Mainly regulated through warnings, but the Central Bank employees are not discouraged or barred from investing and holding them. For tax purposes, they are treated as capital property, and they are subject to capital gains tax. They are classified as “other income” in individuals’ tax returns. Originally, crypto exchange was subject to VAT in the measure of 25% of the sum, but it then was turned into a VAT-exempt payment.	No
Oman	Unclear	Mainly regulated through warnings.	No
Pakistan	Implicit ban	Ban on financial institutions from partaking in crypto. Warning for individuals discouraging investing in crypto. Both criminal and fiscal authorities have launched investigation on crypto trading for tax avoidance and money laundering.	No
Philippines	Unclear	If someone uses crypto in remittances and payments, it must comply with existing regulation and be licensed by the central bank.	No
Poland	Allowed	Several regulators have issued warnings in 2018. Tax legislation subjects crypto to income tax with two brackets at 18% and 32%. Crypto exchange is classified as property right transfer, taxed at 1% of the value of the transaction.	No

Country	Legal Status	Ontological Status and Taxes	CBDC
Portugal	Unclear	In August 2019, Portugal has officially adopted the *Hedqvist* line that VAT is not charged on cryptocurrency transactions (Partz, 2019a).	No
Quatar	Outright Ban	Bitcoin is illegal, and banks are barred from taking part in any crypto activity.	No
Romania	Unclear but restrictive	The Romanian National Bank discouraged local financial institutions from getting involved in crypto. Income from crypto transactions is taxable.	No
Russia	Unclear	Mining is considered a business, subject to taxation based on energy consumption. ICOs are only for accredited investors. Crypto is considered property. Crypto cannot be exchanged for rubles or foreign currencies unless it is carried out by licensed operators. The Ministry of Telecom recommended registering “industrial miners” as businesses, fixating energy consumption thresholds, and exempting them from taxation for two years, and even providing a public trading platform to ensure transparency.	No?
Samoa	Unclear	Mainly regulated through warnings.	No
Saudi Arabia	Unclear	The Saudi Arabia Monetary Authority (SAMA) issued multiple warning against crypto.	In 2017, SAMA announced the pilot of a local digital currency, the Riyal, only used in transactions between banks (Arab News, 2017).

Country	Legal Status	Ontological Status and Taxes	CBDC
			Furthermore, the SAMA also worked with Ripple in implementing ILP-enabled payment systems (Ripple, 2018a).
Serbia	Unclear	Mainly regulated through warnings.	No
Singapore	Allowed	Monetary Authority of Singapore passed a new AML piece of regulation that applied the 2019 FATF "travel rule" to DLT transactions, which states that data about payment originator must travel with the payment itself (Allison, 2020; Payment Services Act 2019, 2019). ICOs are judged on a case by case basis, and if they are considered securities then they are subject to the same regulations. If just one of the tokens that an exchange lists is a security, then the whole business would be subject to regulation as a financial market and intermediary (Ciambella & Chong, 2020). Crypto are taxed as income based on the exchange rate of the currency at the day of the transaction. Singapore does not have a capital gains tax, but profits of exchanges, miners, and traders are taxed as revenues. ICO taxation is thorny, based on where the ICO promoters and investors are based. Sale of tokens is subject to the goods and services tax if both the seller and the buyer of the token are based in Singapore.	Yes: Singapore is probably the jurisdiction with the broadest agenda for DLT and CBDC implementation through so-called Project Ubin. Launched in 2016 (MAS, 2016), it went from establishing a domestic clearing and settlement infrastructure (MAS, 2017) to tokenising the Singaporean currency (Deloitte, 2017a), to construct Delivery-versus-Payment (Deloitte, 2018; MAS, 2018a) and cross-border Payment-versus-Payment capabilities (Bank of Canada et al., 2018; Bank of Canada & Monetary Authority of Singapore, 2019; MAS, 2018b) using DLT, to experiment with interoperability with commercial blockchains (MAS, 2019).

Country	Legal Status	Ontological Status and Taxes	CBDC
		Singapore has its own Personal Data Protection Act, shaped similarly to the GDPR. Personal data cannot be accessed.	
Slovakia	Unclear	Revenues from crypto are taxed, and crypto transactions are taxable transfers. Cryptoassets are considered short-term financial assets other than money and priced at market value at the time of purchase. Mining is kept off-book until the mined assets are sold (The Slovak Spectator, 2018). In 2013 the National Bank of Slovakia issued a warning to inform the general public that virtual currencies are not national currencies and that unauthorised currency production constitutes a criminal offense.	No
Slovenia	Unclear	Regulation is limited to consumer warning (Novak, 2018).	No
South Africa	Unclear	Crypto need to be declared as income, but it is unclear whether they constitute capital gains or income.	No
South Korea	Allowed and regulated	There are strict requirements for both traders and exchanges: for example, they both have to have banking relationships with the same bank, and the bank has the right to examine the quality and resilience of the IT infrastructure of the exchange before providing banking services. Foreigners are barred from trading. New amendments to the Act on Reporting and Specified Financial Transaction Information have included requirements to report transactions from traders when the	

Country	Legal Status	Ontological Status and Taxes	CBDC
		daily or weekly withdraws or deposits go beyond certain thresholds, or when there is the suspicion that transactions are purposefully divided up to avoid reporting, etc. KYC is mandatory for exchanges towards traders. South Korea passed a law in March 2020 providing requirements for exchanges to provide services only based on "real name bank account" traders (Lee, 2020). The city of Seoul was considering introducing a local cryptocurrency (Crichton, 2018).	
Spain	Unclear	Financial regulator and central bank warned that no regulation or guarantee covers crypto. Crypto profits are subject to Income Tax but exempt from VAT.	No
Swaziland	Unclear	Mainly regulated through warnings	No
Sweden	Unclear but restrictive	The Swedish Financial Supervisory Authority established that crypto is subject to mandatory reporting, for the absence of which there have been cases of fines to up to 1 million SEK (~ £ 80,000). Riksbank stated that cryptocurrencies are not money. Mining is not considered a service remunerated in Bitcoin, so it is not subject to income tax (Skatteverket, 2015).	Riksbank is planning an e-Krona, and it is currently running a pilot that will last until February 2021 (Riksbank, 2020).
Switzerland	Allowed	Zug became a crypto hub called "Crypto Valley", and the canton authorities accept crypto for the payment of administrative fees up to CHF 200.	No

Country	Legal Status	Ontological Status and Taxes	CBDC
		No ICO-specific regulation, they are considered on a case by case basis. If an ICO qualifies as a security, then the same authorisations for security exchanges apply. Payment and utility tokens are not securities. If an ICO guarantees a certain rate of return on the investment, then ICO operators are required to gain a banking license. AML applies to crypto, and KYC applies to exchanges that hold the private keys on behalf of others. Crypto is treated like foreign currency for tax purposes, and they are subject to wealth tax. Public consultation on a DLT draft bill was concluded in June 2019, but it does not seem to have been followed through.	
Taiwan	Uncertain	Mainly regulated through warnings.	No
Tajikistan	Unclear	Mainly regulated through warnings.	No
Thailand	Originally banned, now allowed	Thailand banned any cryptocurrency related business in February 2018. Since then, however, the regulation relaxed significantly. In May 2018, a decree provided AML oversight and capital requirements in order to launch ICOs (Theparat & Chantanusornsiri, 2018). In June 2018, the Thai SEC pushed new regulation and allowed XRP, BTC, ETH, BCH, ETC, LTC, and XLM as trading pairs with ICOs, and it imposed ICO and brokerage fees, as	No

Country	Legal Status	Ontological Status and Taxes	CBDC
		well of taxing annual volumes of ICO firms and exchanges (Polkuamdee, 2018). This regulation also puts capital limits on each ICO. In 2019, Thailand introduced the possibility to issue securities on DLTs (Polkuamdee, 2019a). As of 2020, cryptocurrencies are taxed at 7% VAT and 15% capital gain. In 2020 new regulation is awaited but it still has not been issued (Polkuamdee, 2019b).	
Trinidad and Tobago	Unclear	No legislation but the Finance Ministry issued a warning on the 24th of February 2018 to highlight the risks of cryptocurrencies.	No
Uganda	Unclear	Mainly regulated through warnings	No
UK	Unclear	HM Revenues and Customs says that the taxation of crypto depends on the activities involved. VAT is only applicable to the sales of goods and services in exchange for crypto, and not to the purchase and sale of crypto themselves. Crypto exchanges are subject to profit taxation. Individual traders and investors are charged with capital gain taxes.	No
Ukraine	Unclear	Mainly warnings until 2017. In 2018, the cybercrime division of the Ukrainian Police invited to ban the use of cryptoassets unless their status is clarified. In May 2020, the Ministry of Digital Transformation published a draft bill on Virtual Assets, and the consultation	No, although in the past Ukraine was said to be piloting blockchain-based voting platforms (Bitcoin Magazine, 2016; C. Kim, 2018).

Country	Legal Status	Ontological Status and Taxes	CBDC
		closed in June 2020. Under the provisions of this bill, crypto businesses would be allowed to open bank accounts (Partz, 2020b).	
United States	Unclear and Multi-level	The United States regulation of the matter differs across the Federal-State level divide, as well as across regulators and authorities. At the federal level, the purchase and sale of cryptocurrencies is only regulated if the cryptocurrency is deemed to be a security, or if the transaction was part of a money transfer business under federal regulation, as per the definitions of the FinCEN. The CFTC regulates futures and other derivatives having crypto as their underlying asset. The SEC applies the Howey Test to cryptoassets to retrieve whether they constitute securities or not (SEC, 2019) and "The automation of certain functions through this technology, 'smart contracts,' or computer code, does not remove conduct from the purview of the U.S. federal securities laws." (SEC, 2017, p. 2). FinCEN and the Department of Treasury's Office of Foreign Assets Control (OFAC) require money transmitter to abide by KYC, AML, CFT regulation by not providing services to people in the Specially Designated Nationals and Blocked Entities List (SDN List) (Dewey, 2020).	

Country	Legal Status	Ontological Status and Taxes	CBDC
		The Internal Revenue Service taxes crypto as property (Internal Revenue Service, 2014). Cryptocurrency held for more than a year are subject to capital gains taxes, and each transaction needs to be reported in its date, recipient, amount, costs, etc. New York was the first state to pass a comprehensive regulation of cryptocurrencies, called BitLicense, on the 8th of August 2015 (NY Department of Financial Services, n.d.). Under this regulation, a business needs a BitLicense if its business is receiving, transmitting, storing, holding, maintaining custody of, buying, selling, controlling, administering, or issuing virtual currency, as well as performing exchanges. Individuals, as well as businesses that use cryptocurrency solely for purchase and sale of goods do not need the license. Charities that accept donations in crypto are exempt from the license. Mining does not require a license, as well as privately selling the coins mined by an individual miner. Providing advice on buying and selling cryptocurrency likewise does not require a BitLicense. BitLicense requires at least $ 500,000 paid in a surety bond or account to protect its customers (New York BitLicense, 2015, sec. 200.9(a)). Capital requirements vary depending on business model and risk assessment carried out by the superintendent tasked with issuing BitLicenses (New York BitLicense, 2015, sec. 200.8). On the 11th of	

Country	Legal Status	Ontological Status and Taxes	CBDC
		December 2019, the NY State's Department of Financial Services announced a public consultation on a policy framework through which licensed businesses can list cryptocurrencies and a listing policy through which the DFS will greenlist new coins if they are supported by at least three unrelated licensed cryptocurrency businesses (NY Department of Financial Services, 2019). Wyoming adopted a bill that creates the category of "utility token" as a non-financial product, hence excluding it from securities regulation (Wyoming House Bill 70, 2018). It previously amended money transmission regulation to allow crypto exchanges (*Wyoming House Bill 19*, 2018), authorised the use of blockchain for the recording of shareholders and of shareholding votes (Wyoming House Bill 101, 2018), introduced crypto-friendly types of corporations (Wyoming House Bill 126, 2018), and excluded cryptocurrencies from state property taxes (Wyoming Senate Bill 111, 2018). Back in 2014, California approved a law that legalised the use of cryptocurrencies for purchases of goods and services, as well as for transmitting payments (California Assembly Bill 129, 2014). Colorado passed a law in May 2018 that allowed the use of DLT for the registry of official state documents (Colorado Senate Bill 86, 2018). In 2019, Colorado passed the "Digital	

Country	Legal Status	Ontological Status and Taxes	CBDC
		Token Act" that exempts cryptocurrencies from securities regulation (Colorado Senate Bill 23, 2019). Interestingly enough, while Wyoming's bills were overwhelmingly partisan in their backing, being sponsored solely by Republicans except from Bill 111, which had one democratic senator as sponsor along seven republicans, Colorado's bills are more transversal and led by democrats. New Hampshire allowed the use of cryptocurrencies for political campaign donations in 2014 (Kaler, 2014). Nation-wide, the Federal Election Commission allowed donations denominated in crypto in May of the same year (FEC, 2014). Colorado and West Virginia used blockchain applications for primary and local election voting (Yakubowski, 2018, 2019a). Since November 2018, it is possible to pay taxes using cryptocurrencies in Ohio (Tobias, 2019). Texas's Banking Department (2019) passed memorandum 1037, which states that no money transmitter license is required to operate cryptocurrencies in Texas. Arizona has activated a regulatory sandbox "to test innovative financial products or services without first obtaining full state licensure or other authorisation that otherwise may be required" (Arizona Attorney General, n.d.).	

Country	Legal Status	Ontological Status and Taxes	CBDC
		Plattsburgh, in New York State, held a local ban of cryptocurrencies until March 2019 (Dewey, 2020).	
Uzbekistan	Unclear	In September 2018, the Uzbek president signed a decree legalising crypto trading, exchanges, and mining, setting licensing requirements (Tassev, 2018b). In December 2019, the same government reverted its stance and barred any purchase of cryptocurrency, even from licensed exchanges (Zmudzinski, 2019c).	No
Vanuatu	Unclear	No regulation.	No
Venezuela	Controversial	Decree 3196 established the *Superintendencia de los Criptoactivos y Actividades Conexas Venezolana* as the supervisory authority of cryptocurrencies. the holder of petro will be able to exchange the market value of the cryptoasset for the equivalent in another cryptocurrency or in bolívares. On March 8, 2018, the *Asamblea Nacional* (National Assembly, the Venezuelan Congress), declared that the issuance of a domestic cryptocurrency such as the petro is illegal, because in order to enter into a public debt and borrow on behalf of the Venezuelan government, congressional approval and a special law is required under the National Constitution. In addition, only the Central Bank of Venezuela may issue national currency.71 The Asamblea National further stated that oil reserves are public national assets that belong to the Republic and are non-transferrable	Yes: Petro (GBV & SUPC, 2018), under Decree 3196 of December 8, 2017.

Country	Legal Status	Ontological Status and Taxes	CBDC
		assets, and therefore cannot be used as guarantee for any debt.	
Vietnam	Unclear	Originally, Vietnam implicitly banned cryptocurrencies because they did not represent legal tender and legitimate means of payment (Law Library of Congress, 2018, p. 130). Although the country's position has not changed since 2018 (Musharraf, 2020), a new task force has been established, which seems to point to a potential change in policies (Haig, 2020).	No
Zambia	Unclear	Mainly regulated through warnings	No
Zimbabwe	Unclear	Mainly regulated through warnings	No

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