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Cryptocurrencies, a controversial innovation? Unpacking argumentation analysis in economic geography

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ABSTRACT

In this paper, we analyze the global controversy surrounding the innovation of cryptocurrencies, developing an analytical framework to assess the empirical structure of arguments. By unpacking an argumentation analysis of a comprehensive set of scholarly, media, and industry publications, we identify six key dimensions of disagreement, comprising 42 distinct arguments. These dimensions include the raison d'être, environmental impact, social inclusion, susceptibility to illegal activities, economic impact, and potential for decentralization and democratization. Our findings reveal entrenched positions supported by robust scholarly research and empirical evidence. Cryptocurrencies represent a controversial innovation, for which global resolution remains elusive. While the controversy may appear unbounded, we plead for a geographical approach, emphasizing that localized institutional contexts are crucial for exploring potential trajectories of the controversy. Finally, our analysis illustrates the potential of argumentation analysis to properly disentangle complex societal disagreements, and it therefore promises to enrich the methodological pluralism in economic geography.

> "Bitcoin has been controversial since its creation, drawing significant criticism from politicians, bankers, economists, investors and academics" (Butler, 2022, p. 87).

1. Introduction

Controversies echo the winds of change, the looming of hopes and new opportunities as well as of fears and risks. Controversies indicate that whereas some endorse the introduction and implementation of change, others reject the change either to preserve the current state or to promote alternative futures. Controversies represent the societal restraint of change, and the unfolding of a controversy decides whether that change happens or not, or how society and the initial novelty become aligned. Most innovations are arduous (Glückler & Bathelt, 2017), meeting a lack of interest or even immediate resistance. It is therefore, that social science and geography take an interest in how futures that are deemed desirable or necessary can meet sufficient benevolence and surpass periods of controversy to finally adapt to and transform the current state of a system.

Innovation, being "the first positive sanction of the user" (Akrich et al., 2002, p. 188), is key to economic development, an association that has been extensively scrutinized in economic geography. Among the many approaches taken, economic geographers have studied the *conditions for innovation*, focusing on creativity (e.g., Grabher, 2001; Grandadam et al., 2013), relatedness (e.g., Frenken et al., 2007), and knowledge complexity (e.g., Balland & Rigby, 2017). They have also examined the effects of different *types of knowledge*, including tacit (e.g., Amin & Cohendet, 2004; Gertler, 2003), radical (e.g., Frenken & Punt, 2023), disruptive (e.g., Kemeny et al., 2022), and different bases of knowledge (e.g., Asheim et al., 2017) on regional development. Moreover, geographers have explored the *workings of spatial systems* of innovation, including local production systems and clusters (e.g., Bathelt et al., 2004), regional (e.g., Hassink et al., 2019) and national innovation systems (e.g., Lundvall, 2007), as well as socio-technical regimes at global scale (e.g., Fuenfschilling & Binz, 2018).

Despite this rich body of work, there has been less emphasis on the controversies that emerge during the innovation process, and on how local institutional contexts shape both the evolution of these controversies and their outcomes. Addressing this gap is crucial for economic geography, because resolving such controversies will be decisive on whether innovations fail or succeed and how they adapt to criticism and resistance to ultimately merit legitimacy. In this paper, we elaborate on

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the concept of controversy as well as on the structural elements that characterize it. We apply the emergent conceptual framework to the contemporary disagreement about the potential, utility, and impact of the seemingly unbounded nature of cryptocurrencies, highlighting the role that economic geography can play in enhancing our understanding of these processes and the controversies they generate.

Venturini (2010, p. 264) suggests that when aiming to explore a controversy researchers should avoid (i) cold (e.g., marginal or unimportant), (ii) past (e.g., historical or resolved), (iii) boundless (e.g., opaque, undefined) and (iv) underground (e.g., hidden, inaccessible) controversies. Cryptocurrencies stand out as a rich source of controversies (Molling et al., 2020) that represent a valuable subject for examination. The contemporary disagreement about cryptocurrencies is exactly the contrary of the characteristics to be avoided when engaging with the quality and evolution of a controversy: The crypto controversy is 'hot' featuring considerable intensity and raising serious questions about social, environmental and ethical legitimacy (e.g., Dittmar & Praktiknjo, 2019; Masanet et al., 2019; Mora et al., 2018, 2019). It also is an ongoing, evolving disagreement inviting for in-vivo observation as to how it is changing in real-time, with an active exchange of arguments and evolving discourse driven by ever new emerging perspectives, challenges, and developments. Finally, the controversy is taking place in public forums, discussions, media outlets and academia, ensuring that it is observable and open to scrutiny.

After reviewing the rise of cryptocurrencies in the global market as well as the evolution of public reports about this development in Section 2, we conceptualize the notion and features of controversy for empirical analysis in Section 3. In Section 4, we discuss our approach to argumentation analysis, and outline the methodology used to compose and analyze a body of documents, including scholarly, media and industry publications. In Section 5, we present the detailed findings of our argumentation analysis. We characterize six dimensions of controversy, including the raison d'être, environmental impact, social inclusion, susceptibility to illegal activities, economic impact, and its potential for decentralization and democratization. In Section 6, we respond to the, at least implicitly inherent, a-spatiality of the way controversies are usually looked at. Instead, we propose a geographical view and sketch elements of a research agenda that seeks to study the role of geographical and institutional variety in the unfolding of localized controversies and the success or failure of a novelty to experience acceptance and diffusion. As such, we emphasize the need for a geographical understanding of contested innovation processes and propose some first elements of an emerging analytical framework to study controversial innovation in economic geography (Glückler, 2014; Glückler & Eckhardt, 2022; Glückler & Panitz, 2014).

2. Crypto: is it a hype and is it over?

Cryptocurrencies embody a novel concept of digital assets built upon the blockchain technology (Giudici et al., 2020). These assets, capable of seamless exchange and direct transfer between network participants, have evolved from a niche volunteer project of cypherpunks to a controversial and globally operating industry (Tumasjan, 2021). Its origins can be traced back to the idea of Bitcoin, which was conceived by the pseudonymous figure Satoshi Nakamoto, whose identity remains unknown. Nakamoto introduced the idea of Bitcoin in a 2008 white paper, describing it as a "purely peer-to-peer version of electronic cash [that] would allow online payments to be sent directly from one party to another without going through a financial institution" (Nakamoto, 2008, p. 1). The underlying conception was to challenge and reshape the legitimacy of the prevailing monetary system and traditional governance structure, which had been shaken to their core by the 2008 financial crisis (Swartz, 2018; Weber, 2016). The emergence of Bitcoin was inextricably linked to the zeitgeist of its time, emerging from a complex tapestry of technological, social, and economic factors that had eroded trust in established organizations. Cryptocurrencies arose as an embodiment of cryptographic empowerment, transforming cryptography as a tool once wielded by the state into a mechanism of individual (technological) sovereignty with increased authority over individuals' economic lives (Butler, 2022; Swartz, 2018, p. 625).

From the first transaction (10,000 Bitcoins for a pizza in May 2010), the cryptocurrency landscape continued to evolve into a comprehensive ecosystem that today boasts an array of over 26,000 different currencies (Coinmarketcap, 2023) and is experiencing widespread adoption on a global scale (Butler, 2022). In the course of ever-increasing adoption of the innovation (Bazán-Palomino, 2023; Saiedi et al., 2021), which on a large scale is mainly based on crypto-investments rather than everyday transactions (Van Der Merwe, 2021), one can observe a consistent pattern of high volatility in transaction volumes, market valuations, and media coverage, alongside a concurrent rise in both adoption rates and academic research (see Fig. 1).

One of the key factors in the public controversy surrounding cryptocurrencies has been the highly volatile market price (Hassan et al., 2022; Kristoufek, 2015). Already in the early days of price unsteadiness, for instance, the Nobel Laureate in economics Paul Krugman (2013) asserted in his New York Times column that "Bitcoin is evil" and emphasized its characterization as a bubble, while in the same year, an article entitled "when will the people who called Bitcoin a bubble admit they were wrong?" appeared in the Washington Post (Lee, 2013). Nevertheless, at this juncture, the scholarly output at this point remained negligible, with only 16 academic articles published on the topic by the end of 2013. That changed in 2019 with the emerging 'gold rush' atmosphere (Allen, 2022), bringing in a continuous stream of new participants to the crypto market. Following a period of sharp ups and downs in market prices, cryptocurrencies came under widespread public and academic scrutiny due to an eventual crash in the crypto market. Bitcoin was dubbed a gimmick and criticized as a "distraction from the real work that must be done" (Acemoglu, 2021). Furthermore, the cryptocurrency landscape faced a series of scandals, including governance issues at one of the world's largest cryptocurrency exchanges, FTX, which led to the arrest and subsequent 25-year prison sentence of its CEO, as well as the suspension of withdrawals at several global crypto lenders, plunging the market into a 'crypto winter' (Chohan, 2022; Fulwood, 2022; Jalan & Matkovskyy, 2023; Mark & Vynck, 2022).

So, is the hype over? The question is another source of controversy, depending on the normative beliefs and future expectations of market players, regulators, and observers. On the one hand, cryptocurrencies have recently experienced a sharp decline in value, accompanied by scandals, with select countries, including China, imposing outright bans on cryptocurrencies (Griffith & Clancey-Shang, 2023). On the other hand, the current landscape portrays an unprecedented surge in media coverage, complemented by a substantial upswing in scholarly publications. Esteemed scholars openly and vigorously express their viewpoints (e.g., Acemoglu, 2021; Frankel, 2021; James, 2018; Krugman, 2013, 2018, 2023), while governments have adopted cryptocurrencies as an official means of exchange, e.g., Zug/Switzerland or El Salvador (Canton Zug, 2020; Morisson & Turner, 2022; Urquhart & Lucey, 2022). It is noteworthy that the underlying blockchain technology is acknowledged as a 'frontier technology' (United Nations, 2018) and that it ranks among the top '100 Radical Innovation Breakthroughs for the Future' (European Commission, 2019). All of this occurs within a period akin to the inception of cryptocurrencies, characterized by a global macroeconomic landscape deemed challenging. The world is grappling with the aftermath of the COVID-19 pandemic, elevated levels of inflation, a war in Europe, global political tensions, and an increasingly urgent need for sustainable transition. From their embryonic origins rooted in mistrust and disillusionment, cryptocurrencies have followed a trajectory at the intersection of technological innovation, economic paradigms, and societal reimagination, while their adoption has consistently generated controversy.

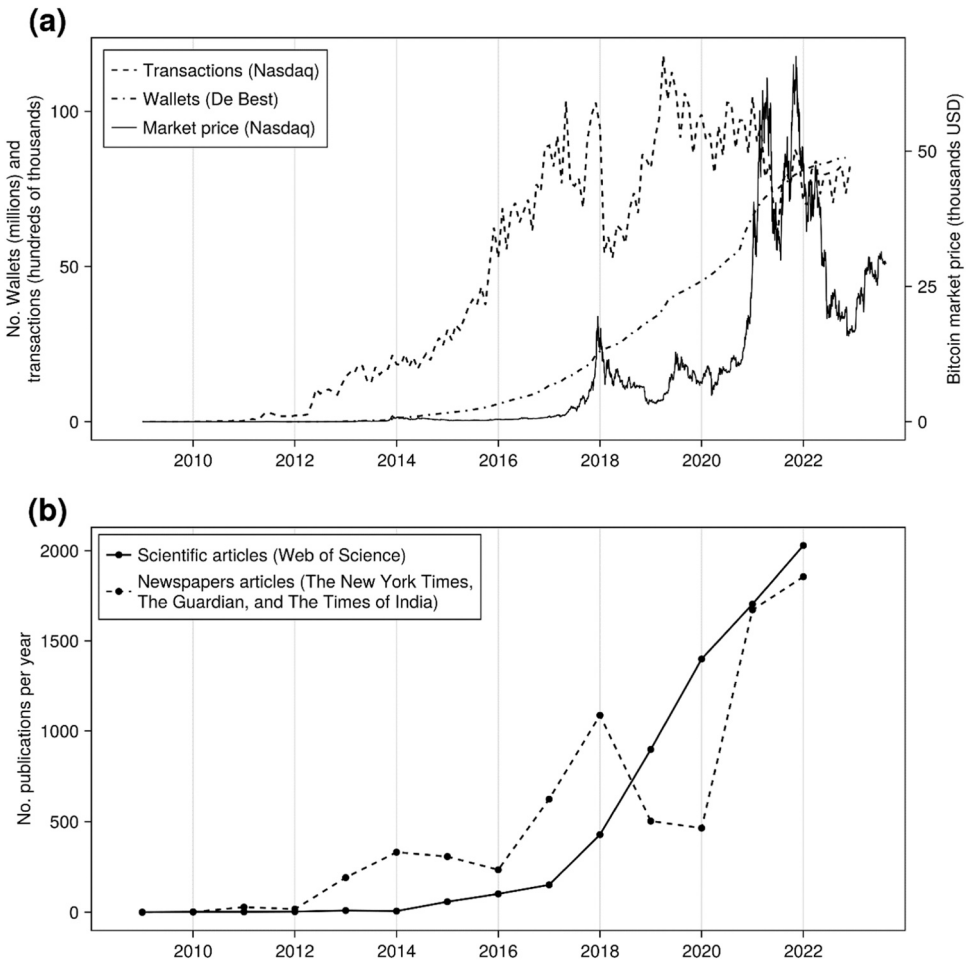

Fig. 1. (a) Development of the crypto market size, 2009 – 2023 (De Best, 2023; Nasdaq Data Link, 2023a, 2023b). **(b)** Trends in news coverage and academic publications, 2009 – 2022 (Clarivate, 2023; LexisNexis, 2023).

3. Forms of disagreement: conceptualizing a controversy

A controversy is often referred to as a heated disagreement, an exchange of opposing arguments. Because it often leaves a trace on paper or recordings, it can be studied by identifying disagreement and by unraveling articulated and documented opinion, reasoning, and argument. A strong opposition, for instance, could be witnessed during the Covid-19 pandemic, when disagreement emerged over whether the virus existed, where it had originated, whether it was contagious, whether it caused illness, whether vaccines would help against or aggravate infection (Cáceres, 2022). Whereas many of these questions were addressed by substantive and reasonable arguments, others appeared irreconcilable and attracted conspiracies (Romer & Jamieson, 2020; Ullah et al., 2021; Uscinski et al., 2020; van Mulukom et al., 2022). Consequently, this topic was not only marked by controversy but also exhibited characteristics of other forms of disagreement, and the closure was not achieved through rational means (e.g., through external coercion).

Therefore, it is crucial to have a precise and explicit understanding of what constitutes a controversy and how it can be empirically explored. Controversies differ from other types of disagreements in the qualitative nature of their outcomes and, therefore, in the way they come to an end (Dascal, 1998, p. 150f.): In a *discussion*, there is a disagreement about a specific concept or result, which is *solved* by correcting the error through an accepted procedure, such as calculating or repeating an experiment. In contrast, a *dispute* never involves the acceptance that the divergence is based on an error, but is typically rooted in different attitudes, feelings, or preferences. It can be ended by any (external) procedure (e.g., calling the police or throwing the dice). Hence, this type of disagreement is not solved but only *dissolved*. A *controversy*, instead, characterizes a sustained exchange of reasonable arguments within a common conceptual framework, just as defined below. Contenders accumulate arguments to grow the weight of their own position over that of their opponents to finally close the controversy. This introduces a dynamic element, as controversies can rekindle after their closure depending on a shift in the weight of the arguments. Consequently, a controversy is neither solved nor dissolved; but it may be *resolved* (Dascal, 1998; Engelhardt & Caplan, 1987; Fritz, 2019).

Drawing on the sociology of science and argumentation theory, we propose the following explicit definition: a controversy is a public (McMullin, 1987) and persistent (Martin, 2014) exchange of arguments between people having a disagreement (Freudenthal, 1998) over empirical facts or conceptual interpretations (Engelhardt & Caplan, 1987), and where all incompatible views (Tjosvold, 1985) subscribe to a common conceptual framework (Freudenthal, 2002) for them to have reasonable claims to truth (Freudenthal, 1998), and to potentially reach closure (Engelhardt & Caplan, 1987).

Each of the defining elements are necessary, and, taken together, this definition has a few important implications for the analysis. First, because a controversy is public and persistent, it must be observable, often in oral and written text but also in images, symbols, or gesture, and therefore becomes susceptible to empirical analysis. Multiple techniques used in qualitative as well as quantitative social science research methods can be employed, including qualitative content analysis and

discourse analysis as well as lexicometry or semantic, topic or discourse network analysis. Second, the disagreement about positions, arguments, concepts or facts must be united under a broad yet commonly accepted conceptual understanding of what is logic, reason and truth. Then, different positions, even when totally opposite and mutually exclusive, are fundamentally commensurable and can be reconciled by way of logical analysis, definitory clarification, empirical evidence or changes in normative preferences and beliefs. This is a precondition for mutual exchange of arguments and creates the empirical possibility to resolve the controversy, i.e. reach a situation of closure by way of conviction. This foundational principle plays a crucial role in shaping the dynamics and outcomes of controversies, offering the potential for constructive resolution, and effective decision-making (Vollmer & Seyr, 2013). Consequently, by the way we define a controversy, we simultaneously exclude conspiracy theories between incommensurable worldviews from the analysis because they can at best be silenced but impossibly be reconciled.

Controversies offer a great opportunity: they point to the pros and cons as well as to the intersection of different views on a phenomenon. They help capture normative beliefs, perceived uncertainty and the state of evidence and substantive knowledge about a phenomenon. We argue that understanding controversies is useful to come up with substantively critical questions about uncharted territory, to clearly demarcate differences in beliefs and to reorient the search for certainty and agreement on a new phenomenon. This process enhances the overall understanding of the potential impacts of an innovation, as a "controversy functions as a funnel, bringing diverse problems together, and it has the potential to act as a sieve that separates important concerns from those without real merit" (Mazur, 1987, p. 281).

In the next section, we outline the methodology of argumentation analysis to empirically discern the structure of the controversy regarding three elements: (i) *positions*, i.e., the valued preferences and beliefs; (ii) *premises*, i.e., the evidence or claims of facts in support of the positions; and (iii) *conclusions*, i.e., the interpretations and inferences drawn from the premises to support a position.

4. Research design: deploying an argumentation analysis

Building on the above conceptualization, we seek to scrutinize the structure of the controversy surrounding cryptocurrencies by systematically analyzing scholarly, media and industry publications. To accomplish this objective, we deploy a method of argumentation analysis. Argumentation analysis differs from other types of semantic analysis of large bodies of text. Discourse analysis, for instance, has been more visible and used more frequently in geographical research, drawing in different techniques. For instance, the method of STCA, socio-technical configuration analysis (Heiberg et al., 2022), monitors and evaluates the interactions between social and technical elements to convey actor coalitions and concept configurations. Similarly, controversy mapping (Venturini & Munk, 2022) is a technique that builds on actor-network theory to analyze and visualize public disagreements. In contrast to both, argumentation analysis serves a different purpose: to systematically unravel and dissect multiple arguments within a controversy. Our approach to argumentation analysis serves to deconstruct arguments by breaking them down into their components (Simosi, 2003; Toulmin, 1958). By focusing on positions, the premises that support them, and the conclusions drawn, argumentation analysis provides the opportunity to identify the main points of disagreement and unpacks criticism while focusing on the reasonableness of the discourse (Van Eemeren & Henkemans, 2016). We use argumentation analysis as a novel approach that has not yet been applied to geographic research, and by tailoring it to the crypto controversy, we aim at gaining a deeper understanding of the complexity of controversies (Kutrovátz, 2008).

To build the text corpus for our analysis, we sought to capture the diversity across public discourse, including the media, academia, and industry. While recognizing the value of other document types such as policy papers or NGO reports, our focus was to maintain a manageable corpus to outline the lines of controversy on cryptocurrencies, considering the scope of our research and resource constraints. Nevertheless, we aimed to integrate sources such as opinion pieces from highly visible platforms, such as the Project Syndicate, where a diverse spectrum of political leaders, policymakers, scholars, business leaders, and civic activists get a voice to present their arguments (e.g., Bill Gates, Daron Acemoğlu, Emmanuel Macron, Joseph E. Stiglitz, Ngozi Okonjo-Iweala, etc.). We constructed the text corpus in two stages: first, we build an initial body of documents from the public realms of media, academia and industry; secondly, we aggregate additional documents by tracing complementary cues found in the initial set of documents.

In the first stage of our analysis, we conducted keyword searches in academic databases (e.g., Google Scholar), newspaper archives (e.g., Nexis Uni), and industry report repositories to generate an initial corpus of texts for our argumentation analysis. For newspaper articles, we prioritized sources with a broad audience and high credibility to comply with the definition of controversy: a public and persistent, hence widely visible disagreement. In academia, we chose journal articles based on their relevance and impact within the field (incl. journal impact), and regarding industry, we selected online reports based on their visibility and comprehensiveness in discussing aspects of cryptocurrency. The initial text corpus consisted of 72 documents, including 32 newspaper articles and opinion pieces (e.g., NYT, Project Syndicate), 20 journal articles (e.g., Nature, Political Geography), and 20 industry reports (e.g., Chainalysis, Roland Berger).

In the second stage, we conducted a software-assisted qualitative content analysis with MAXQDA (VERBI Software, 2019), to iteratively code text and inductively construct key categories (Mayring, 2004) by way of continuously reviewing, paraphrasing and categorizing the empirical material. This involved systematically coding the text corpus to deconstruct the arguments outlined, continuously refining our categories to capture the nuances of the controversy. On balance, the coding indicated that all three arenas of public discourse contained controversial voices. To cover the spectrum of the controversy, we subsequently employed the strategy of confirming and disconfirming cases (Miles & Huberman, 1994). This involved an additional search process to include sources that either supported or challenged prevailing arguments, increasing confidence in our representation of the controversy. Adhering to the principle of theoretical saturation (Glaser & Strauss, 1967), we continued to expand our text corpus and the coding process until no new information emerged. Adding these complementary documents to the database lead to a final text corpus of 108 documents, being composed of: 79 journal articles, 13 industry reports, 9 other sources such as press releases from government organizations, and 7 newspaper articles and opinion pieces.

The discrepancy between the initial set of documents and the final set of texts is due to our focus on the arguments presented in the scientific literature. In cases where similar arguments appeared in different types of texts, we prioritized the inclusion of scholarly articles to emphasize that a defining element of a controversy is the presence of reasonable claims to truth. To validate our findings, we link the presentation of arguments, positions, and premises in the following sections to the various sources that provide supporting evidence.

5. The crypto controversy

In this section, we deploy argumentation analysis as outlined above to assess the range of arguments and lines of opposition in the cryptocurrency controversy. This analysis outlines the arguments, premises, and inferences that justify the opposing positions in support of or against cryptocurrencies. Altogether, we identify and categorize 42 distinct arguments across six dimensions, which we deconstruct in detail (Table 1): raison d'être, environmental impact, inclusion, susceptibility to illegal activities, economic implications, and potential for decentralization and democratization.

Table 1
Analysis of the premises, arguments and counter-arguments approving or disapproving cryptocurrencies (CCs).

Arguments against CCs	Counter-arguments in support of CCs
Position 1a: Cryptocurrencies lack legitimate purpose	**Position 1b: Cryptocurrencies are globally established**
A1: Unlike successful innovations (e.g., Zoom, iPad or Venmo) of similar age, CCs have not become part of daily lives.[1]	**cA1:** Due to developmental and technological parallels with the early stages of email, the full potential of BCs and CCs has yet to be realized.[9]
A2: Because most of the objectives of CCs can be achieved without their use[2], and because of their insufficient currency characteristics[3] as well as their relatively slow transaction rates[4], CCs miss reasonable applications[5]	**cA2:** Given the extensive market size of CCs[10, 11] and the profound implications of the recent crypto-collapse[12], CCs have already achieved global impact.
A3: Due to the scarcity of customer demand, CCs play only an insignificant role in practice.[6]	**cA3:** Because of the high level of adoption by individuals[13] and institutional investors[14], CCs can no longer be ignored as a part of our global economy[15].
A4: In consequence of the limited acceptance of CCs in commerce[6,7] and of the limited adoption by the 'traditional' banking sector[8], the overall CC adoption remains marginal.	**cA4:** With the presence of an extensive startup ecosystem[16] and the acceptance as a payment method by over one-third of U.S. SMEs[17], CCs are already well established.
Position 2a: Cryptocurrencies are environmentally unsustainable	**Position 2b: Cryptocurrencies promote sustainable transition**
A5: Because only BTC's infrastructure consumes more energy than entire countries (such as Belgium or Chile)[18], and because traditional transaction systems are more energy efficient[19], the ecological footprint created by CCs is too large to be tolerable.	**cA5:** Due to the high efficiency and scalability of the underlying blockchain technology[26], CCs will help to promote the sustainability transition of monetary transactions.
A6: Due to the enormous greenhouse gas emissions caused by BTC mining[20, 21] (e.g., equal to 1 million cars in the same period[22], 800 kg CO_2/BTC transaction[21]), it can push global warming over 2°C within three decades[23].	**cA6:** Due to disputable assumptions and a lack of analytical rigor, scientific research falsely overestimates CC-mining's negative impact on global warming.[27, 28]
A7: Because Ethereum and BTC mining (in 2021) alone will cause over 27,000 future deaths[24] CC mining negatively impacts human lives.	**cA7:** By changing Ethereum's consensus mechanism in 2022[29] and by relocating mining to green energy regions[30], the industry has shown its responsiveness to environmental concerns.
A8: Because mining operations generate significant electronic waste, CCs further exacerbate environmental problems.[21, 25]	**cA8:** Through the inclusion of CC mining as an energy surplus smoothing instrument[31] and through the stimulation of renewable energy production, CCs can promote the production of renewable energy.[32, 33]
Position 3a: Cryptocurrencies foster social exclusion	**Position 3b: Cryptocurrencies offer access to the economy**
A9: Because of the underlying libertarian[34], techno-capitalist[35], and right-wing mentality[20] of the crypto community, CCs have a disintegrative character.[36]	**cA9:** By overcoming geographical barriers, CCs alleviate the challenge of physical distance between individuals and traditional financial institutions.[38]
A10: Due to the underrepresentation of disadvantaged people with lower incomes, CCs reinforce prevailing socio-economic disparities.[37]	**cA10:** By seamlessly sending and receiving remittances or salaries without significant fees, CCs integrate disadvantaged people (such as migrants, temporary 'guest workers' or the 'unbanked') into key processes of market-based governance.[42, 43, 44, 45]
A11: The limited availability of resources essential for CCs (such as smartphones, internet, and financial literacy) excludes many individuals from the global south.[38, 39]	**cA11:** Through the ability to bypass oppressive centralized authorities, CCs are a means of circumventing unjust and restrictive financial practices.[46]
A12: As wealthy economies tend to benefit CC investments[11], while the negative impacts are mostly experienced in emerging markets and developing countries[40], they serve an "exclusive" circle of a privileged few[41].	**cA12:** As global crypto-based cooperatives have demonstrated, CCs facilitate the growth of alternative economies[47] towards a more just financial system.
Position 4a: Cryptocurrencies promote crime and anonymity	**Position 4b: Cryptocurrencies offer security and transparency**
A13: Due to poor and patchy regulation and a lack of regulatory oversight, the CC world attracts criminals[8, 48].	**cA13:** Because CCs provide a tamper-proof system of immutable data where transactions can only be accessed by the rightful owners, they offer technology-based security.[32,55,56]
A14: With ~25 % of CC users linked to illicit practices[49] (e.g., $20.6 billion received by illicit addresses, and $6 billion worth of CCs laundered in 2022 alone)[11], CCs are a lubricant for illegal activities[50, 51].	**cA15:** People overestimate the size of illegal businesses with CCs because the share of illicit CC transactions in the overall transaction volume was only 0.24 %, i.e., $20.6 billion (2022)[57], which is small compared to the conventional economy[58].
A15: Due to the prevalence of privacy-focused practices[52] and the anonymous nature of CCs, tracking illicit transactions for subsequent sanctions is nearly impossible.[53, 54]	**cA14:** Due to the transparency of transactions, police forces track stolen funds, identify perpetrators, and enforce sanctions[11, 59, 60], reducing fraud and corruption[43].
Position 5a: Adopting cryptocurrencies leads to financial risks and uncertainty	**Position 5b: Cryptocurrencies act as safe havens and a hedge against inflation**
A16: Due to the price decline in response to economic uncertainty and financial shocks[61], CCs don't offer the qualities of a safe haven.[62]	**cA16:** Because CCs have proven their safe-haven qualities in times of political and economic instability (e.g., during the COVID−19 pandemic, the 2016 US elections, or the bursting of the Chinese market bubble in 2015)[67], they serve as a reliable asset in times of uncertainty.
A17: Because of the extreme market fluctuations (e.g., BTC value swings[10]; actual value losses for ¾ of BTC users[13]), the spectacular meltdowns of CCs (e.g., of Iron Titanium in 21, and the bankruptcy of third-party organizations (e.g., the trading platform FTX; or the crypto-lender Celsius Network)[63, 64, 65], CCs expose adopters to financial risks.	**cA17:** As CCs offer alternative ways to protect savings (e.g., in regions such as Latin America and Africa[21, 61, 68], they can help adopters cope with demonetization.[69, 70]
A18: Since most CCs don't offer a double bottom (e.g., resulting in a total loss of ~20 % of all BTC ever mined)[66], they expose users to great risk.	**cA18:** By being linked to a commodity or fiat currency and/or having a limited supply and fixed issuance schedule[71, 72], CCs can reduce uncertainty.
Position 6a: Cryptocurrencies are de-facto centralized	**Position 6b: Cryptocurrencies are a decentralized system**
A19: Due to the limited number of mining pools[34], hardware manufacturers and the concentration of mining operations[52] in geographic clusters[73, 74, 75], CCs are characterized by a centralized mining value chain.	**cA19:** Since CCs operate on a distributed network (e.g., BTC ~16,000[77]; ETH ~10,000 nodes[78]) without a central authority[79], they offer technological decentralization[75].
A20: Because of centralized decision making, top-down governance[75], and few leading service providers (such as CC exchanges)[76], CCs feature concentrated control.	**cA20:** Through their inclusive governance models with consensus-based community decisions, CCs ensure that a broad and diverse range of stakeholders have a voice in the decision-making process.[80]
A21: With most CCs (e.g., 80 % of BTC) owned by long-term investors, CCs show centralized ownership.[20]	**cA21:** Due to their codebase stored in public repositories, CCs ensure a continuous and transparent decentralization of the system.[81]

[1]Krugman (2021); [2]Jones (2021); [3]García-Monleón et al. (2021); [4]Zhang et al. (2022); [5]Zook & Grote (2022); [6]Jonker (2019); [7]Copsey et al. (2022); [8]Auer et al. (2023b); [9]Lakhani & Iansiti (2017); [10]Coinmarketcap (2023); [11]Grauer et al. (2022); [12]Griffith (2022); [13]Auer et al. (2023b); [14]Arcane Research (2021); [15]Butler (2022, p. 88); [16]Dealroom & RockawayX (2023); [17]Munich Re (2020); [18]CCAF (2023); [19]De Best (2023); [20]Atkins (2022); [21]Urquhart & Lucey (2022); [22]Krause & Tolaymat (2018); [23]Mora et al. (2018); [24]Truby et al. (2022); [25]Vaughan et al. (2022); [26]Khazzaka (2022); [27]Dittmar & Praktiknjo (2019); [28]Masanet et al. (2019); [29]de Vries (2023); [30]Finanzinspektionen (2021); [31]Kristoufek (2020); [32]Andoni et al. (2019); [33]Foti & Vavalis (2021); [34]Hayes (2023); [35]Crandall (2019); [36]Baldwin (2018); [37]Auer & Tercero-Lucas (2022); [38]Demirgüç-Kunt et al. (2022); [39]Zook (2023); [40]Rogoff (2022); [41]Au (2022); [42]Campbell-Verduyn (2020); [43]Kshetri (2017);

[44]Onyekwere et al. (2023); [45]Ozili (2023); [46]Bouraoui (2020); [47]Rasillo (2023). [48]Garrido et al. (2022); [49]Foley et al. (2019); [50]Europol (2021); [51]Trozze et al. (2022); [52]Howell et al. (2023); [53]Mackenzie (2022); [54]Navamani (2023); [55]Ghosh et al. (2020); [56]Kang (2023); [57]Grauer et al. (2023a); [58]Scheiber & Flitter (2020); [59]U.S. Department of the Treasury (2022); [60]Bundeskriminalamt (2023); [61]Choi & Shin (2022); [62]Smales (2019); [63]Jalan & Matkovskyy (2023); [64]Lubben (2023); [65]Service (2022); [66]Zumbrun (2022); [67]Stensås et al. (2019); [68]Blau et al. (2021); [69]Urquhart & Zhang (2019); [70]Mariana et al. (2021); [71]Nakamoto (2008); [72]Wang et al. (2020); [73]Sun et al. (2022); [74]Blandin et al. (2020); [75]Heo & Yi (2023); [76]Tumasjan (2024); [77]Bitnodes (2023); [78]Etherscan (2023); [79]Chapron (2017); [80]Lumineau et al. (2021); [81]Lucchini et al. (2020).

5.1. Dimension 1: raison d'être

5.1.1. Position 1a: cryptocurrencies lack legitimate purpose

The first position builds on statements pointing to the missing legitimate purpose of cryptocurrencies (Acemoglu, 2021; Krugman, 2022). This point is underlined by a variety of arguments and related premises. For instance, Krugman (2021) highlights that cryptocurrencies are not integrated into our daily lives by drawing a comparison with other information technologies. He describes how technologies such as the *iPad*, *Zoom* or *Venmo* have become daily accompaniments twelve years after their launch, whereas cryptocurrencies are little understood and used. This may also be due to the lack of possible applications because many of the goals that blockchain applications aim to achieve can be accomplished without using cryptocurrencies (Jones, 2021). One key factor in this phenomenon is the lack of intrinsic value in cryptocurrencies, as they cannot be integrated into productive processes or directly consumed. Additionally, they lack essential currency characteristics that would provide objective value, making cryptocurrencies incapable of being recognized as true forms of currency (García-Monleón et al., 2021). Current research manifests that the actual impact of cryptocurrencies is limited, and people miss viable applications of it (Zook & Grote, 2022). In a study examining online retailers, Jonker (2019) demonstrated that their actual crypto-acceptance as a payment method is exceptionally low (2 %). This can be attributed to a lack of customer demand, ultimately reducing the likelihood of widespread adoption, as only 6 % of online shopping consumers make usage of cryptocurrencies in crypto-accepting retailers. But even large organizations are reluctant to adopt the technology. It has yet to be widely adopted by businesses (Copsey et al., 2022) and banks' direct involvement with cryptocurrencies remains limited (Auer et al., 2023b). Moreover, the technology is comparatively slow, allowing up to 7 transactions per second (TPS) for Bitcoin, 15 TPS for Ethereum, while PayPal and Visa realize 110 and 1700 TPS, respectively (Zhang et al., 2022).

5.1.2. Position 1b: cryptocurrencies are globally established

The counter position emphasizes that cryptocurrencies are already well established with its full capabilities yet to be realized for decades to come. Similar to the reasoning that cryptos are a damp squib, one can apply the comparison with other technologies to stress its disruptive potential. Lakhani & Iansiti (2017) demonstrate that the underlying technology of cryptocurrencies shows clear parallels to the early email and internet technology, which took more than 30 years to reshape the economy. Both focus on bilateral interactions, and the development and maintenance are open, distributed, and shared. Just like email, cryptos first caught on with an enthusiastic but relatively small community. So, the authors conclude that, cryptocurrencies are far from reaching their full potential. But even 14 years after its market introduction cryptocurrencies already signify a substantial market size. By mid-2023, there were more than 26,000 different currencies in circulation, and despite the significant losses during the 'crypto winter', the total market capitalization made up $1.1 trillion (Coinmarketcap, 2023). In addition, the transaction volume only for Bitcoin had reached $15.8 trillion in 2021 (Grauer et al., 2022). Following Butler (2022, p. 88) "it may be a moot point as to whether Bitcoin is money; in practice, it is used across the world as such". When it comes to the individual adoption, calculations show that within a seven year period to June 2022 a cumulative total of 565 million downloads of crypto exchange apps were realized and an estimated 220 million individuals worldwide have become cryptocurrency owners (Auer, et al., 2023a). In the context of business adoption, at least one-third of small and medium-sized US businesses accept cryptocurrencies as payment (Munich Re, 2020), and the blockchain industry has seen a rapid rise of businesses and new ventures. Today, the sector amounts to 11.3 thousand startups, 101 unicorns and has collected VC funding of $31.4b, globally in 2022 (Dealroom & RockawayX., 2023). As an asset class, cryptocurrencies have found strong institutional demand, further legitimizing their place in the market (Arcane Research, 2021). Furthermore, the crypto industry generated significant wealth, with Bitcoin and Ethereum alone generating $70 billion more than the national economy of Greece in 2017 (Wimbush, 2018), while the recent crypto collapse is connected to the broader tech industry retreat, demonstrating the industry's growing mainstream status (Griffith, 2022).

5.2. Dimension 2: environmental impact

5.2.1. Position 2a: cryptocurrencies are environmentally unsustainable

The second thread of arguments against cryptocurrencies relates to their environmental unsustainability. For example, the infrastructure of the largest virtual currency Bitcoin requires vast amounts of energy to run computer codes that underpin the system (Atkins, 2022; Urquhart & Lucey, 2022). Only Bitcoin's electricity consumption per year surpasses that of countries such as Belgium or Chile (CCAF, 2024), and it has been estimated to generate as much carbon dioxide over 30 months as 1 million cars in the same period (Krause & Tolaymat, 2018). Additionally, each Bitcoin transaction consumes more than $100 worth of electricity and generates more than 800 kg of carbon dioxide (Kohli et al., 2023; Urquhart & Lucey, 2022) thereby equaling the energy consumption of several hundreds of thousands of VISA card transactions (De Best, 2023). According to the study of Truby et al. (2022) the combined emissions caused by the two largest cryptocurrencies only in 2021 will be responsible for more than 27,000 future deaths. Despite efforts to increase the use of clean energy sources for mining, less than 60 % of energy comes from renewable sources (Bitcoin Mining Council, 2023; Vaughan et al., 2022). This has resulted in mining operations (of Bitcoin alone) being responsible for significant greenhouse gas emissions that. Following the adoption rate of other widely accepted technologies, its usage could lead to global warming above 2°C within less than 30 years (Mora et al., 2018). Moreover, each $1 in BTC market value created is responsible for $0.35 in global climate damages (Jones et al., 2022). Finally, Bitcoin mining operations generate significant electronic waste, estimating that Bitcoin produces as much electronic waste as the Netherlands (Urquhart & Lucey, 2022), as the lifetime value of the mining infrastructure is less than three years (Vaughan et al., 2022). The notion of environmental unsustainability is closely intertwined with the contention that cryptocurrencies lack a valid purpose, thereby eliminating any minimal "justification" for accepting the environmental cost associated with carbon emissions required for their mining. All of these factors lead to the demand for governments to actively prohibit and "de-socialize high energy-consuming blockchain technology" (Mohsin et al., 2023, p. 651).

5.2.2. Position 2b: cryptocurrencies promote sustainable transition

The example of mining operations' impact on climate serves as a compelling illustration of how the controversy resonates within the scientific community. The afore mentioned article by Mora et al. (2018)

entitled "Bitcoin emissions alone could push global warming above 2°C" achieved wide recognition (ranked 23rd of 354,656 tracked articles of a similar age, more than 14 thousand accesses). But responses indicate structural limitations of the applied methodology (Dittmar & Praktiknjo, 2019) and emphasize that the underlying "scenarios must be approached with more rigour and greater analytical care if they are to be of use" (Masanet et al., 2019, p. 654). While cryptocurrencies have been criticized for their environmental impact, they can also promote the sustainability transition in various ways. A study demonstrates that on a single transaction level Bitcoin is up to three times more energy-efficient than the classical system and through its scalability the technology offers the opportunity to become million times less energy consuming when applied in a large scale (Khazzaka, 2022). The responsiveness to environmental issues is well illustrated by the example of Ethereum. In 2022, Ethereum replaced its proof-of-work mining mechanism with an alternative known as proof-of-stake. This change is estimated to have reduced the network's energy consumption by over 99.8 %. In absolute terms, this reduction is equivalent to the electricity demand of a country such as Ireland (De Vries, 2023). The inclusion of cryptocurrency miners can also serve as a smoothing tool for the overproduction of green energy, helping to balance unstable electrical systems (Kristoufek, 2020) and prevent energy waste. Furthermore, initiatives like SolarCoin, which is officially recognized by the International Renewable Energy Agency, use cryptocurrencies to reward low-carbon and green energy production (Andoni et al., 2019; Foti & Vavalis, 2021). As energy becomes more expensive, the consumption is high for mining, and miners are keen to be act more sustainably, cryptocurrencies could foster the production of renewable energy (Kristoufek, 2020), as for example seen in the increasing presence of crypto-asset producers in the Nordic region (Finanzinspektionen, 2021).

5.3. Dimension 3: inclusion

5.3.1. Position 3a: cryptocurrencies foster social exclusion

Thirdly, cryptocurrencies and DeFi have come under scrutiny for their role in perpetuating social exclusion; evoking a system of "capitalism on steroids" (Wójcik, 2021, p. 883), with certain socio-demographic groups and regions facing limited representation in their adoption. The genesis of Bitcoin and the prevailing focus on cryptocurrencies have been linked to libertarian (Hayes, 2023), 'techno-capitalist ideologies' (Crandall, 2019) and 'right-wing populism and political extremism' (Atkins, 2022) of 'cyber-kinetic elites' (Simpson & Sheller, 2022) emphasizing the exclusive nature of the crypto community (Baldwin, 2018). Recent empirical studies provide evidence supporting this claim, revealing a correlation between Bitcoin ownership and individuals who embrace high-risk behavior and libertarian political values (Foley et al., 2022; Lichti, and Tumasjan., 2023). On an individual level, statistics show that the average American cryptocurrency owner is a 38-year-old white male with an annual income of $111k (Gemini, 2022), raising concerns that cryptocurrencies may exacerbate existing socioeconomic disparities (Auer & Tercero-Lucas, 2022). While some argue that cryptocurrency adoption has limited impact on wealth inequality, there is a growing worry that it could perpetuate disparities by catering to a privileged few (Au, 2022). While affluent economies tend to dominate cryptocurrency investments, the negative consequences are predominantly experienced in emerging markets and developing countries (Rogoff, 2022). Despite the hopes of replacing exclusionary practices, the analysis by Campbell-Verduyn & Giumelli (2022) indicates that blockchain technologies, when experimented with in Africa, may inadvertently reinforce exclusionary conditions rather than remedying them. Moreover, beyond Africa, the intricate characteristics of digital assets like cryptocurrencies, coupled with limited availability of essential resources like smartphones, internet access, and financial education, may impede the participation and integration of individuals from the global south (Demirgüç-Kunt et al., 2022; Zook, 2023).

5.3.2. Position 3b: cryptocurrencies offer access to the economy

A commonly reiterated position regarding cryptocurrencies portrays it as a catalyst for democratizing finance offering a path towards financial inclusion and independence (Urquhart & Lucey, 2022; Zook & Grote, 2022). The virtual currencies can also be deployed to enhance the growth of alternative economies in a postcapitalist financial framework, as the example of FairCoop and their cryptocurrency FairCoin shows (Rasillo, 2023). Anyone can participate in the cryptocurrency network as a user, miner, or validator without needing permission from any centralized authority, promoting inclusivity and accessibility. Accordingly, they have the capacity to enhance financial inclusivity by offering an alternative pathway for unbanked groups of persons to access formal financial services to participate in the financial economy (Chapron, 2017; Ozili, 2023; Underwood, 2016). For instance, the technology can alleviate the challenge of physical distance between individuals and traditional financial institutions and enable the receiving of salaries (Demirgüç-Kunt et al., 2022). It also allows the sending and receiving of remittances, and facilitates business transactions without major fees enhancing the 'inclusion' of migrants, temporary 'guest workers', and the 'unbanked' into key processes of market-based governance (Campbell-Verduyn, 2020; Grauer et al., 2022; Kshetri, 2017). An empirical study in Nigeria demonstrates that the efficiency and cost-effectiveness of cryptocurrencies, makes them an attractive option for users looking to reduce transaction fees and conduct cross-border transactions seamlessly (Onyekwere et al., 2023). In the country, affected by political instability, COVID-19, and oil price collapses, cryptocurrencies have become a viable solution to address the challenges, with adoption spanning various demographics amid high unemployment (Grauer et al., 2023b). This goes along with the premise that the cryptocurrency infrastructure stems from the perceived shortcomings of conventional financial systems. Specifically, the expansion of crypto infrastructure correlates with a lack of trust in banks and the overall financial system and is often linked to the presence of economic crises at the national level (Saiedi et al., 2021). By utilizing cryptocurrencies, individuals can bypass the limitations imposed by traditional financial institutions and conduct transactions globally without interference from authorities in countries with unfair and restrictive financial practices (Bouraoui, 2020). Furthermore, one can observe a significant correlation of cryptocurrency adoption with the Gini Index, indicating that increased income inequality serves as a driving force behind the adoption of cryptocurrency (Bhimani et al., 2022). In the aftermath of the 2022 crypto crisis, grassroots adoption of cryptocurrencies in lower-middle-income countries has rebounded significantly stronger than in other regions (Grauer et al., 2023b), potentially reducing global income and wealth inequality (Othman et al., 2020). In fact, according to the Global Crypto Adoption Index 2023, India, Nigeria and Vietnam are the top three countries with the highest cryptocurrency adoption rates (Grauer et al., 2023b).

5.4. Dimension 4: use in illegal activities

5.4.1. Position 4a: cryptocurrencies promote crime and anonymity

One of the main reasons for the adoption of cryptocurrencies, such as Bitcoin, is their perceived usefulness for engaging in illicit trade (Saiedi et al., 2021). A crucial aspect contributing to the promotion of crime through cryptocurrencies is the lightly regulated crypto exchanges, which remains patchy compared to existing regulated exchanges for traditional financial assets and makes them attractive hubs for illicit transactions (Auer et al., 2023b; Garrido et al., 2022). Estimations indicate that about a quarter of all users and nearly half of Bitcoin transactions are linked to illicit practices (Foley et al., 2019). The variety of fraudulent activities is also largely caused by the anonymous character of cryptos, making it difficult to trace (illicit) transactions (Mackenzie, 2022; Navamani, 2023). This is underscored by the prevalence of privacy-focused practices, as a significant number of nodes operate in the TOR network, which is focused on anonymous

communication (Howell et al., 2023). The anonymity aids in avoiding detection and facilitates illegal activities, such as money laundering, fraud, bypassing financial sanctions, evading taxes, and circumventing capital controls (Europol, 2021; Trozze et al., 2022). For example, illicit addresses received $20.6 bn, cybercriminals laundered cryptocurrencies amounting $6 billion, and darknet markets had revenues of $1.5 bn in cryptocurrency in 2022 alone (Grauer et al., 2022). Consequently, it is unsurprising that certain nation-states, e.g. North Korea, are directing their attention towards leveraging the technology for criminal purposes. Hackers linked to the country reportedly stole nearly $1.7 billion worth of digital assets in 2022 (Grauer et al., 2023a).

5.4.2. Position 4b: cryptocurrencies offer security and transparency

The counter position stresses that cryptocurrencies offer opportunities for security and transparency. Through the underlying decentralized and distributed ledger system that openly records transactions in cryptographically linked blocks, the technology ensures integrity and fosters a sense of trust and security (Koroma et al., 2022; Navamani, 2023). The accompanying security mechanisms, such as proof-of-work or proof-of-stake and public/private key pairs, ensure that only the rightful owner can access and authorize transactions without the need for a trusted authority (Andoni et al., 2019; Ghosh et al., 2020; Kang, 2023; Nakamoto, 2008). Moreover, due to the transparency and compared to traditional fiat currencies, the blockchain technology can also reduce fraud and corruption (Kshetri, 2017) and make it possible to track stolen funds and their thieves, making them accountable for their crimes (Grauer et al., 2022). Contrary to common misconceptions, illicit crypto transactions represent a small percentage of the overall cryptocurrency transaction volume (0.24 %; $20.6 bn), indicating a downward trend in such activities (Grauer et al., 2023a). In addition, these figures look particularly small when compared with the volume of fraudulent transactions in the conventional economy: Scheiber and Flitter (2020) suggest on the ground of leaked documents that the major banks alone were knowingly involved in illicit transactions totaling $2 trillion from 1999 to 2017. Recent actions by regulators have demonstrated the possibility and enforceability of sanctions in the cryptocurrency world, proving that the crypto sphere is not a legal vacuum (U.S. Department of the Treasury, 2022). For instance, the German Federal Criminal Police Office recently seized Bitcoins amounting to the equivalent of around $ 49 million in the course of investigations against money laundering service that disguised the origin of Bitcoin valued $ 3 billion (Bundeskriminalamt, 2023).

5.5. Dimension 5: economic implications

5.5.1. Position 5a: adopting cryptocurrencies leads to financial risks and uncertainty

As indicated at the outset of the article, the extreme volatility of cryptocurrencies and their association with financial uncertainties are central concerns that challenge their position as serious assets and stable investment options. Compared to fiat money cryptocurrencies do “what money should not do: that is, introduce uncertainty into transactions” (Ingham, 2020, p. 114). Additionally, some experts suggest that cryptocurrencies like Bitcoin are not a safe haven asset in times of economic uncertainty (Smales, 2019), and like “any Ponzi scheme, the investment must be constantly talked-up” (Baldwin, 2018, p. 6). Calculations suggest that around three-quarters of users have experienced losses on their Bitcoin investments (Auer et al., 2023a), and the most common reason for purchasing crypto assets remains speculative in nature (Aju & Burell, 2023). Unlike traditional safe-haven assets like gold, Bitcoin prices have shown a decline in response to financial shocks, undermining the notion of cryptocurrencies as a reliable hedge (Choi & Shin, 2022). This feature aligns with the widespread belief that most crypto assets carry considerably higher investment risks compared to more traditional financial assets like stocks (Pessa et al., 2023). The extraordinary volatility possesses further risk and is evident through numerous examples of significant market fluctuations. For instance, Bitcoin’s value declined from $69,000 in November 2021 to $16,000 a year later, resulting in a substantial decrease in the total crypto market cap (Coinmarketcap, 2023). Even more extreme fluctuations have been observed in mid-sized coins like Iron Titanium, which collapsed from $51 to $0.0004 in just 24 h (Urquhart & Lucey, 2022), along the total meltdown of stablecoins like TerraUSD, resulting in a substantial market value reduction of $500 billion (Jalan & Matkovskyy, 2023). In addition, the bankruptcy of major crypto exchanges like FTX as well as crypto lenders with millions of customers like Celsius Network further fuel uncertainties about the long-term stability of cryptocurrencies and their interconnected organizations (Jalan & Matkovskyy, 2023; Lubben, 2023; Service, 2022). This even led to significant write-offs of prominent venture capital firms such as BlackRock and Sequoia (Jalan & Matkovskyy, 2023). The absence of a double bottom in most cryptocurrencies, exemplified by the total loss of approximately 20 % of Bitcoin (Zumbrun, 2022), contributes to the notion of heightened risks associated with these digital assets.

5.5.2. Position 5b: cryptocurrencies act as safe havens and a hedge against uncertainty and inflation

Amidst their inherent risks and uncertainties, cryptocurrencies have demonstrated the capacity to function as safe havens in periods of global economic and political turmoil. Evidenced by their ability to serve as hedges against inflation (Urquhart & Zhang, 2019) they provide alternative avenues for safeguarding savings in regions plagued by currency devaluation and political instability. Here, cryptocurrencies have emerged as significant contributors to the financial landscape during times of economic uncertainty and market volatility (Mariana et al., 2021). One significant factor contributing to this perception is, for example in the case of Bitcoin, the limited supply of cryptocurrencies, achieved through fixed issuance schedules, making them more resilient to inflation and currency devaluation (Nakamoto, 2008). In regions like Latin America and Africa, where long-term hyperinflation has been experienced, cryptocurrencies have emerged as potential escape from demonetization (Blau et al., 2021; Choi & Shin, 2022; Urquhart & Lucey, 2022). For instance, they have been recognized as complementary assets in African stock and gold markets, providing safe-haven qualities, diversification, and assurance for investors, particularly during the COVID-19 pandemic (Nkrumah-Boadu et al., 2022). These attributes have been substantiated through empirical investigations and have likewise manifested during significant global events, such as the US election in 2016, the Brexit referendum in 2016, and the burst of the Chinese market bubble in 2015 (Stensås et al., 2019). Here stablecoins, like Tether, can also help to minimize risks (Wang et al., 2020). Furthermore, regions facing political instability (like Afghanistan during Taliban’s return to power), have turned to cryptocurrencies as a means of preserving their wealth amid uncertainty and upheaval (Grauer, 2021). This has led to a belief that cryptocurrencies are the future of money in these regions, with a majority of people showing interest in investing in them (Gemini, 2023).

5.6. Dimension 6: centralization

5.6.1. Position 6a: cryptocurrencies are de-facto centralized

While cryptocurrencies are purportedly decentralized, their de facto centralization has continuously been the subject of the controversy (Zook, 2023). Envisioned as decentralized, participatory system, it rather “reinforced the concentration of capital and power over time” (Hayes, 2023, p. 4). One primary reason for this phenomenon is the (geographical) centralization of the mining value chain, ownership, and governance (Blandin et al., 2020; Heo & Yi, 2023). Research indicates that the increasing complexity of mining over the past decade has led to the centralization of mining activities (Hayes, 2023; Howell et al., 2023). A limited number of mining pools, hardware producers, and mining operations exercise substantial control over the network’s computing power. For instance, only two mining pools held accountable

for over 51 percent of the total hash rate of Bitcoin and commercial mining activities constituted an additional 25 percent (Hayes, 2023, p. 7). Examining the geographical aspect, 62 % of the collective computational capacity dedicated to Bitcoin mining is centralized within a mere 0.25 % of the Earth's land area and concentrates in regions with cheap energy sources (Sun et al., 2022). This clustering of mining entities raises concerns about the possibility of a 51 % attack, wherein an individual participant could gain full control over a significant portion of the mining hash-rate, posing serious threats to the integrity and security of the whole system (Ghosh et al., 2020; Navamani, 2023). Furthermore, a select group of long-term investors holds a considerable portion of Bitcoin, estimated at around 80 % (Atkins, 2022), indicating further de-facto centralization. Moreover, cryptocurrencies have witnessed highly concentrated money laundering activities, further undermining their decentralization claims (Grauer, 2021; Grauer et al., 2022). The governance aspects of cryptocurrencies also reveals centralized characteristics. Decision-making authority, such as rule or algorithm modifications, tends to rest in the hands of a limited number of individuals, often founders or key stakeholders, excluding broader participation. During problem-solving scenarios, centralized, top-down control and monitoring typically govern coordination efforts (Heo & Yi, 2023). A further aspect underpinning the centralization tendency is the growing control through service providers, like centralized cryptocurrency exchanges and wallets (Tumasjan, 2024).

5.6.2. *Position 6b: cryptocurrencies are a decentralized system*

The last position focuses on the inherent characteristics of cryptocurrencies, which are characterized by and adopted because of their decentralized nature (Johnson, 2016). Being built on the blockchain technology, transaction records are distributed across a network of computers (nodes) instead of being stored in a central authority's database (Chapron, 2017). Once recorded on the blockchain, transactions become practically irreversible, preventing any single authority from altering past transactions, reducing the potential for centralized control or interference (Tumasjan, 2021). This is made possible by the multiple participants of the system that independently validate and record the transactions (Chen et al., 2022). At the end of 2023, the Bitcoin peer-to-peer network included over 16,000 nodes (Bitnodes, 2023), while approximately 10,000 nodes are connected through the Ethereum network (Etherscan, 2023). This decentralization of cryptocurrencies is backed by Heo & Yi (2023) who analyzed the (de)centralization in the governance of ten major cryptocurrency blockchain systems. In addition, many cryptocurrencies adopt community-based governance models, where network upgrades and improvements are collectively decided upon through consensus among participants (Lumineau et al., 2021). Lastly, many cryptocurrencies adopt open-source code, which is stored in public repositories for most cryptocurrencies (Lucchini et al., 2020), allowing developers to contribute, review, and modify the codebase transparently, and thereby ensuring the continued decentralization of the system.

6. Pleading for a geographical approach to innovation controversies

What does this argumentation analysis teach us on how to disentangle the crypto controversy? The above content analysis of the argumentation structure offers several conclusions: First, the crypto controversy has become more complex over time, with supporters and opponents continuously accumulating numerous and distinctive sets of arguments and counter-arguments along a growing number of dimensions of disagreement. This cumulative character of 'piling up arguments' supports the claim that *controversies* are more inconclusive than *discussions* (Dascal, 1998), hence more enduring, and they are more likely to close with a *resolution* rather than a *solution*.

Second, our content analysis shows that the disagreement is rarely about the validity of facts but rather about the construction of models and measures as well as the interpretation of the facts. Whereas most premises are undisputed, they feed opposing conclusions. This, again, reinforces the character of a controversy as durable and enduring, because new empirical evidence need not necessarily deliver the missing facts to *solve* the disagreement. Instead, the disagreement is fruit of different valuations, interests and frames underlying the interpretation of premises.

Third, because the crypto controversy is enduring, and because it is built on accumulated sets of arguments supporting different beliefs rather than facts, questions arise as to how the controversy will evolve in the future and how it is linked to the process of diffusion of cryptocurrencies in societal practice. At this point, the analysis reaches its limitation when conducted as space- and placeless. Instead, when linking the realm of published speech (text) with that of innovation adoption (practice), geography becomes an important element in any analysis of a controversy. As the crypto controversy continues to go on, it may eventually reach closure at some point in the future, and in some places more likely than in others. Because controversies are an exchange of arguments among localized individuals and framed in particular institutional contexts (Glückler & Bathelt, 2017), we argue that geography makes a real difference for whether, how, and where change can surpass controversy or not.

Other controversial and cutting-edge innovations like living technologies showed that they are "highly sensitive to the social, regulatory and political context as well as the environmental ecosystem into which the innovation is deployed" (Cisnetto & Barlow, 2020, p. 3). This is consistent with research on techno-economic paradigms, which emphasizes the need for institutional adaptation for technology adoption (Perez, 2010), as every technological revolution triggers significant socio-economic upheaval and requires extensive institutional change to realize its full potential. Resistance to diffusion of controversial innovation highlights a socio-institutional mismatch, where existing regulatory and social frameworks are not aligned with emerging technological opportunities (Cassiolato et al., 2009; Freeman, 2009; Perez, 2002).

Consequently, and in line with Engelhardt and Caplan (1987), a 'geography of controversies' would help unravel how different forms of rationality are pursued with success or failure in different places. The diversity of places and localized institutional contexts represents a great variety of locational opportunities for creating top-down jurisdictional advantage (Feldman & Martin, 2005), e.g., by regulatory intervention, as well as bottom-up institutional processes, e.g., institutional entrepreneurship, and dynamic social networks. Unique networks of relationships and sets of institutions localized in distinct geographical places – we call them spatial pockets of innovation – make a difference for the legitimacy and adoption of innovations (Lawrence & Phillips, 2004; Storper, 2018). In the case of cryptocurrencies, the Canton of Zug (Switzerland) illustrates how temporal, regional, and actor-specific combinations of top-down legislation by public authorities and bottom-up initiatives by institutional innovators has fostered the creation of a locational opportunity space ('Crypto Valley') for this controversial innovation to gain traction (Morisson & Turner, 2022). The importance of the local institutional context in facilitating innovation echoes findings from other controversial or even illegal innovations. In the Cognac region, for example, strict regulations on production techniques of spirits led to inefficiencies, prompting institutional entrepreneurs to reinterpret the legal framework and develop new, legally compliant products by redefining the rules of the industry (Moodysson & Sack, 2018). A different approach was observed in the Bavarian brewing industry, where craft brewing conflicted with a centuries-old purity law. Only by way of 'institutional folding' was it possible for craft brewing innovations to thrive, i.e. by layering new practices over traditional ones in ways that legitimized the new brewing techniques and, simultaneously, delegitimized existing institutions. This process not only helped craft-brewing innovations succeed in the face of controversy, but ultimately established the new creations as among the most innovative

products worldwide (Glückler & Eckhardt, 2022).

Together, regulation as well as institutional change may build locally specific and contingent momentum to either oppress or facilitate the use and further diffusion of cryptocurrencies in local, regional and national economic practices. Researchers in economic geography should become interested in the dynamics operating in spatial pockets of innovation, including places and spaces that lock-out change by way of banning and forbidding novel technologies as well as those where technological pioneers, institutional entrepreneurs and susceptible communities create seedbeds for adoption and gradual alignment between incumbent societal practices and new technologies. A geographical research agenda for the analysis of controversies should focus on three related elements of a controversy: (i) the logic and structure of arguments, premises and inferences that it rests on, (ii) the relational structure of who participates in a controversy and how it is conducted, and (iii) the spatial pockets where novel technologies and innovations unfold and co-evolve with a dynamic controversy.

7. Conclusion

Contemporary controversies often revolve around issues related to science and technology (Glückler & Panitz, 2024), including artificial intelligence, robots, full self-driving vehicles, de-centralized blockchain applications, genetic engineering, etc. Due to their crucial impact on shaping our future, disagreements about these technologies have gained significant prominence not only in public discourse but also in academic and policy arenas (Venturini & Munk, 2022). Examining an innovation during a phase of controversy not only uncovers the contextual expressions of its time (e.g., Cisnetto & Barlow, 2020; Weart, 1987), but also highlights the challenges that arise during the diffusion of innovation (Mazur, 1987). Studying controversies is a highly dynamic process that becomes increasingly complex with each new dimension added, akin to "diving in magma" (Venturini, 2010, p. 258). This complexity is fueled by the constant introduction of new actors and external influences that can significantly alter the trajectory of the controversy. New innovations or technological advances can either resolve or intensify contested qualities of an innovation, while external influences or shocks can introduce new arguments and add additional dimensions to the controversy.

In this paper, we present three key implications: First, we utilize the sociology of science and argumentation theory to define controversies as a distinct form of disagreement. Controversies involve a public and sustained exchange of arguments over empirical facts, where all opposing viewpoints operate within a shared conceptual framework, enabling them to make reasonable truth claims. This sets controversies apart from other types of disagreements – such as discussions, disputes, or conspiracy theories – which may be solved by correcting errors, dissolved through external interventions, or where rational closure is unattainable. In contrast, controversies feature multiple reasonable arguments, each with premises and conclusions that support specific positions, offering the possibility of constructive resolution.

Second, building on this conceptualization, we applied argumentation analysis to investigate whether cryptocurrencies are subject to controversy and to empirically disentangle the semantic structure of positions, arguments, and underlying premises. In line with recent calls for methodological pluralism and the purposive exploration of new analytical approaches in economic geography (Bathelt & Li, 2020; Martin, 2021), our approach—an analytical technique that, to our knowledge, has not previously been used in geography—provides a novel and timely evaluation of the diverse and globally dispersed controversy surrounding the legitimacy of cryptocurrencies. We have identified and outlined the structure of 42 distinct arguments and the underlying premises that support the various positions in this crypto debate. These findings are categorized into six key dimensions of disagreement: the raison d'être of cryptocurrencies, their environmental impact, potential for social exclusion, susceptibility to illegal activities, economic consequences, and their capacity for decentralization and democratization. While participants in the controversy hold differing positions, they share a common conceptual framework. For instance, although there is consensus on the amount of electricity required to run the Bitcoin network, it is normative beliefs that lead to differing conclusions. Controversialists draw contrasting positions from the same fact (e.g., energy consumption as justified versus unjustified), yet all operate within a shared worldview grounded in reason and logic. Our analysis meets the definition of controversy, as each position presented in the paper is well-supported by scholarly research, empirical evidence, and logical rigor. Our exploratory research suggests that cryptocurrencies are caught in a situation of disagreement that truly justifies their qualification as a controversy: it is globally public, has proven to be persistent since its inception in 2009, rests on arguments that have reasonable claims to truth and appears almost impossible to resolve definitively, at least at this moment of its evolution.

Third, while the controversy surrounding cryptocurrencies may appear unbounded, we advocate for a geographical approach to understanding controversies. A geographical perspective is particularly valuable for developing a deeper understanding of both the evolution of the controversy and the uncertain, contingent consequences of establishing a controversial innovation. The efforts of both supporters and opponents are embedded within specific territories and shaped by distinct institutional contexts. In some regions, public discourse and societal institutions that scrutinize and adopt innovations may be restrictive, while in others, they may be more receptive and even supportive. It is here, where we echo Engelhardt and Caplan's (1987) call for the conceptualization of a geography of controversies.

CRediT authorship contribution statement

Yannick Eckhardt: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Johannes Glückler:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

Declaration of Competing Interest

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

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