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A Text-Embedding-Based Approach to Measure DeFi Patent Landscaping: Evidence from Bitcoin and Ethereum

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Abstract

The rapid and enormous market capitalization achieved by Bitcoin in recent years has also increased demand for cryptocurrencies based on blockchain technology. At present, Bitcoin and Ethereum are the leading cryptocurrencies in terms of market capitalization and trading volume. As such, those cryptocurrencies play a central role in the ongoing Decentralized Finance (DeFi) process, which regards the development of a financial ecosystem based on blockchain technology. This comparative study seeks to contribute to filing a gap in the intellectual property management literature by examining the main technological trends associated with both cryptocurrencies based the analysis of patent information. We have found that both Bitcoin and Ethereum started to become a technological hotspot from 2016 onwards, as the number of patent applications for both cryptocurrencies started to skyrocket in this particular year. We also present evidence that both Bitcoin and Ethereum patents address data processing issues, rather than hardware technologies. Furthermore, we observed that the US and China are the main patent applicants regarding Bitcoin, while China is by far the leading applicant of Ethereum patents.

Keywords: *Bitcoin, Ethereum, Patent landscaping, Cryptocurrency, Intellectual property*

1. Introduction

The market for cryptocurrencies has received garrulous attention in the last few years, especially as a result of the great increase achieved by Bitcoin since its launch in 2009. Fundamentally, Bitcoin consists of a digital currently with a strong potential to disrupt the market for payment solutions (Böhme *et al*., 2015). As such, Bitcoin has rapidly gained massive visibility as the first cryptocurrency that managed to reach global large-scale adoption, as well as an explosive market valuation could be observed in recent years (Bonneau *et al*., 2015).

Given the rapid and strong increased in market capitalization of Bitcoin, a growing number of other cryptocurrencies based on blockchain were proposed. At present, besides Bitcoin, there are currently more

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than 20,000 cryptocurrencies available. However, the wide majority of them is absolutely irrelevant in terms of market capitalization and viability. As such, the second most relevant cryptocurrency is named Ethereum.

Fundamentally, Bitcoin and Ethereum are similar as both currencies rely on blockchain technology. However, besides being launched a few years lates, as Ethereum was launched only in 2015, there also relevant differences regarding performance and the service layers of Ethereum blockchain. In short, Ethereum was designed to address a number of shortcomings identified in the earlier Bitcoin proposition (Buterin, 2014).

Since patents have become a fundamental instrument to protect innovation efforts, the development of strategies associated with patent applications has been gaining attention as an increasingly relevant research topic (Dolfsma, 2011; Grimaldi *et al.*, 2018). In this way, despite the growing economic importance of patents and the recent emergence of cryptocurrencies, literature remains silent on patent strategizing regarding similarities and differences between Bitcoin and Ethereum. As such, the objective of this paper is to improve understanding of patent strategizing regarding technologies related to both Bitcoin and Ethereum.

This paper is structured as follows. In Section 2, we examine the literature on patent landscaping, Bitcoin and Ethereum. Section 3 describes our research method. Section 4 is dedicated to examine the results and discusses patterns of patent applications associated with technologies addressing Bitcoin and Ethereum. Section 5 discusses our findings in the light of constructs from the literature. Finally, we put forward our conclusions in Section 6.

2. Literature Review

In this section, we both set the context for our analysis and provide some definitional clarity by examining relevant literature on patent landscaping techniques, as well as the characteristics of both Bitcoin and Ethereum.

2.1. Patent Landscaping

It is widely believed that intellectual property plays a growing role in in the development of new technologies (Aldieri and Vinci, 2016). As such, patent data is a rich source of information of the strategy of technology-intensive firms (Wolfram *et al.*, 2018). As stated by Ernst (2003), a growing number of scholars are developing new techniques to analyze patent information. Accordingly, as argued by Clarke *et al*. (2020), the combinations of methods focusing on identifying business relevant patterns based on patent information is referred to as patent landscaping. More specifically, Trippe (2015) argues that “There is no single or universally accepted definition of a Patent Landscape Report; in general, one can say that it constitutes an overview of patenting activity in a field of technology, in a specific geographical area. A landscape normally seeks to answer specific policy or practical questions and to present complex information about this activity in a clear and accessible manner for audiences with different background”.

Several scholars have discussed patterns identified by examining patents protecting technologies in different domains and countries. Rugraff (2017) analyzed patent applications as a dimension of R&D effort of firms based in the Czech Republic. Aldieri and Vinci (2016), in turn, focused on patent citation statistics concerning patent applications filed in the US, Japan, and Europe, while Kyebambe *et al*. (2017) also analyzed patent citation data to as a means of forecasting future technological trends. Besides, Menon *et al*. (2015) analyzed patent information as a means of identifying mainstream trends for the Indian seed industry.

Moreover, it is widely believed that patterns of patent applications follow domain specific trends (Cavalheiro *et al.*, 2014). Therefore, it is very important to keep searching for patterns based on patent information from different technical domains, as the patterns cannot be simply extrapolated to all technical domains. In this way, it is possible to identify several examples of high-impact research based on patent information from different technological areas. As an example of the massive technological development in the wind energy domain, Kapoor *et al*. (2015) has focused on the proposition of citation categories in patent portfolios associated with the European wind industry. Beyond this, Cho *et al*. (2018) observed a recent growth in patenting activity regarding high-rise building technologies in China. Cavalheiro and Brandao (2017), in turn, relied on patent landscape analysis to identify a recent growth in patent filings by the Brazilian footwear industry. Finally, Messeni *et al.* (2015) examined meta data of patent documents in the biotechnology, such as number of claims, characteristics of applicants and the scope of inventions, so as to identify the main drivers of patent citation.

2.2. Decentralized Finance (DeFi)

The main objective of Decentralized Finance (DeFi), also called open-finance, is to provide financial services based on blockchain in a decentralized manner. According to Pineiro-Chousa *et al*. (2022), DeFi can be regarded as a disruptive process that involves the use of blockchain technology, smart-contracts, decentralized ledgers, and applications based on open protocols to support the development of a wide variety of financial products and services.

As such, the success of decentralized finance has attracted widespread interest from investors, as tradable tokes, often called cryptocurrencies, are increasingly being used for governance, utility, and security (Pineiro-Chousa *et al*., 2022). For instance, Wan *et al.* (2022) explain how blockchain can be deployed to support collaborative innovation in the manufacturing industry. Moreover, Sriman and Kumar (2022) describe the use of Ethereum blockchain to conduct financial transactions.

In fact, cryptocurrencies markets, including the Bitcoin and Ethereum markets, have experienced tremendous growth over the past decade (Yi *et al*., 2022). Therefore, those cryptocurrencies play a central role in DeFi initiatives aiming at creating a new financial ecosystem based on blockchain technology (Kim *et al*., 2021).

2.3. Bitcoin

The vision of digital money did not appear with Bitcoin, but was conceived in the early 1980s (Tschorsch and Scheuermann, 2016). The market value of all Bitcoins in circulation started from approximately $227 K when Bitcoins were first publicly traded in July 2010 (Garcia *et al*., 2018). However, the original concept of a digital currency required a central authority, such as a bank, in order to be implemented and managed. Nevertheless, this limitation of early centralized digital currencies was circumvented by the use of sophisticated cryptography techniques. This specific type of digital currency became widely known as cryptocurrency (Garcia *et al.,* 2018).

Fundamentally, the original foundation of Bitcoin was defined by the article "Bitcoin: a Peer-to-Peer Electronic Cash System" of Satoshi Nakamoto, published on the internet in 2008. This paper proposed the schema for a peer-to-peer network allowing the development of a system for electronic transactions without relying on trust (Nakamoto, 2008). Although Bitcoin was the first widely adopted cryptocurrency in the world, there were other earlier digital currencies presenting characteristics similar to Bitcoin, including proof-of-work and digital scarcity (DeVries, 2016).

An early example of digital currency, ecash was the first adopter of proof-of-work process for spam control. Moreover, as pointed out by Narayanan and Clark (2017) there a few cryptocurrencies relying on the concept of distributed digital scarcity prior to Bitcoin, including Bit Gold and B-money.

In essence, Garcia *et al.* (2018) explains that Bitcoin comprises a descentralized structure, which includes distributed ledgers. More specifically, Bitcoin employs blockchain as a public distributed ledger containing the full record of all public transactions. As such, that cryptocurrency is totally independent, as it does not need traditional financial institutions to support the execution of its transactions (Böhme *et al*., 2015). As stated by Porras-Gonzalez *et al.* (2019), blockchain can be considered as a distributed ledger technology to record and transfer data in a secure, transparent, decentralized and verifiable way. Clearly, blockchain plays an important role as a central instrument to record value (Pazaitis *et al*., 2017).

2.4. Ethereum

Ethereum was launched in 2015, only a few years after bitcoin. This cryptocurrency was proposed in 2014 by Vitalik Buterin through a whitepaper describing Ethereum and its vision (Buterin, 2014). Just like Bitcoin, Ethereum is also a decentralized blockchain-based cryptocurrency. However, there are some relevant differences to be found between those cryptocurrencies. First of all, Ethereum has a higher transactions performance. For instance, new blocks on the Bitcoin blockchain are added on an average of every 10 min, while new blocks are added to the Ethereum blockchain approximately every 15 s (Lennart, 2021). Furthermore, although Bitcoin and Ethereum have relied on proof-of-work consensus, which demands high energy consumption from miners, Ethereum 2.0 is adopting a proof-of-stake algorithm, which limits the amount of energy required by miners to reach consensus.

Given the growing market capitalization and adoption of Ethereum, more and more studies are being published on this cryptocurrency. For instance, Shakya and Kapoor (2021) proposed a decentralized polling system based on the Ethereum blockchain. Caballero-Gil *et al*. (2022), in turn, proposed a proposed an Ethereum-

based decentralized car rental system that relies on smart contracts. Besides, Zhang and Bai (2022) relied on Ethereum blockchain to build smart contracts to manage wind power network security needs. Beyond this, Lennart (2021) examined transaction patterns of Non-Fungible Tokens (NFT) by collecting data from the Ethereum blockchain. Also collecting data from the Ethereum blockchain, Kim *et al.* (2021) proposed a method that used machine learning technique to predict Ethereum prices.

2.5. Research Hypothesis

Based on the literature review on issues associated with strategic patenting and Bitcoin, it was possible to reformulate the four research hypotheses proposed by Cavalheiro and Cavalheiro (2022) in order to test them with both Bitcoin and Ethereum cryptocurrencies:

- H_1: *Increased valuation of both Bitcoin and Ethereum is likely to motivate an increase in patent filings concerning technologies related to Bitcoin (Lang,2001; Galini, 2002; Dolfsma, 2011; Cho et al, 2018).*
- H_2: *Firms based in developed countries are more likely to file patent applications associated with Bitcoin and Ethereum technologies (Lall, 1992; Nelson, 2007; Godinho and Ferreira, 2012).*
- H_3: *Enterprises are more likely to file patent applications associated with technologies related to Bitcoin and Ethereum, as compared to individuals and research institutions (Pavitt, 2005; Nelson, 2007; Boldrin and Levine, 2013).*
- H_4: *Patent classification codes are likely to reveal technological trends of Bitcoin and Ethereum (Galini, 1992; Bonino et al., 2010; Godinho and Ferreira, 2012; Boldrin and Levine, 2013; Park and Yoon, 2017).*

3. Research Method

This section is dedicated to describe our research methodology designed to test the hypotheses proposed above. In this study, we propose a text-embedding-based approach to measure DeFi patent landscaping with a special focus on the two primary cryptocurrencies, namely, Bitcoin and Ethereum. Therefore, this study adopts a quantitative patent landscaping method, which relies on the collection and analysis of patent information (Lang, 2001; Ernst, 2003; Bonino *et al*, 2010; Dolfsma, 2011). As such, we focused on searching and retrieving patent documents addressing technologies associated with both Bitcoin and Ethereum cryptocurrencies for the period between 2009 and 2021. Furthermore, this study can also be characterized as an exploratory and descriptive research (Gil, 1999). Since our investigation focusses on a topic that has not been previously examined by literature, this research has an exploratory nature. Besides, since the research objective concerns the description of the characteristics of a phenomenon, our study can also be classified as a descriptive one.

As such, in order to improve understanding of patent strategizing regarding technologies associated with both Bitcoin and Ethereum, we collected patent data addressing those cryptocurrencies. More specifically, we searched for the terms “Bitcoin” and “Ethereum” in the claims as means of identifying the documents with a specific focus on the one of the two most important cryptocurrencies in the world. Our choice to focus on the information disclosed in the claims section of a patent was motivated by the critical important of this segment of a patent application. As stated by Cotropia (2005), patent claims can be regarded as single sentences found at final part of every patent document and can be considered as critical because the formulation of the claims specifies the protected characteristics of the patented invention.

Given the need to search for patent documents on a global scale, the choice of a patent database to conduct our queries was extremely important to our study. Consequently, we have selected the European Patent Office (EPO)’s patent database, which is named Espacenet. At present, that patent database comprises approximately 140 million documents from over 80 countries and regions.

By using Espacenet´s advanced search function, it was possible to run queries. To this end, the search conditions included service included filling dates between January 1, 2009 and December 31, 2022, as well as the word ‘Bitcoin’ (claims=bitcoin) and the word ‘Ethereum’ (claims=ethereum) listed in the claims of the patent document. As a result, we retrieved 647 patent documents comprising the word “Bitcoin” in their claims, while 818 patent documents included the word “Ethereum” in their claims.

Consequently, a large amount of structured data was collected as a result of running queries in the Espacenet database. Both data mining and collaborative filtering techniques based on IPC codes were used to identify relevant patterns in the patent data concerning technologies for Bitcoin and Ethereum (Park and Yoon, 2017). In order to understand the structure of the IPC code, it is worthwhile to mention that the IPC system is composed

of five levels—sections, classes, subclasses, main groups, and subgroups—designed to classify the domains of technologies included in each patent (Chae and Gim, 2019). As a means of identifying the technical area of the retrieved patent documents, the four initial characters of the first IPC code were used to classify each patent document, corresponding to the main group level of the IPC hierarchy. As an illustration, the full IPC code "G06Q20/06" was transformed into "G06Q" and stored in our dataset. In practice, a patent searcher tends to restrict the search effort to documents that are classified in a very particular field on a main group level rather than searching at a section level (Degroote and Held, 2018). Finally, pivot tables were created to generate overviews of frequencies of different attributes associated with the patent documents, such as country of origin of inventors, category of applicants, and IPC codes.

4. Results

This section is aimed at collecting and analyzing data to test the four research hypotheses formulated in Section 2.5.

4.1. Examining Bitcoin Patent Applications

Firstly, we examined the total number of patent applications addressing technologies associated with Bitcoin and Ethereum for the period between 2009 and 2021. In short, H_1 proposed that market opportunities associated with the explosive adoption and valuation of Bitcoin are likely to motivate an increase in patent filings concerning technologies related to both Bitcoin and Ethereum. To test this hypothesis, we applied the following search strings within the Espacenet database to select all patent applications of interest concerning the period between 2009 and 2021: "Filing date: 01012009-31122021", "claims=bitcoin". We also applied the search string: "claims=ethereum". This query was adjusted and repeated for each year in the interval between 2009 and 2021. In total, 647 patent applications could be retrieved mentioning Bitcoin in their claims, while 818 patent documents included the word "Ethereum" in their claims..

Figure 1 demonstrates that the first patent application addressing Bitcoin was filed in 2010, but a strong growth in Bitcoin patent filings could be observed from 2016 onwards. This growth continued until 2018, when a total of 139 patent applications mentioning bitcoin in their claims were filed in the same year. Ethereum patent applications, in turn, started to be filed in the same year of its launching, as Ethereum was launched in 2015. In the first year of operation, 7 patent applications were filed addressing Ethereum technologies. Following a patterns similar to Bitcoin, Ethereum patent applications started to increase rapidly from 2017 onwards, reaching a peak of 224 patent applications in 2018.

A careful interpretation is required regarding the number of patent applications observed in 2019, 2020

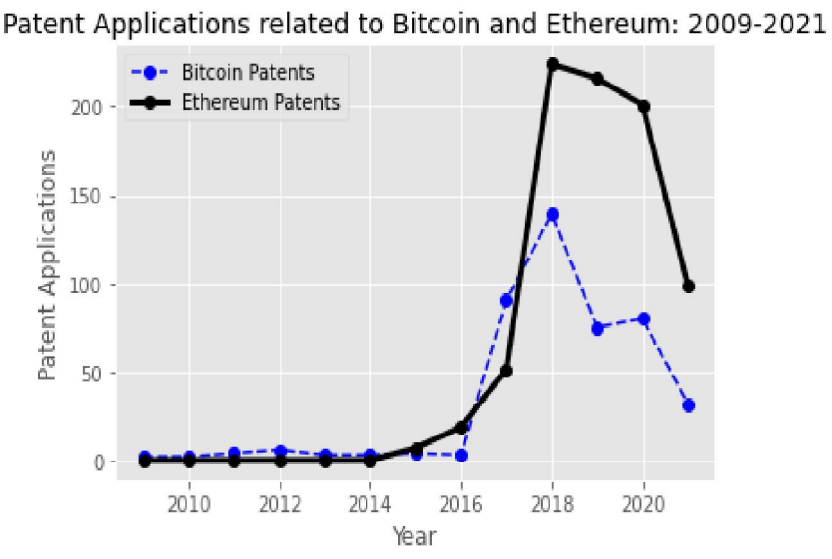

Figure 1: Country of Origin of Patent Applications Related to Bitcoin and Ethereum Technologies: 2009-2021

and 2021. The reduction in patent applications does not mean that the technological developments around Bitcoin and Ethereum started to slow down, but rather a consequence of incomplete data. The patent applications are not immediately classified and published. In general, a period of, at least, 18 months is required to publish a patent application with corresponding IPC codes. As such, increased patent activity from 2016 onwards can be regarded as strong empirical support to H_1.

4.2. Main Countries of Origin of Bitcoin and Ethereum Patent Applications: 2009-2021: 2009-2021

Another relevant aspect concerning the development of technologies associated with Bitcoin and Ethereum concerns the country of origin of the patent applications. That specific information can provide us an overview of the geographical distribution of the technological development for cryptocurrencies. In this way, our H_2 points out that firms based in developed countries are more likely to increase patent filings as a consequence of the explosive growth in market valuation of cryptocurrencies in recent years.

In order to assess the country of origin of the technologies disclosed in the retrived patent documents, we concentrated on the country of origin of the inventors, rather than the country of origin of the applicant. This choice resulted from our preliminary assessment of the retrieved patent documents. Clearly, a large portion of the patent documents present as applicants firms legally consisting of offshore companies registered in small countries, largely known as tax havens. Therefore, when we just focus on the country of origin of the applicant, we might reach an incorrect conclusion that many small countries like Antigua and Barbuda have become technological superpowers for cryptocurrencies. As such, to avoid incorrect interpretations, our study considers the country of origin of the inventor as the evidence of the origin of the patent document.

In Table 1, the countries with the largest number of patent applications addressing both Bitcon and Ethereum are listed. Although we observed a geographic concentration of patent applications, our H_2 must be rejected. The majority of patent applications originated from China, United States, and Korea. These three countries were responsible for 76.8% of all patent applications addressing Bitcoin and Ethereum in their claims.

Table 1: Top-10 Country of Origin of Patent Applications Related to Bitcoin and Ethereum Technologies: 2009-2021

Country of Priority Bitcoin	Bitcoin Patent Applications	Ethereum Patent Applications	Total Number of and Ethereum Patent Applications
China [CN]	162	612	774
United States [US]	175	77	252
Korea [KR]	55	44	99
Great Britain [GB]	23	6	29
Japan [JP]	16	13	29
Germany [DE]	8	15	23
Canada [CA]	9	6	15
Australia [AU]	7	6	13
Italy [IT]	3	7	10
Taiwan [TW]	5	4	9

4.3. Identifying Largest Patent Applicants Related to Bitcoin and Ethereum Technologies: 2009-2021

Since H_3 suggests that enterprises are likely to accomplish the majority of Bitcoin and Ethereum patent filings, we need to identify this group of firms highly interested in protecting technologies applicable to the Bitcoin and Ethereum value-chain. Hence, we have provided an overview of all applicants of Bitcoin and Ethereum patent filings based on three categories, which include Enterprise, Individuals, and Education and Research.

We observed that enterprises comprise the most active category for both Bitcoin and Ethereum patent applicants. Out of 647 Bitcoin patent applications, 355 were filed by enterprises. Similarly, out of 818 Ethereum

patent applications, 454 were filed by enterprises. For both cryptocurrencies, approximately 55% were filed by enterprises.

To illustrate the share of each patent applicant, Figure 2 represents the patent application share of each category: Enterprise, Individuals, and Education and Research. Individuals are second category of Bitcoin applicants, as they have filed 149 patent applications addressing Bitcoin in their claims, while only 74 individuals filed Ethereum patent applications.

Universities and Research Institutions, in turn, have filed 110 patent applications related to Bitcoin. At the same time, 238 Ethereum patent applications were filed by Education and Research institutions. Out of those 238 patent applications, 220 were filed by Chinese Educations and Research institutions.

In essence, enterprises consist of the category of applicants that can be considered as most active with respect to technologies related to Bitcoin, being responsible for approximately 55% of all patent applications. Therefore, our H_3 is confirmed and cannot be rejected.

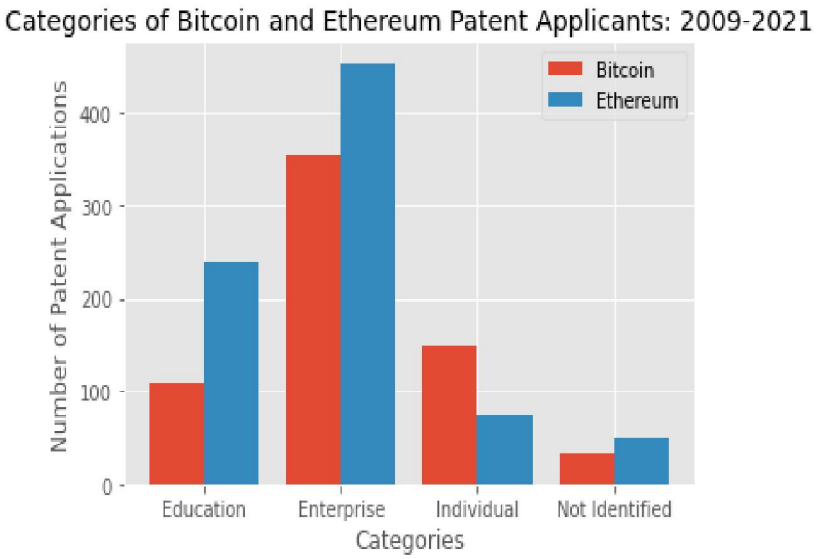

Figure 2: Share of Bitcoin Patents Filed by Each Category of Applicant: 2009-2021

4.4. Identifying Most Active Technical Areas of Bitcoin and Ethereum: 2009-2021

Since our research is aimed at identifying relevant patterns of patent application concerning both Bitcoin and Ethereum, we focused on the subclass level of the IPC codes found in the Espacenet database. As pointed by the World Intellectual Property Organization (2016), a record of each patent document comprises different fields such as title, abstract, claims, and one or more IPC codes, representing the application and function of a particular patent.

In order to test our H_4, we analyzed the the IPC code on a subclass level of the 642 documents. Table 2 lists the most active technical areas within bitcoin patent applications. Clearly, the IPC subclass G06Q can be regarded the most active, comprising more than 46% of patent applications. Therefore, it is possible to observe that data processing issues is a critical technical area attracting the development of many technologies, rather than electric signal processing, or hardware technologies. As our H_4 states that IPC codes of patent documents can provide an indication of the most relevant technical areas within Bitcoin, we found evidence supporting H_4.

Table 2: Top 5 Technical Areas of Bitcoin and Ethereum Patent Applications

IPC Subclass	Description	Bitcoin Patent Applications	Ethereum Patent Applications	Total Number of Bitcoin and Ethereum Patent Applications
G06Q	Data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes.	301	273	574
G06F	Electric digital data processing.	181	381	562
H04L	Electric communication technique.	63	77	140
G06K	Recognition of data, presentation of data, record carriers, handling record carriers.	12	23	35
G06N	Computer systems based on specific computational models.	8	11	19

5. Discussion

We have examined patent applications proposing new technologies to be added to both Bitcoin and Ethereum value chain. To this end, we have collected patent data from the Espacenet database containing IP filings from 2009 to 2021. Accordingly, we have provided a rich description of major trends involving the technological developments associated with Bitcoin and Ethereum.The main findings on this study are derived from the test of the four hypotheses formulated in section 2.4, which were adjusted from Cavalheiro and Cavalheiro (2022).

Our H_1 proposed that the increased market capitalization of Bitcoin and Ethereum should be considered an opportunity motivating an increase in patent filings concerning technologies related to Bitcoin and Ethereum. As such, the strong increase in patent filing that took place in the period between 2016 and 2021 provided strong empirical support to H_1, as more patent applications from 2019 onwards are likely to become public in the near future, given the time required by patent offices to publish patent applications. As such, a pattern could be distinguished as an increasing of number of patent applications following a growing valuation of Bitcoin (Godinho and Ferreira, 2012; Cavalheiro *et al.*, 2014; Cavalheiro and Cavalheiro, 2022).

Moreover, we observed different patterns concerning patent applicants for Bitcoin and Ethereum. On the one hand, for Bitcoin, we observed that the vast majority of patent applications were filed by applicants located in the United States, but also China, and Korea, which demonstrates that not only applicants in developed countries are filing bitcoin patents. On the other hand, for Ethereum, Chine is the absolute leader in terms of country of origin of applicants, as approximately three quarters of Ethereum patent applications have a Chinese priority. Consequently, since our H_2 claims that firms based in developed countries are more likely to increase the number of patent filings and the majority of developed countries did not generate a single patent filing, our H_2 is not supported and we need to reject this hypothesis.

Our H_3, in turn, suggests that enterprises, rather than individuals or research institutions, are more likely to file the majority of Bitcoin patent applications. In this regard, we observed that current Bitcoin and Ethereum patent applicants comprise a diverse group including enterprises, individuals and universities (Drivas *et al.*,

2016). Clearly, enterprises are the most active categories of applicants with respect to both Bitcoin and Ethereum. As a consequence, our H_3 can be confirmed.

Our H_4 emphasizes the importance of IPC patent classification codes, as a strong instrument to identify hotspot areas in the development of emerging technologies, such as Bitcoin. By examining IPC codes of the retrieved patent documents, it became clear that most Bitcoin and Ethereum technologies address data processing issues, rather than hardware technologies. Therefore, we found empirical evidence supporting our H_4.

Finally, although IPRs are becoming the most valuable assets in the current knowledge-based economy, the extant literature does not provide sufficient understanding on the use of the IP system by firms operating in the cryptocurrency arena. Thus, this study attempts to provide a contribution to start filling in this important knowledge gap.

6. Conclusion

This study addressed the main similarities and differences with respects to the technological trends associated with the two most important cryptocurrencies, namely Bitcoin and Ethereum. We employed patent landscaping techniques to identify relevant patterns based on patent information. We have observed a strong growth in patent filings addressing both cryptocurrencies from 2016 onwards, following a growing market capitalization. Clearly, we have found evidence that the expansion of Bitcoin also motivates the need to architect new technology and Ethereum's growth seems to be a direct consequence of Bitcoin's market capitalization growth. Additionally, most active IPC codes for both cryptocurrencies seem to be the same. We also found relevant differences between Bitcoin and Ethereum. Although the US and China were the most important country of origin of Bitcoin patent applications, China is by far the leading technology developer of Ethereum solutions. Besides, the findings obtained by this study can be useful to other researchers, as well as practitioners and policy makers.

This study also presents a number of limitations that need to be disclosed. First of all, we only retrieved patent documents addressing "Bitcoin" or "Ethereum" in their claims. However, other patent documents are also likely to be relevant to the value chain of cryptocurrencies, even without explicitly mentioning the name of the cryptocurrency. Additionally, many technologies associated with cryptocurrencies are also likely to be protect by trade secret, rather than patents. Those technologies could not be included in our research. Additionally, it was possible to identify interesting directions for further research. For instance, more sophisticated quantitative models can be developed combining patent information with market capitalization, trading volumes, and adoption figures. Besides, qualitative research can contribute to enrich findings from patent information by combining them with interviews with cryptocurrency entrepreneurs and inventors.

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