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## **BITCOIN LITERATURE: A CO-WORD ANALYSIS**

### **Abstract:**

A technical article in 2008 and the follow-up open-source software in 2009 released by Satoshi Nakamoto have modified the concept of currency and seem to continue affecting our economic and financial thinking. In less than 8 years, bitcoin, a digital currency, is not only accepted as a mean of payment but also traded in numerous 'bitcoin exchanges', which have accumulated a market capitalization of around 10.7 billion U.S. dollar. The phenomenon raised the interest of scholars across wide disciplines including finance, economics, law, and computer science. Research articles regarding bitcoin has gradually formed a growing body of literature, which reflects the state of the art of bitcoin research. However, there is no systematic survey of this literature up to now. The purpose of this study is to fill the gap by systematically surveying the bitcoin literature in the hope to uncover the main discussion topics and made suggestions for future research.

We collect a total of 253 articles directly related to bitcoin from the Scopus database. In addition to providing basic descriptive statistics of this dataset, we apply co-word analysis to separate the literature into groups. This is done by establishing a network in which articles are nodes and co-usage of the key terms links these articles. The network is then separated into groups based on nodes' similarity in their connectivity. The result is a division of the articles into three groups each contain distinct discussion topics. The first group is a pool of technological articles which elaborates on improving various aspects of bitcoin technology. The second group focuses on bitcoin's impacts to existing financial system and real economy. The discussions in the third group call for a legal framework to regulate bitcoin and other digital currency.

In the end, we model the bitcoin research in a PEST (political, economic, social, and technological) analysis structure and suggest that the influence of bitcoin and the associated technology on society as a whole is a big gap waiting to be filled in future research.

### **Keywords:**

bitcoin, digital currency, cryptocurrency, literature survey, co-word analysis

**JEL Classification:** G00, E50, K40

## Introduction

Satoshi Nakamoto, who the person is still a mystery, released a technical article in 2008 (Nakamoto, 2008) and followed it up with open-source software in 2009. The subject of these two releases, bitcoin, has modified and seems to continue changing the concept of currency. Bitcoin is one type of digital currency that is backed not by any central authority or banks but collectively by bitcoin community members. Its transactions, in technical terms, are done through peer-to-peer network and are recorded in blockchain, a public distributed yet cryptographically secured ledger. Bitcoin's unconventional characteristics make one scholar describes it as "... commodity money without gold, fiat money without a state, and credit money without debt." (Bjerg, 2015)

In around 8 years, bitcoin is not only accepted as a mean of payment but also traded in numerous "bitcoin exchanges", which have accumulated a market capitalization of around 10.7 billion U.S. dollar (Bitcoin-Watch, 2016). The phenomenon raised the interest of scholars across wide disciplines including finance, economics, law, computer science, and others. Research articles regarding bitcoin has gradually formed a growing body of literature. The literature examines bitcoin from various dimensions and tries to answer questions like: What is it? How does it work? How to improve it? Who user it? Are we able to control it? What is its economic, social, technological impact? Is it going to last long? etc. The purpose of this study is to conduct a comprehensive survey on this literature.

A total of 253 articles directly related to bitcoin are collected from the Scopus database. In addition to examine basic statistics of this set of data, we conduct a co-word analysis on this set of data in order to separate it into groups of articles with concentrated themes. This results in three groups of articles with distinct discussion topics, which can be described as *Technological*, *Economic and financial*, and *Regulatory*. In the end, we model the bitcoin research in a PEST (political, economic, social, and technological) analysis structure and suggest that the influence of bitcoin and the associated technology on society as a whole should be the topic for future research.

## Data and Methodology

We first design a query string that contains the terms 'bitcoin', 'cryptocurrency', and 'cryptocash'.<sup>1</sup> The query string identified 295 articles in the Scopus database. We retrieved all these articles on July 4th, 2016. Among them, some are listed without

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<sup>1</sup> The query string is "(TITLE (bitcoin\*) OR TITLE (cryptocurrenc\*) OR TITLE (cryptocash\*))", under the syntax define by the Scopus database.

authors, some are non-academic, some are non-English, and some are duplications. After removing these articles, 252 articles remain. Few of these articles have their abstract missing. The abstracts for these articles are manually padded to the records in the dataset. We then manually added the original article by Satoshi Nakamoto as it is not included in the Scopus database. In the end, 253 articles become the subject of this study.

The next step is establishing an article relation network through co-word analysis. The network consist 253 nodes; each represents an article in the dataset. Two nodes are treated as related if the two articles they represent use the same term provided in a keyword list. The list is extracted from the terms in the articles' titles and abstracts under the condition that their overall appearance counts are equal or higher than three. Several commonly used terms are excluded from the keyword list even though they have high appearance count.<sup>2</sup> For those article pairs which share more than one term, the number of co-sharing terms is indicated as the weight in the link between nodes. The article network is therefore a weighted and non-directional network. In this network, articles are linked according to their similarity in term usages. This provides a base to separate the articles into groups of distinct discussion topics.

There are several efficient methods to separate a network into subnetworks. Two widely used ones are the edge-betweenness (Girvan and Newman, 2002) and VOS (visualization of similarities) methods (Waltman et al., 2010, Van Eck and Waltman, 2007). In this study, we adopt the VOS method for the reason that the edge-betweenness method is not suitable for highly dense network such as the article relation network we constructed in this study. The implementation of the VOS method in Pajek software (Batagelj and Mrvar, 1998) is used to conduct the clustering.

## Descriptive Statistics

### Article Sources

Where are the bitcoin articles published? The sources scatter around in books, conference proceedings, and journals. Table 1 presents a summary statistics for the sources of the top 10 bitcoin articles. Around 20% of the articles are published in *Lecture Notes in Computer Science (LNCS)*, which is followed by *Handbook of Digital Currency: Bitcoin, Innovation, Financial Instruments, and Big Data (HDC)*, and *Proceedings of The ACM Conference on Computer and Communications Security (PACCCS)*.

<sup>2</sup> These commonly used terms includes: bitcoin, currency, transaction, cryptocurrency, digital, payment, network, decentralized, exchange, money, and peer-to-peer.

As regards to total citations, *LNCS* leads the pack; *Proceedings - IEEE Symposium on Security and Privacy* and *PACCCS* runs at the 2<sup>nd</sup> and the 3<sup>rd</sup>. *HDC* is a fairly recent publication hence has obtain virtually no citations.

**Table 1. Top 10 sources for bitcoin articles**

Source title	Total articles	Total citations	Active years
<i>Lecture Notes in Computer Science</i> (including subseries <i>Lecture Notes in Artificial Intelligence</i> and <i>Lecture Notes in Bioinformatics</i> )	52	85	2012~2016
<i>Handbook of Digital Currency: Bitcoin, Innovation, Financial Instruments, and Big Data</i>	23	1	2015~2015
<i>Proceedings of The ACM Conference on Computer and Communications Security</i>	11	35	2012~2015
<i>Communications of The ACM</i>	5	9	2014~2016
<i>PLoS One</i>	5	18	2014~2015
<i>Proceedings - IEEE Symposium on Security and Privacy</i>	5	51	2013~2015
<i>Lecture Notes in Business Information Processing</i>	4	0	2014~2015
<i>ACM International Conference Proceeding Series</i>	3	1	2014~2016
<i>Cato Journal</i>	3	7	2015~2015
<i>Communications in Computer and Information Science</i>	3	2	2014~2014

Source: analysis of this study

## Authors

Table 2 lists the eight authors who have published more the five articles in our dataset. All of them are affiliated with technology oriented organizations with the exception of Chuen, DLK, who is affiliated with a financial economics institute and is the editor of the book *HDC*.

## Topic Groups

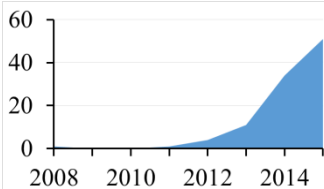
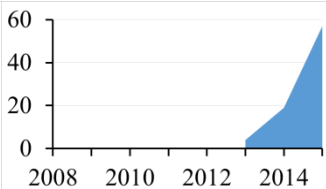
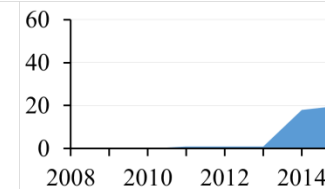
After conducting VOS clustering, the network is separated into three groups; each consists of 115, 94, and 44 articles. In order to comprehend the major discussion topic of each group, we examine the terms used in the title and abstract of the articles in each group. Term appearances in each group are enumerated and aggregated. The results are shown in Table 3 in which numbers in the parentheses are the average keyword count per article in the titles and abstracts. It should be noted that each term is count only once in an article even though the term appears more than once in the titles and abstracts.

**Table 2. Authors published more than five articles**

Authors	Total articles	Active years	Remarks
Chuen, DLK	7	2015~2015	SKB Institute for Financial Economics, Singapore Management University, editor <i>Handbook of Digital Currency</i>
Wattenhofer, R	7	2013~2016	Distributed Computing Group, ETH Zurich
Decker, C	7	2013~2016	Distributed Computing Group, ETH Zurich
Karame, GO	7	2012~2015	NEC Research Labs
Bonneau, J	5	2014~2015	Applied Cryptography Group, Stanford University
Dziembowski, S	5	2014~2016	Cryptology and Data Security Group, University of Warsaw
Miller, A	5	2014~2015	Computer Engineering, University of Illinois at Urbana-Champaign
Moore, T	5	2013~2015	Security Economics Lab, University of Tulsa

Source: analysis of this study

**Table 3. Bitcoin topic groups**

Group ID	1	2	3
Topics	<i>Technological</i>	<i>Economic and financial</i>	<i>Legal and regulatory</i>
No. articles	115	94	44
Terms	protocol (0.400) security (0.252) attack (0.235) distributed (0.217) mining (0.191) bitcoin transaction (0.183) anonymity (0.183) model (0.174) bitcoin network (0.165) privacy (0.157) blockchain (0.157) miner (0.157) cryptography (0.148) secure (0.139) power (0.139) key (0.122) proof-of-work (0.104)	market (0.436) financial (0.351) future (0.287) economy (0.213) price (0.191) risk (0.149) innovation (0.149) rate (0.138) model (0.128) impact (0.117) media (0.106) economic (0.106)	legal (0.432) law (0.205) regulatory (0.205) risk (0.182) regulation (0.136) laundering (0.114) illegal (0.114) security (0.114) framework (0.114) dollar (0.114) mining (0.114)
No. new articles (2014-2015)	85 (85/115=73.9%)	76 (76/94=80.9%)	38 (38/44=86.4%)
Paper growth			

Source: analysis of this study

In Table 3, only terms with average appearances greater than 0.10 are listed. Based on these terms as well as reading of the articles in each group, the main topic for the 1<sup>st</sup> group is identified as *Technological*, while that for the 2<sup>nd</sup> group is *Economic and financial*; for the 3<sup>rd</sup> group is *Legal and regulatory*. It can be seen from the “Paper growth” row in Table 3 that most of the bitcoin articles are published in the period 2013 to 2015. Over 80% of the articles for the *Economic and financial* as well as the *Legal and regulatory* group are published in 2014 and 2015. *Technological* and *Economic and financial* groups are experiencing sharp growth. We briefly introduce these three topic groups in the following sections.

### ***Technological***

Articles in this group explore the bitcoin system from a technological point of view. The discussion subjects include mining, anonymity, peer-to-peer (P2P) network, security, etc. Some articles specifically elaborate on bitcoin’s potential problems and propose technical solutions and alternative approaches (Barber et al., 2012, Bradbury, 2013).

Mining adds transaction blocks to bitcoin’s public ledger and it is designed to be resource intensive. Each time a new block is added, the miner gets 12.5 bitcoins incentive.<sup>3</sup> It is therefore important to find ways to accelerate the mining process. Several articles discuss ways to achieve faster mining (Dev, 2014, Courtois et al., 2014, Lewenberg et al., 2015).

Increasing anonymity is a concern for bitcoin users. The subject thus attracts scholars’ attention (Saxena et al., 2014, Herrera-Joancomartí, 2015). Zerocoin (Miers et al., 2013), mixcoin (Bonneau et al., 2014), and CoinShuffle (Ruffing et al., 2014) are examples of bitcoin extensions that addresses the privacy concern.

Beside technical issues, the long-term impact of the bitcoin technology is also a subject of discussion. In this regards, one computer scientist comment that bitcoin contains “... a remarkable body of knowledge, and we’re going to be teaching this in computer science classes in 20 years, I’m certain of that.” (Extance, 2015).

### ***Economic and Financial***

Bitcoin, as an alternative currency, has stimulated wide discussions in the economic and financial domain. The subject of interest include bitcoin market, cash vs. asset, banking, accounting, etc. There exists several exchange markets that one can buy and sell bitcoin (Bhaskar and Lee, 2015). Scholars analyze historical bitcoin price data in some of these exchanges in order to uncover the characteristics of the market (Baek

<sup>3</sup> The incentive is initially set to 50 bitcoins; fell to 25 bitcoins in November 28<sup>th</sup>, 2012. On July 9<sup>th</sup>, 2016, the reward fell again to 12.5 bitcoins. This event is known as a “halving”.

and Elbeck, 2015, Yang and Kim, 2015, Cheah and Fry, 2015). Baek and Elbeck (2015) point out that bitcoin market are mostly internally driven and that external economic factors do not have significant impact on market return. Cheah and Fry (2015) show that the fundamental value of Bitcoin is zero

There are discussions on whether bitcoin is asset or currency. Glaser et al. (2014) find strong evidence that new bitcoin users sees it as an alternative investment vehicle (asset) rather than as means for payment (currency). Others (Baek and Elbeck, 2015, Kristoufek, 2013) further indicate that bitcoin market is speculative.

Will bitcoin system replace our cash-based society? The future of bitcoin is discussed in a large amount of articles in our dataset. While most articles maintain a positive tone on this subject, some are neutral. For example, Wonglimpiyarat (2016) suggests that bitcoin is more likely to lead the world towards a less cash rather than cashless society. Nevertheless, there are articles that are quite negative about the future of bitcoin. Dowd and Hutchinson (2015) suggests that "... we would still rate its longer-term chance of survival as zero." Their main argument is that distributed trust in bitcoin is not really trustable.

### ***Legal and Regulatory***

Existing legal models are not prepared for disruptive innovation such as bitcoin. "Is it legal?" is a common question an individual would ask when first introduced to bitcoin. Doguet (2012) delves into bitcoin's legal status under the United States law. In addition, he evaluates three possible methods of regulating bitcoin and suggests that "prohibition is not the answer". Similar discussions on bitcoin's legal and regulatory issues are the dominant themes of the articles in this group.

There are also several discussions on the prevention of crime that takes the anonymity advantage of bitcoin, notably money laundering. Möser et al. (2013) and (Sat et al., 2016) investigate different anti-money laundering (AML) approaches and suggest regulatory options to aid AML.

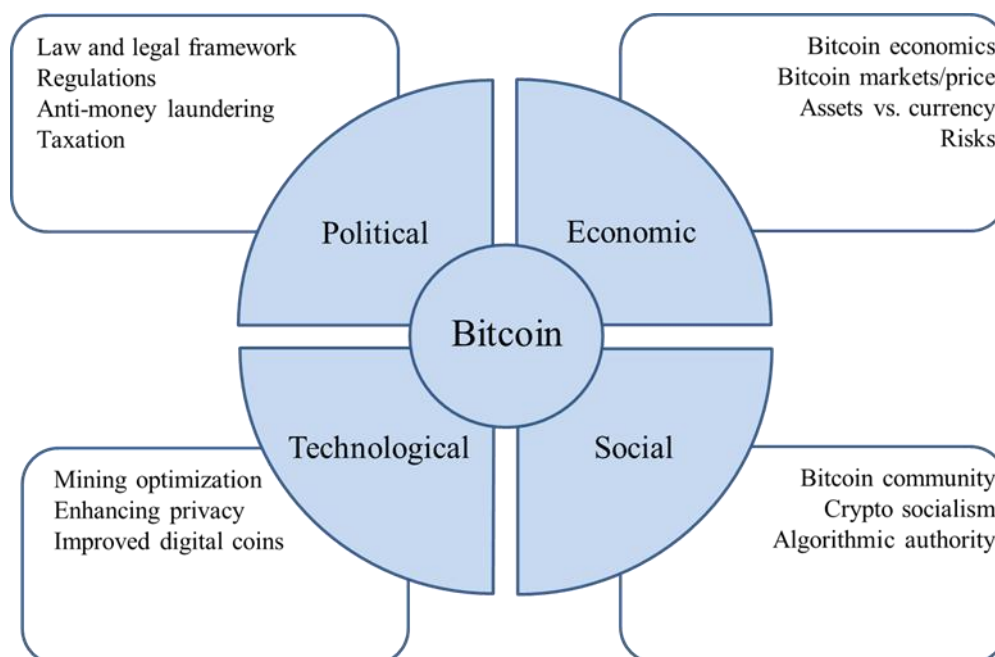
While the United States Internal Revenue Service (IRS) has determined that bitcoin will be treated as property for United States federal tax purposes (Wiseman, 2016), taxation regarding bitcoin has recently been examined by several scholars. Bal (2015) suggests that current law is generally able to capture transactions for tax purpose in digital currencies, yet taxpayers still need some guidance.

## Discussions and Conclusions

The impact of a disruptive innovation such as bitcoin to our society as whole can be wide and profound. The above analysis shows that current bitcoin research is separated into three categories: *Technological*, *Economic and financial*, as well as *Legal and regulatory*. However, bitcoin's impacts do not limit to these issues. To expand our view on the scope of bitcoin research, we propose an analytical model following a commonly used macroeconomic analysis structure--PEST (political, economic, social, and technological). It is suggested that a comprehensive body of bitcoin literature should cover all domains in the PEST model.

Political domain concerns how the government intervenes in the economy; usually include law, regulation, and taxation, etc. Economic domain has something to do with economic growth, financial markets, exchange rates, etc. Social domain includes issues such as social interactions, human behaviors, health consciousness, and attitude toward innovations, etc. Technological domain is about technology improvement, technology incentives, and the rate of technological change. Figure 1 exhibits the PEST model for bitcoin research.

**Figure 1. PEST model for bitcoin research**



*Source: proposed by this study*

Under the PEST model, the topic group *Technological* fits properly within the Technological domain; while the *Economic and financial* and *Legal and regulatory* group fall in the Economic and Political domains, respectively. However, Social domain



finds no direct correspondence with any of the topic group. The PEST model thus helps us realizing that bitcoin's social impacts are largely understudied.

Understudied it may be, we still see articles related to Social domain scattered around in the three topic groups. For example, Hernandez et al. (2014) find that bitcoin users are less sociable by analyzing Twitter messages. Lustig and Nardi (2015) propose a term "algorithmic authority" to refer to the phenomenon that mathematical algorithm "direct human action and to verify information, in place of relying exclusively on human authority." Nevertheless, the amount of this type of articles is too little to form a significant group.

In conclusion, bitcoin has opened ample research opportunities in various scientific domains. The related literature is sharply on the rise and sees no sign of relenting. Technological oriented research will continue. The impact of bitcoin and its associated technology on the political and the economic domain is not yet fully discussed. More importantly, a big research gap is to be filled in the social domain.

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