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# Bibliometrics-based evaluation of the Blockchain research trend: 2008 – March 2017

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**ABSTRACT**

The aim of this study is to review the literature growth and author productivity of Blockchain technology research from 2008 to March 2017. 801 articles were retrieved from Scopus database and analyzed with bibliometrics approach using different perspective views. The author productivity was derived using the Lotka's law and K-S test was performed to verify the reliability. The result indicates that the number of literatures on Blockchain is still increasing. Three stages of Blockchain research change were discovered. In 2008 to 2013, the topics were related to the Bitcoin and cryptocurrencies; in 2014 to 2015, the number of Bitcoin literatures grew rapidly; after 2016, a lot of researchers are paying attention to the techniques of Blockchain and smart contract. Moreover, the distribution of author productivity meets the study of Lotka. This study presents state-of-the-art and abstract the trend of Blockchain research regarding several perspectives of bibliometrics analysis.

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**KEYWORDS**
Blockchain; bibliometrics; Lotka's law

## Introduction

In the late 1980s, cryptography started to become broadly known and understood. Many researchers began to use cryptography to build digital In the late 1980s, cryptography started to become broadly known and understood. Many researchers began to use cryptography to build digital currencies. Chaum (1982) introduced a project using the blind signature, a digital signature that blinds the message in a setting with a central server that is trusted to prevent the double-spending problem. Although these earlier digital currencies worked, the central clearing house used to settle transactions were prone to data leakage as third parties were involved.

A new revolution in the global finical industry started at the end of 2008 when the pseudonymous Nakamoto (2008) proposed a peer-to-peer electronic cash system called Bitcoin that combines other inventions such as b-money (Dai 1998), time-stamping (Haber and Stornetta 1991; Bayer, Haber, and Stornetta 1993; Massias, Avila, and Quisquater 1999), Hashcash (Back 2002) and Merkle Tree (Merkle 1980) to create a decentralised system that does not rely on third parties to authorise currency issuance or transaction validation.

Bitcoin, the digital cash is denoted as BTC or Btc, the unit of currency to store and transmit value among users in the Bitcoin network. The Bitcoin network comprises a wide range of computing devices (mainframes, laptops and smart phones) and is easily accessible. Unlike traditional currencies, Bitcoin is one of the best-known virtual cryptocurrencies which Blockchain, the technology that enables the existence of cryptocurrency was invented.

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Each user of the Bitcoin system owns the key pair that includes one private key and one public key in a digital wallet that is used to prove ownership of the transactions in the Bitcoin network. That is, every transaction requires a valid signature from the users, which can only be generated by valid keys to be included in the Blockchain. The public key is used as the Bitcoin address to receive Bitcoin sent by the other users; the private key is used to unlock the value and spend it or transfer it to a new recipient.

Bitcoin is a decentralised, peer-to-peer system; no mint or central bank issues Bitcoin. Bitcoin is created as a reward through a competitive process called 'mining' in which Bitcoin users as miners use their computers to find the solution of a mathematical problem. The way to find a solution is called 'proof-of-work'. After mining, the first miner who finds the solution wins the competition, gets the Bitcoin reward, and can link the block to the chain, a public ledger known as the Blockchain.

Blockchain, the technology underlying Bitcoin, which uses a peer-to-peer network to authenticate transactions, is the most important computing invention of this generation. Many institutions have invested in developing Blockchain technology and are applying it in many different application areas. For example, to handle transactions beyond traditional financial transactions, the Blockchain mechanism can replace the need for the physical signature to an escrow account; for non-financial applications, Blockchain can be used as a way to prove authentication between exchanges, such as for digital content or art.

The Blockchain revolution is broken down into three categories: Blockchain 1.0, 2.0 and 3.0. Blockchain 1.0 is the application associated with cryptocurrencies used in digital payment systems. Blockchain 2.0 includes the entire economical market that uses the Blockchain to extend traditional transactions, such as stocks, bonds, and smart contracts. Blockchain 3.0 encompasses applications beyond those covered by Block 1.0 and 2.0, such as vote counting, digital health records and digital art (Swan 2015).

Ethereum was invented by Vitalik Buterin in 2013. A Homestead version was published in 2014 (Wood 2014) as a next-generation cryptocurrency and decentralised application platform (Buterin 2014). More than a Blockchain or a protocol overlaid on a Blockchain, Ethereum is a platform with programmable transaction functionality that can run all applications like a unified development computing machine. Contract has its own code. The Contract Internal Transaction is compiled into byte code by Contract before being deployed to Blockchain. Similarly, Hyperledger project (www.hyperledger.org) was proposed by Linux Foundation is an industry initiative project that aims to build a standardised and production-grade digital ledger with open source technologies.

In recent years, many researchers have attempted to review literatures on Blockchain (Karafiloski and Mishev 2017; Cao et al. 2017; Yli-Huumo et al. 2016; Conoscenti, Vetrò, and De Martin 2016) by focusing on its concept, research methods and applications in the specific field, such as IoT and big data. Although these studies have provided some insights, additional analysis via bibliometrics by using a set of mathematical and statistical methods to measure the quantity and quality of publications has not conducted. Such an analysis can help to discover productivities, performances and connections of authors and publications from quantity, quality and structural indicators.

To address this issue, the study reviews Blockchain researches on literatures and authors from 2008 to March 2017 by using the bibliometrics approach. Data for this purpose were retrospectively collected from Scopus database. The analysis of literature scattering was conducted via 7 aspects from spatial and time dimensions to shed light on trends. For author productivity analysis, the top 10 most productive authors of journal papers were investigated and summarised. Lotka's law which is regarded as one of the classical laws of bibliometrics was derived to describe the frequency of publication by authors in the Blockchain field and Kolmogorov-Smirnov (K-S) goodness-of-fit test for conformity of the observed data to the theoretical distribution was performed.

## Research methodology

As interest continues to grow in quantifying research trends within publications, various quantitative techniques have produced, such as citation analysis, bibliometrics and so on. Bibliometric methods

have been applied in many forms after Campbell (1896) produced the first study by using statistical methods to describe subject scattering in publications. Nowadays, bibliometrics is a type of research method used in library and information science to describe the phenomena of publications in a given filed. Lotka's law of author scientific productivity, Bradford's law of core journal scattering and Zipf's law of word occurrence are the three most important laws in bibliometrics (Ikpaahindi 1985).

This paper followed the research cycle of bibliometrics which involves the process of defining the blockchain relevant keywords, collecting data and performing analysis.

### *Keywords define and data collection*

The initial step of the bibliometric analysis, the Scopus database was adopted as the data source of this study. Scopus is the largest database with multidisciplinary scientific literatures, analysis tools and has introduced by Elsevier in November 2004 (Aghaei Chadegani et al. 2013). In 2017, Scopus website (http://www.scopus.com) claims that

> it has more than 69 million articles in the database and convers 34, 346 peer-reviewed journals that are evaluated and validated by the Content Selection and Advisory Board (CSAB) for inclusion or exclusion in Scopus against transparent and fair criteria.

There are plenty of protocols based on the Blockchain. Ethereum and hyperledger are two of the best supported Blockchain technologies behind bitcoin. The architecture of ethereum likes bitcoin which is also a public blockchain with a built-in cryptocurrency called Ether. Compared with bitcoin, an automatic programming mechanism called smart contract plays as the most important different feature in the ethereum and hyperledger. According to the relationships mentioned above, keywords 'Blockchain', 'bitcoin', 'ethereum', 'hyperledger', 'cryptocurrency' and 'smart contract' were selected and did query with TITLE-ABS-KEY in the pilot study. Data was collected in April 2017 with the timespan limited to 2008 – March 2017 which was chosen in order to limit the amount of data to be analysed and to start in a specific time when the Blockchain that was proposed by Nakamoto since 2008.

After the retrieving process of raw data from pilot study, some duplicates and irrelevant papers were exist. Lots of return papers were related to the keyword 'Blockchain' had different meanings and were out of the scope of this study. By quickly human inspection, most of these papers were related to keywords 'polymer' and 'colloid'; therefore, limitations 'NOT ("polymer")' and 'NOT ("colloid")' were added in the search query.

While refining the search results, unpublished articles, working papers and duplicates that may belong to more than one combination of keywords were excluded during data purification process. Finally, this search resulted in 801 relevant articles.

### *Literature scattering analysis*

To understand the literature scattering, the statistical examination was conducted via 7 characters from spatial and time dimensions. Related fields such as document types, countries, institutions, subject classes, resources, keywords and some indicators were exported from raw data. For spatial dimension, document types, countries and institutions were included; for time dimension, publication years, subject classes, journals and keywords were included.

### *Author productivity analysis*

To analyse the influence of particular authors, the author fields such as name, institution, country, number of articles, citations and h-index were first extracted from the raw data. After ordering, top 10 most productivity authors of journal paper were listed and discussed. Next, Lotka's law was derived to describe the publication frequency by authors in this given field. Finally, K-S goodness-of-fit test for conformity of the observed data to the theoretical distribution was performed.

The Lotka's study indicated that 60 % of authors make a single publication during a given time period. As the number of publications by a single author increases, the number of authors decreases.- $x^n y =$ constant is the formula to represent the inverse power law of author productivity (Lotka 1926). The validity of Lotka's law has been studied and applied to other areas by researchers. Pao (1985) and Nicholls (1986) are the most notable contributors and stated that the author productivity distribution difference is not significantly between observed and theoretical value by the Lotka model. Currently, K-S goodness-of-fit test method is adopted and recommended by some researches (Ahmed and Rahman 2009; Tsai and Yang 2010; Sudhier 2013).

## Two dimension analysis of literature scattering

### *The spatial dimension*

#### *Document types: conference papers compromised the most*

There were 801 total Blockchain related articles from Scopus database used for this study, distributed in 5 source types (Journals, Conference Proceedings, Book Series, Books and Trade Publications) and over 11 different document types. The total articles included 375 conference papers compromising 46.82% of total data, followed by articles (241, 30.09%), conference review (65, 8.11%), book chapter (44, 5.49%), article in press (25, 3.12%), review (22, 2.75%) and book (11, 1.37%). The unlisted document types were less than 1%.

#### *Countries: USA achieves the most important position*

Table 1 showed number of articles, percentages and citation indices by countries for the top 10 most productive countries. Of these 10 countries, 5 were from Europe, 2 from Asia, 2 from South America and 1 from Oceania. The United States (211 articles) ranked the first among all countries with the highest number of articles, followed by the United Kingdom (94), Germany (63), Switzerland (38) and China (31). The hybrid-index (h-index) is a value to evaluate the scientific effects (Raj and Zainab 2012). Glänzel et al. (2006) pointed out that the h-index combines the assessment of both quantity and quality of papers. In terms of citation and h-index, the ranking of countries slightly changed. Figure 1 showed the relationship between the citation and h-index by countries. USA achieved the most important position for both aspects and Germany was in the second place.

#### *Institutions: the eidenossische Technische Hochschule Zurich in Switzerland was the most powerful institution in Blockchain research area*

The articles of institution were accumulated by the institution affiliation of authors. The top 10 institutions from all over the world in Scopus database with 100 articles were ranked according to the number of articles during this research period. From Table 2, the Eidgenossische Technische Hochschule Zurich in Switzerland has published 26 articles was the most powerful institution in Blockchain research area. From statistical result, top 5 leading institutions belonged to Switzerland

**Table 1.** Number of articles and citation indices by countries (top 10).

| | Country | #Articles | % of 801 | Total citation | h-index |
|---|---|---|---|---|---|
| 1 | United States | 211 | 26.34 | 483 | 14 |
| 2 | United Kingdom | 94 | 11.74 | 124 | 7 |
| 3 | Germany | 63 | 7.87 | 170 | 8 |
| 4 | Switzerland | 38 | 4.74 | 120 | 7 |
| 5 | China | 31 | 3.87 | 13 | 2 |
| 6 | Australia | 29 | 3.62 | 54 | 6 |
| 7 | Italy | 29 | 3.62 | 32 | 3 |
| 8 | Canada | 24 | 3.00 | 61 | 3 |
| 9 | France | 24 | 3.00 | 54 | 3 |
| 10 | Singapore | 21 | 2.62 | 17 | 3 |

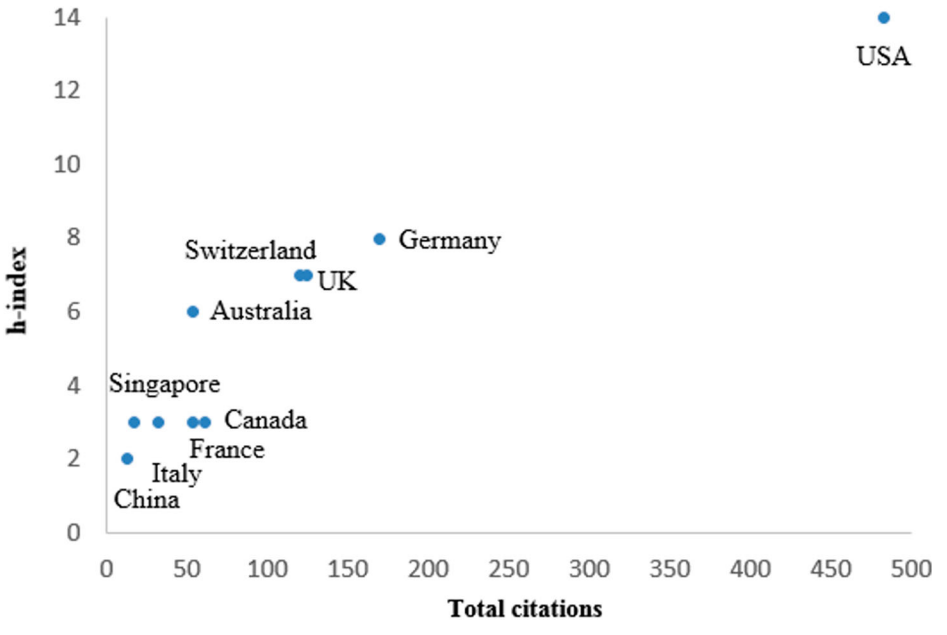


**Figure 1.** The relationship between h-index and total citations by countries.

and USA which coincided with the country analysis of national level productivity. In terms of total citations and h-index, the Eidgenossische Technische Hochschule Zurich was also the highest.

## *The time dimension*

### *Publication years: the study interests and popularity of Blockchain topics are increasing by years*

Within the collected data, the literature production was rising since 2008 by the year and the citation was also increasing steadily and reached the highest record in 2013 as shown in Figures 2 and 3. Two figures indicated that Blockchain researches became famous during these years. In order to understand the publication trends of different topics, the keywords 'Bitcoin', 'Blockchain', 'smart contract (include "ethereum" and "hyperledger")' and 'cryptocurrency' were queried separately. In Figure 4, the developing process with different topics could be divided into three stages according to the numbers of article growth. The first stage was from 2011 to 2013 after the technologies Blockchain and Bitcoin that was proposed by Satoshi Nakamoto since the end of 2008. During this stage, most of articles were related to the Bitcoin and cryptocurrency. From 2014 to 2015 was the second stage and

**Table 2.** Number of articles and citation indices by institutes (top 10).

| | Institute | #Articles | % of 801 | Total citation | h-index |
|---|---|---|---|---|---|
| 1 | Eidgenossische Technische Hochschule Zurich | Switzerland | 26 | 113 | 6 |
| 2 | Cornell University | USA | 15 | 73 | 4 |
| 3 | UCL | USA | 15 | 13 | 2 |
| 4 | University of Maryland | USA | 12 | 57 | 3 |
| 5 | Microsoft Research | USA | 11 | 79 | 5 |
| 6 | Singapore Management University | Singapore | 10 | 3 | 1 |
| 7 | University of Illinois at Urbana-Champaign | USA | 9 | 12 | 2 |
| 8 | London School of Economics and Political Science | UK | 9 | 28 | 2 |
| 9 | Massachusetts Institute of Technology | USA | 9 | 36 | 3 |
| 10 | NEC Deutschland GmbH | Germany | 8 | 85 | 4 |

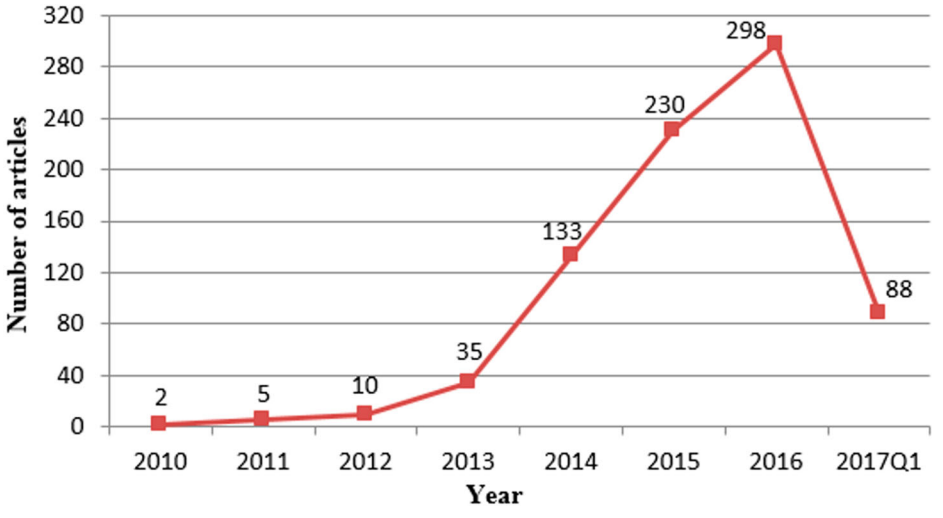


**Figure 2.** Number of articles by years.

the number of articles related to Bitcoin grew rapidly. At the same time, some articles related to the Blockchain were also published. However, the situation was changed in final stage from 2016 to March 2017. A lot of researchers started to pay attention to the topics related to Blockchain and smart contract. Meanwhile, the number of Bitcoin articles increased slowly. These trends acted in concert with the study of Blockchain revolution 1.0 and 2.0 by Swan in 2015 (Swan 2015).

Over the past couple of years, Blockchain technology is growing at a rapid pace in the emerging market and continuing embrace by the industries around the world. Commercial banks, stock exchanges, governments and tech companies are trying to integrate or develop the systems with

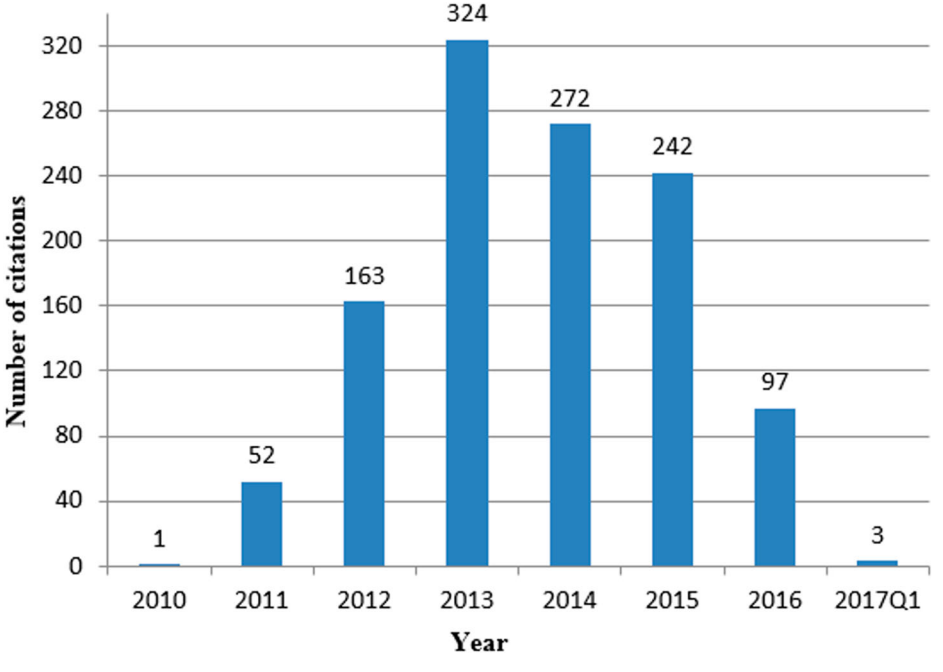


**Figure 3.** Number of citations by years.

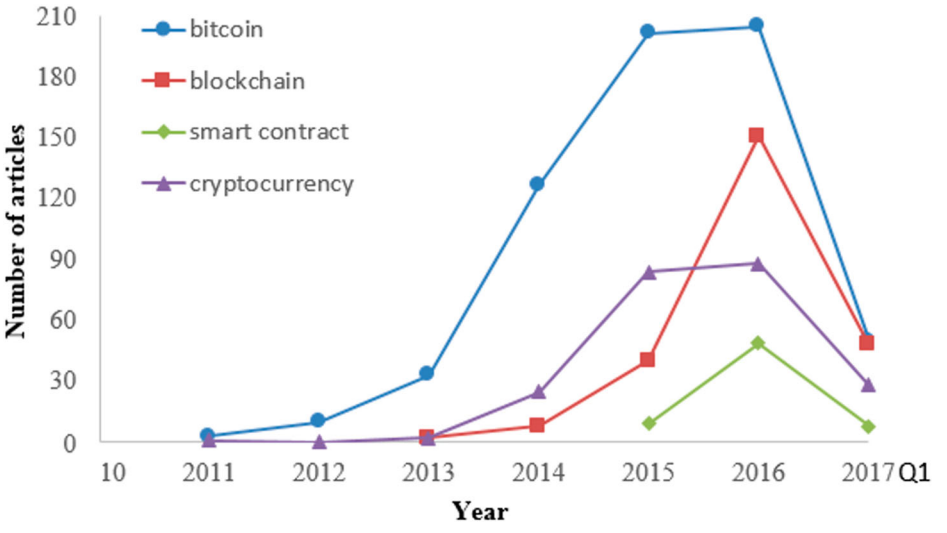


**Figure 4.** The publication trends by years with different topics.

blockchain applications. Compared with other researches by using bibliometrics, the research timespan in this paper is short due to fast, short-term and influencing characteristics of Blockchain technology. Although the time period of each stage is short, the changes of blockchain research interest are revealed.

### *Subject classes: Blockchain has been enter the matured and adopted stage for different applications*

This study used the subject classes which were provided by Scopus to identify the research areas of Blockchain researches. The articles were distributed in 23 subject classes and the top 10 productive classes were shown in Table 3. Computer Science (533) was the most dominant subject class for the Blockchain publication, followed by Mathematics (201) and Economics, Econometrics and Finance (132). From the distribution of articles by three stages that were used for the analysis of publication year with different topics above, seven out of ten classes (Computer Science, Mathematics, Engineering, Decision Sciences, Medicine, Biochemistry, Genetics and Molecular Biology and Arts and Humanities) were increasing by stages. More and more studies have focused on these seven fields. The subject classes were concerned more about social science issues with the relationships among individuals and Bitcoin markets such as the class Economics, Econometrics and Finance, Business, Management and Accounting and Social science were decreasing from stage 2 to stage 3. In addition, Table 3 also indicated that researches in Biochemistry, Genetics and Molecular Biology class began

**Table 3.** Number of articles in each subject class by three stages (top 10).

| Class | #Articles | S1 | S1% | S2 | S2% | S3 | S3% |
|---|---|---|---|---|---|---|---|
| Computer Science | 533 | 29 | 5.44 | 224 | 42.03 | 280 | 52.53 |
| Mathematics | 201 | 7 | 3.48 | 99 | 42.95 | 140 | 69.95 |
| Economics, Econometrics and Finance | 132 | 6 | 4.55 | 77 | 58.33 | 49 | 37.12 |
| Engineering | 127 | 13 | 10.24 | 51 | 40.16 | 63 | 49.61 |
| Business, Management and Accounting | 112 | 9 | 8.04 | 64 | 57.14 | 39 | 34.82 |
| Social Sciences | 82 | 8 | 9.76 | 46 | 56.10 | 28 | 34.15 |
| Decision Sciences | 53 | 3 | 5.66 | 16 | 30.19 | 34 | 64.15 |
| Medicine | 27 | 1 | 3.70 | 10 | 37.04 | 16 | 59.26 |
| Biochemistry, Genetics and Molecular Biology | 23 | 0 | 0.00 | 9 | 39.13 | 14 | 60.87 |
| Arts and Humanities | 13 | 1 | 7.69 | 5 | 38.46 | 7 | 53.85 |

Note: S1, Stage 1 from 2011 to 2013; S2, Stage 2 from 2014 to 2015; S3, Stage 3 from 2016 to March 2017.

relatively late. For all, the subject classes of Blockchain researches were distributed from science to social science meant Blockchain and related researches have been recognised as a popular and new application in various fields.

### *Most cited journals: communications of the ACM and PLOS ONE*

Over 34,346 peer-reviewed and 320 trade journals were covered in Scopus. Blockchain papers were published in 160 journals where top 10 journals contained 56 or 20.9% of total 268 papers and received 109 citations. Table 4 listed top 10 most productive journals on Blockchain research. There were 5 publications belong to SCI and SSCI. Major publications were Economist United Kingdom (11), PLOS ONE (11) and Communications of The ACM (8). In the aspect of quality and quantity, the Scimago Journal and Country Rank (SJR) indicator (Scimago 2007) which is inspired by the PageRank algorithm and developed from the information that contained in the Scopus database has provided an alternative to the impact factor (IF) was used in this study. Communications of The ACM ranked first with the highest SJR and PLOS ONE was in the second place. Most of journals published Blockchain related articles after 2014 (from stage2 / S2) and the numbers of articles are increasing. From the subject category point of view, six of ten journals are related to social science and economics. It is noteworthy that the publication topics of international journal of drug policy publishes are drug using and drug policy. However, some studies explored the online drug shopping with the biggest underground drug marketplace called 'Silk Road' has been doing transaction through Bitcoin were included (Van Hout and Bingham 2014; Bancroft and Scott Reid 2016).

Highly cited journal papers were also collected to show that the particular articles were cited by other research publications are listed in the same database. The top 10 cited journal papers were shown in Table 5. Most of papers were published from 2013 to 2014 and the topics were related to the Bitcoin. Five out of ten papers were included in SSCI, 3 where in SCI and 2 belonged to both. The most frequent cited journal paper was '*Bitcoin meets Google Trends and Wikipedia: Quantifying the relationship between phenomena of the Internet era*' written in 2013 by Kristoufek, L. from the Institute of Information Theory and Automation (UTIA) of Czech Republic, has been cited 44 times since being published in the journal of Scientific Reports. Meanwhile, Kristoufek, L. published another journal paper '*What are the main drivers of the Bitcoin price? Evidence from wavelet coherence analysis*' in 2015 with the Bitcoin topic was also included among the 10 most frequently cited papers indicated that Kristoufek, L. had the highest contribution. Besides, among the top 10 cited papers, USA contributed to 2, Switzerland and Czech Republic published 2 papers, Ireland, Hungary, Austria and Germany held 1.

### *Author keywords: Blockchain was the drastic increase*

The distribution of authors' keywords can investigate the popular research topics among researchers and have proved to play an important role of science development (Li et al. 2009). Table 6 listed the

**Table 4.** Number of articles by journals (top 10).

| Name | SCI/SSCI | SJR | TC | h-index | S1 | S2 | S3 | #Articles | % of 268 |
|---|---|---|---|---|---|---|---|---|---|
| Economist United Kingdom | – | 0.10 | 0 | 0 | 3 | 2 | 6 | 11 | 4.10 |
| PLOS ONE | SCI | 1.39 | 45 | 3 | 0 | 6 | 5 | 11 | 4.10 |
| Communications Of The ACM | SCI | 1.91 | 23 | 3 | 0 | 3 | 5 | 8 | 2.99 |
| F1000Research | – | 0.56 | 6 | 1 | 0 | 0 | 4 | 4 | 1.49 |
| Finance Research Letters | SSCI | 0.40 | 8 | 2 | 0 | 0 | 4 | 4 | 1.49 |
| First Monday | – | 0.42 | 1 | 1 | 0 | 1 | 3 | 4 | 1.49 |
| International Journal Of Drug Policy | SSCI | 1.07 | 38 | 4 | 0 | 1 | 3 | 4 | 1.49 |
| Journal Of Internet Banking And Commerce | – | 0.21 | 6 | 1 | 1 | 1 | 2 | 4 | 1.49 |
| Actual Problems Of Economics | – | 0.12 | 0 | 0 | 0 | 2 | 1 | 3 | 1.12 |
| Applied Economics | SSCI | 0.44 | 12 | 2 | 0 | 1 | 2 | 3 | 1.12 |

Note: TC, Total citations; SJR, Scimago Journal and Country Rank indicator; S1, Stage 1 from 2011 to 2013; S2, Stage 2 from 2014 to 2015; S3, Stage 3 from 2016 to March 2017.

**Table 5.** Top 10 cited journal papers.

| Title | Authors | Institute(first) | Country (first) | Source | Year | Citations |
|---|---|---|---|---|---|---|
| Bitcoin meets Google Trends and Wikipedia: Quantifying the relationship between phenomena of the Internet era | Kristoufek, L. | Institute of Information Theory and Automation, Academy of Sciences of the Czech Republic | Czech Republic | Scientific Reports (SCI) | 2013 | 44 |
| Responsible vendors, intelligent consumers: Silk Road, the online revolution in drug trading | Van Hout, M.C., Bingham, T. | School of Health Sciences, Waterford Institute of Technology | Ireland | International Journal of Drug Policy (SSCI) | 2014 | 35 |
| "When perhaps the real problem is money itself!": The practical materiality of Bitcoin | Maurer, B., Nelms, T.C., Swartz, L. | Department of Anthropology, University of California | USA | Social Semiotics (SSCI) | 2013 | 32 |
| Do the rich get richer? An empirical analysis of the Bitcoin transaction network | Kondor, D., Pósfai, M., Csabai, I., Vattay, G. | Department of Physics of Complex Systems, Eötvös Loránd University | Hungary | PLOS ONE (SCI) | 2014 | 29 |
| Bitcoin: Economics, technology, and governance | Böhme, R., Christin, N., Edelman, B., Moore, T. | Department of Security and Privacy, University of Innsbruck | Austria | Journal of Economic Perspectives (SSCI) | 2015 | 26 |
| Bitcoin and Money Laundering: Mining for an Effective Solution | Bryans, D. | Indiana University, Maurer School of Law | USA | Indiana Law Journal (SSCI) | 2014 | 21 |
| Locational signals to reduce network investments in smart distribution grids: What works and what not? | Brandstätt, C., Brunekreeft, G., Friedrichsen, N. | Bremer Energie Institut | Germany | Utilities Policy (SCI, SSCI) | 2011 | 20 |
| The digital traces of bubbles: Feedback cycles between socio-economic signals in the Bitcoin economy | Garcia, D., Tessone, C.J., Mavrodiev, *P.*, Perony, N. | ETH Zurich | Switzerland | Journal of the Royal Society Interface (SCI, SSCI) | 2014 | 19 |
| Is Bitcoin a Decentralised Currency? | Gervais, A., Karame, G.O., Capkun, V., Capkun, S. | ETH Zurich | Switzerland | IEEE Security and Privacy (SCI) | 2014 | 16 |
| What are the main drivers of the Bitcoin price? Evidence from wavelet coherence analysis | Kristoufek, L. | Institute of Information Theory and Automation, Academy of Sciences of the Czech Republic | Czech Republic | PLOS ONE (SCI) | 2015 | 13 |

top 20 authors' keywords which were offered by Scopus database with the specific keyword fields. However, the authority analysis was not sufficient for this research. The singular and plural forms ('cryptocurrency' and 'cryptocurrencies') and synonyms ('peer-to-peer' and 'p2p') were properly processed by manual. The graphical representations of the frequency by stages were depicted in Figures 5 and 6. For all, 'Bitcoin' was the most frequently appeared keyword regardless of year category. 'Electronic Money', 'Cryptocurrency', 'Data Privacy', 'Internet Of Things (IOT)', 'Proof of Work' and 'Exchange Rate' these 6 keywords that emerged to be new in S2. 'Smart Contract' and 'Ethereum' only showed in S3. In the top 20 keywords, the frequencies of 'Blockchain', 'Electronic Money', 'Distributed Computer System', 'Virtual Currency', 'Internet Of Things (IOT)', 'Smart Contract', 'Authentication', 'Proof Of work', 'Payment System' and 'Ethereum' were increasing. From S1 to S2, 'Bitcoin' was the keyword that grew rapidly. The usage of 'Blockchain' from 42 times in S2 to 226 times in S3 was the drastic increase during this period.

**Table 6.** Top 20 authors' keywords by stages.

| | All | | S1 | | S2 | | S3 | |
|---|---|---|---|---|---|---|---|---|
| Keyword | Rank | Frq | Rank | Frq | Rank | Frq | Rank | Frq |
| Bitcoin | 1 | 301 | 1 | 14 | 1 | 159 | 3 | 128 |
| Blockchain | 2 | 269 | 7 | 1 | 6 | 42 | 1 | 226 |
| Electronic Money | 3 | 245 | – | – | 2 | 112 | 2 | 133 |
| Cryptocurrency | 4 | 117 | – | – | 3 | 64 | 4 | 53 |
| Cryptography | 5 | 103 | 2 | 7 | 5 | 52 | 5 | 44 |
| Peer to peer network | 6 | 95 | 3 | 6 | 4 | 53 | 6 | 36 |
| Security Of Data | 7 | 54 | 2 | 7 | 8 | 27 | 11 | 20 |
| Distributed Computer Systems | 8 | 52 | 3 | 6 | 9 | 13 | 7 | 33 |
| Virtual Currency | 9 | 44 | 6 | 2 | 7 | 29 | 13 | 13 |
| Data Privacy | 10 | 31 | – | – | 11 | 10 | 10 | 21 |
| Internet Of Things (IOT) | 11 | 29 | – | – | 17 | 5 | 9 | 24 |
| Smart Contract | 12 | 25 | – | – | – | – | 8 | 25 |
| Electronic Commerce | 13 | 24 | 4 | 4 | 9 | 13 | 18 | 7 |
| Digital Currency | 14 | 22 | 7 | 1 | 9 | 13 | 17 | 8 |
| Proof Of Work | 15 | 21 | – | – | 12 | 9 | 13 | 12 |
| Miners | 15 | 21 | 7 | 1 | 10 | 11 | 17 | 9 |
| Anonymity | 16 | 19 | 5 | 3 | 11 | 10 | 20 | 6 |
| Authentication | 17 | 18 | – | – | 14 | 7 | 14 | 11 |
| Crime | 18 | 17 | 7 | 1 | 14 | 7 | 16 | 9 |
| Payment System | 18 | 17 | 5 | 3 | 18 | 4 | 15 | 10 |
| Ethereum | 19 | 13 | – | – | – | – | 12 | 13 |
| Exchange Rate | 20 | 12 | – | – | 13 | 8 | 21 | 4 |

Note: Frq, Frequency; S1, Stage 1 from 2011 to 2013; S2, Stage 2 from 2014 to 2015; S3, Stage 3 from 2016 to March 2017.

## Author productivity

159 authors who had published journal papers were collected in this field. Among these data, 110 authors (69.18%) only published one paper. The 15 most productive authors who had published more than 3 papers were listed in Table 7. These 15 authors together contributed 31 journal papers and had produced 11.57% of all Blockchain related papers from 2008 to March 2017. The most productive journal paper authors were Bouri, E with 5 papers, followed by Luther, W. J. (4), Roubaud, D. (4) and Wonglimpiyarat, J. (4). Considering the total citations, these 15 most productive authors have received 82 citations for 31 journal papers and an average of 2.65 citations for each paper. Csabai, I., Kondor, D., Posfai, M. and Vattay, G. published 3 papers with 31citations had the highest score and followed by Barratt, M.J. (30) and Garcia, D. (23). In terms of h-index, Barratt, M.J. was the highest and with the value 3. Noteworthy, Csabai, I., Kondor, D., Posfai, M. and Vattay, G these four authors who had the same and highest citation published together with papers '*Do the rich get richer? An empirical analysis of the Bitcoin transaction network*' (29 citations, published in PLOS ONE) and '*Inferring the interplay between network structure and market effects in Bitcoin*' (2 citations, published in New Journal of Physics) from Eötvös Loránd University, Department of Physics of Complex Systems of Budapest, Hungry and Massachusetts Institute of Technology of USA. Besides, the country distributions of these authors included: 1 Middle East country (Lebanon), 1 North Africa country (Tunisia), 6 Europe countries (France, Hungary, Ireland, Switzerland, UK and Norway), 1 Asia country (Thailand), 2 of South America (USA) and 1 of Oceania (Australia) which also represented that authors from all over the world are interested in Blockchain and the related research topics.

To understand the author productivity of all articles, the Lotka's law was derived and the K-S test was performed to verify the reliability. Table 8 listed the author and publication quantities which were retrieved from Scope database on research aspect of Blockchain. Following the steps detailed by Pao (1985), the data were arranged in the Table 9 with the first two columns containing number of publications ($x$) and authors ($y$). The rest four columns $X = \log(x)$, $Y = \log(y)$, XX and XY were calculated. By using the least-square method (Equation 2) to find the slope $n$ value, which was the exponent for Lotka's law. Finally, the value c was calculated through the Equation 3 with the value of $n$, $p = 11$

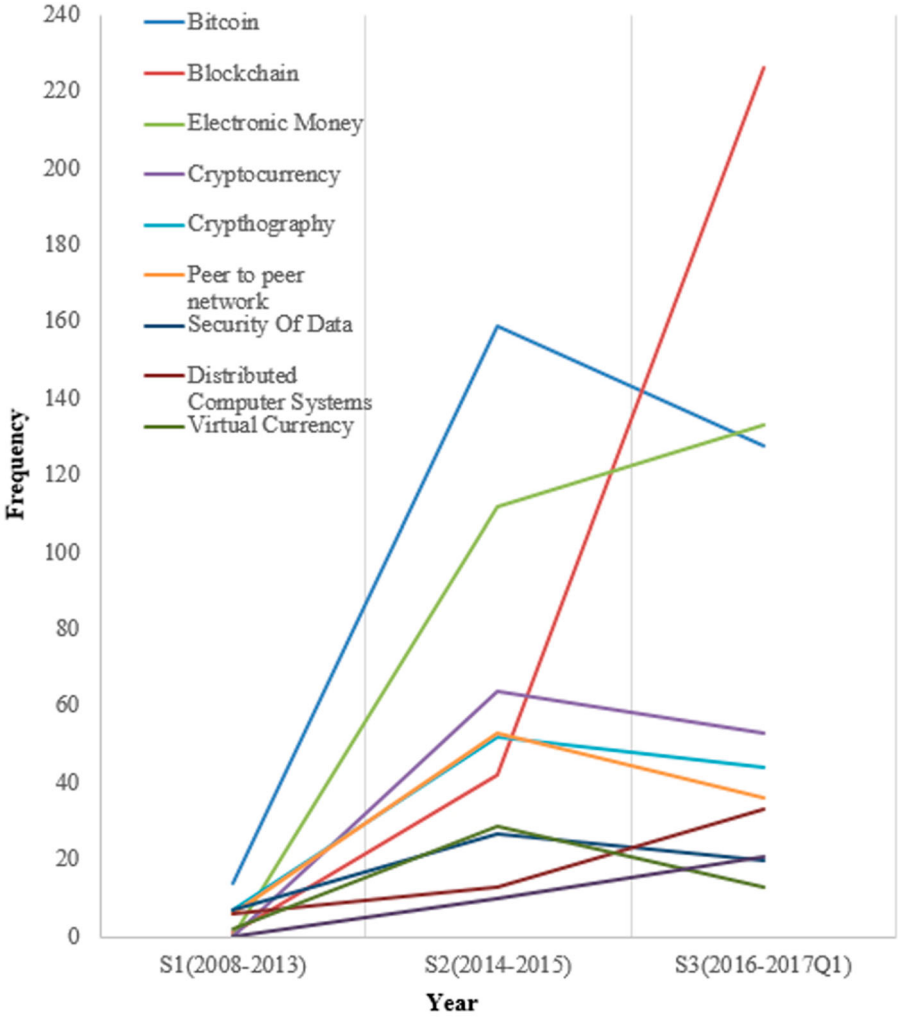


**Figure 5.** The distribution trends of top 10 authors' keywords.

and $x = 1–10$. The experiment got $n = -2.848$, $c = 0.8096$ and explored:

$$f(x) = \frac{0.8096}{x^{2.848}} \tag{1}$$

$$n = \frac{N\sum^{X} Y - \sum^{X}\sum^{Y}}{N\sum^{X} 2 - (\sum^{X} 2)} \tag{2}$$

$$c = \frac{1}{\sum_{1}^{P-1} \frac{1}{x^{n}} + \frac{1}{(n-1)P^{n-1}} + \frac{1}{2P^{n}} + \frac{n}{24(p-1)^{n+1}}} \tag{3}$$

According to the result, the absolute value of $n$ was 2.8480 between 1.2 and 3.8 which satisfied with the suggestion of Pao (1989). Figures 7 and 8 showed the distribution of literature productivity of authors on Blockchain.

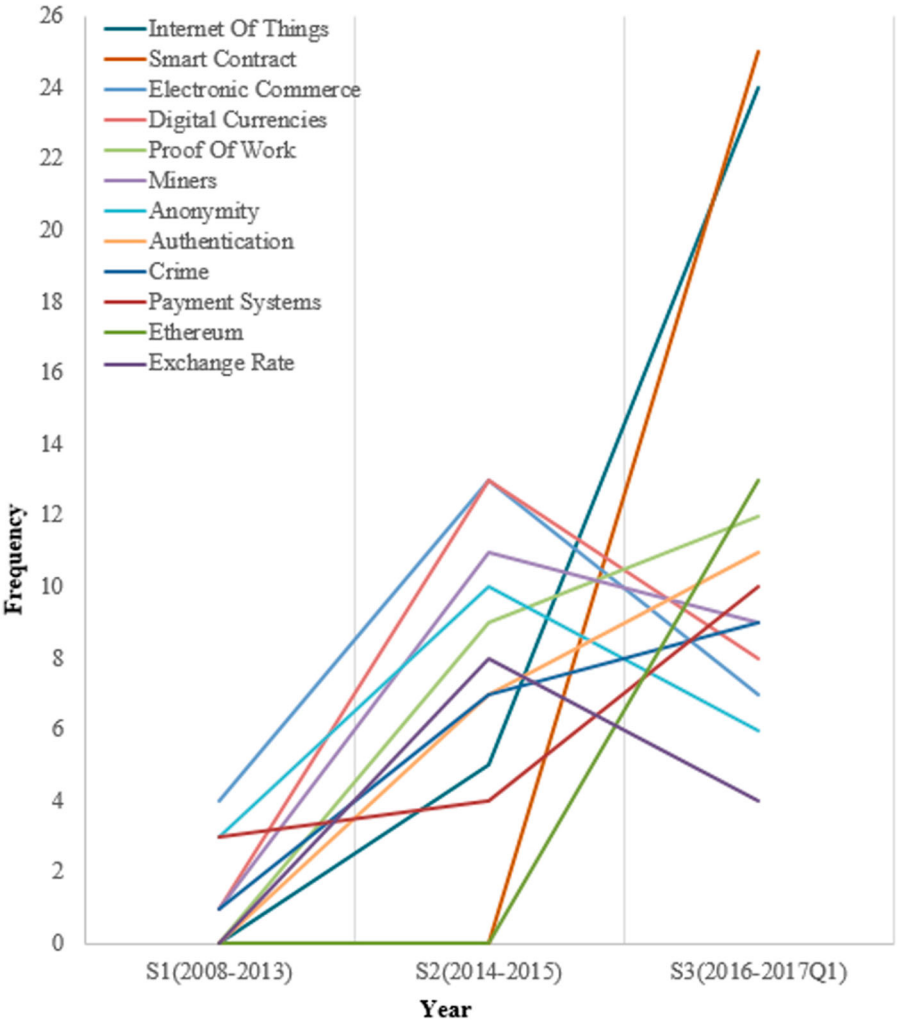


**Figure 6.** The distribution trends of top 11 to top 20 authors' keywords.

Lastly, the experiment compared the functions between observed and theoretical publication distributions by using the K-S test which for goodness-of-fit. According to the K-S test (Table 10), the $D_{max}$ was 0.8144 and the critical value was 0.1293. Because $D_{max}$ was bigger than critical value, the result indicated that the author productivity distribution of Blockchain was satisfied with Lotka's law.

$$\text{Critical Value} = \frac{1.63}{\sqrt{159}} = 0.1293;$$

## Conclusion

Since the end of 2008, Blockchain was known as a distributed ledger for both financial and non-financial activities is one of the fast growing research topics in recent years. To review the productivity of Blockchain researches in this explorative study, the evaluation of literature scattering from spatial and time dimensions via 7 aspects and the analysis of author productivity by investigating top 10 most productive authors and the Lotka's law were included.

**Table 7.** Top 15 most productive authors of journal papers.

| Name | Country | Institution | #Articles | Total Citation | h-index |
|---|---|---|---|---|---|
| Bouri, E. | Lebanon | Universite Saint-Esprit de Kaslik, USEK Business School, Jounieh | 5 | 2 | 1 |
| Luther, W.J. | USA | Kenyon College, Department of Economics, Gambier, | 4 | 1 | 1 |
| Roubaud, D. | France | Montpellier Business School, Montpellier | 4 | 1 | 1 |
| Wonglimpiyarat, J. | Thailand | Thammasat University, College of Innovation, Pathumtani | 4 | 0 | 0 |
| Barratt, M.J. | Australia | University of New South Wales (UNSW) Australia | 3 | 30 | 3 |
| Bouoiyour, J. | France | Universite de Pau et des Pays de L'Adour | 3 | 6 | 1 |
| Csabai, I. | Hungary | Eötvös Loránd University, Department of Physics of Complex Systems | 3 | 31 | 2 |
| Dyhrberg, A.H. | Ireland | University College Dublin | 3 | 8 | 2 |
| Garcia, D. | Switzerland | Eidgenossische Technische Hochschule Zurich | 3 | 23 | 2 |
| Irving, G. | UK | University of Cambridge, Institute of Public Health | 3 | 5 | 1 |
| Kondor, D. | USA | Massachusetts Institute of Technology | 3 | 31 | 2 |
| Molnar, *P.* | Norway | Universitetet i Stavanger | 3 | 5 | 1 |
| Posfai, M. | Hungary | Eötvös Loránd University, Department of Physics of Complex Systems | 3 | 31 | 2 |
| Selmi, R. | Tunisia | Tunis Business Schoo | 3 | 6 | 1 |
| Vattay, G. | Hungary | Eötvös Loránd University, Department of Physics of Complex Systems | 3 | 31 | 2 |

**Table 8.** The quantities of author and publication.

| Publications (x) | Authors (y) | Publication count (xy) | Accumulated publication | Accumulated publication % | Accumulated Author | Accumulated Author % |
|---|---|---|---|---|---|---|
| 2 | 70 | 140 | 140 | 27.24 | 70 | 44.03 |
| 3 | 40 | 120 | 260 | 50.58 | 110 | 69.18 |
| 4 | 25 | 100 | 360 | 70.04 | 135 | 84.91 |
| 5 | 11 | 55 | 415 | 80.74 | 146 | 91.82 |
| 6 | 5 | 30 | 445 | 86.58 | 151 | 94.97 |
| 7 | 1 | 7 | 452 | 87.94 | 152 | 95.60 |
| 8 | 4 | 32 | 484 | 94.16 | 156 | 98.11 |
| 9 | 1 | 9 | 493 | 95.91 | 157 | 98.74 |
| 10 | 1 | 10 | 503 | 97.86 | 158 | 99.37 |
| 11 | 1 | 11 | 514 | 100.00 | 159 | 100.00 |

**Table 9.** Calculation of the exponent n for Blockchain.

| Publications (x) | Authors (y) | $X = \log(x)$ | $Y = \log(y)$ | XY | XX |
|---|---|---|---|---|---|
| 2 | 70 | 0.3010 | 1.8451 | 0.5554 | 0.0906 |
| 3 | 40 | 0.4771 | 1.6021 | 0.7644 | 0.2276 |
| 4 | 25 | 0.6021 | 1.3979 | 0.8416 | 0.3625 |
| 5 | 11 | 0.6990 | 1.0414 | 0.7279 | 0.4886 |
| 6 | 5 | 0.7782 | 0.6990 | 0.5439 | 0.6055 |
| 7 | 1 | 0.8451 | 0.0000 | 0.0000 | 0.7142 |
| 8 | 4 | 0.9031 | 0.6021 | 0.5437 | 0.8156 |
| 9 | 1 | 0.9542 | 0.0000 | 0.0000 | 0.9106 |
| 10 | 1 | 1.0000 | 0.0000 | 0.0000 | 1.0000 |
| 11 | 1 | 1.0414 | 0.0000 | 0.0000 | 1.0845 |
| Total | 159 | 7.6012 | 7.1875 | 3.9770 | 6.2997 |

With the research results of literature growth, the study confirmed that related researches and publications have increased during these years. From the analysis of time dimension, three stages of Blockchain research change were discovered. In 2008 to 2013, the topics were related to the Bitcoin and cryptocurrencies; in 2014 to 2015, the number of Bitcoin literatures grew rapidly; after 2016, a lot of researchers are paying attention to the techniques of Blockchain and smart contract.

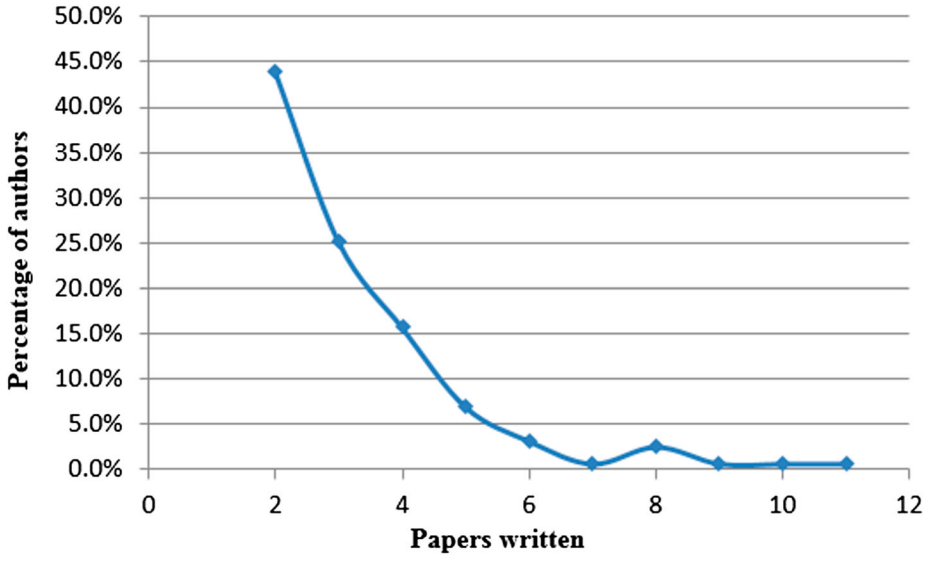


**Figure 7.** Lotka's law of graphical plot.

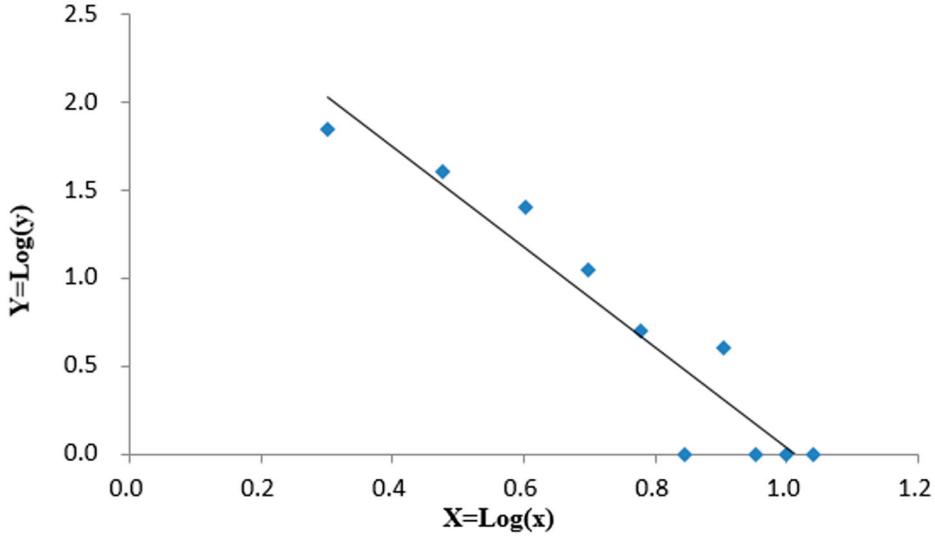


**Figure 8.** Distribution of literature productivity of authors on Blockchain.

**Table 10.** The K-S test for Blockchain.

| Record count | Author | Observation by author | Accumulate value Sn(x) | Expected value by author | Accumulated value Fo(x) | ABS value \|Fo (x)-Sn(x)\| |
|---|---|---|---|---|---|---|
| 2 | 70 | 0.4403 | 0.4403 | 0.1124 | 0.1124 | 0.3278 |
| 3 | 40 | 0.2516 | 0.6918 | 0.0354 | 0.1479 | 0.5439 |
| 4 | 25 | 0.1572 | 0.8491 | 0.0156 | 0.1635 | 0.6856 |
| 5 | 11 | 0.0692 | 0.9182 | 0.0083 | 0.1718 | 0.7465 |
| 6 | 5 | 0.0314 | 0.9497 | 0.0049 | 0.1767 | 0.7730 |
| 7 | 1 | 0.0063 | 0.9560 | 0.0032 | 0.1799 | 0.7761 |
| 8 | 4 | 0.0252 | 0.9811 | 0.0022 | 0.1820 | 0.7991 |
| 9 | 1 | 0.0063 | 0.9874 | 0.0016 | 0.1836 | 0.8038 |
| 10 | 1 | 0.0063 | 0.9937 | 0.0011 | 0.1847 | 0.8090 |
| 11 | 1 | 0.0063 | 1.0000 | 0.0009 | 0.1856 | 0.8144 |

In total, there were 801 related articles retrieved from Scopus database and conference papers compromised the most over 11 document types. Researches were distributed in 23 subject classes and have mainly focused on computer science, mathematics and economics, econometrics and finance. Besides, Blockchain research is an interdisciplinary area with topics from science to social science. 268 journal papers have been concentrated in 160 journals and the major publications were Economist United Kingdom, PLOS ONE and Communications of The ACM. In the both aspects of quality and quantity, the PLOS ONE and Communications of The ACM had the highest scores of SJR indicator that played important roles for dissemination.

Given the importance of understanding the research topics of Blockchain researches, the analysis of authors' keywords were also included. 'Bitcoin' was the most frequently appeared keyword regardless of year category. From 2008 to 2015, the frequency of 'Bitcoin' grew rapidly and the usage of 'Blockchain' was the drastic increase after 2014. 'Smart Contract' and 'Ethereum' that emerged to be the new words after 2016. The distribution of keywords was in accordance with the change of three stages that mention before.

From the analysis of spatial dimension, nine out of top 10 most productive countries were developed countries. USA achieved the most important position for sharing and creating the knowledge of Blockchain related researches. Meanwhile, the Eidgenossische Technische Hochschule Zurich in Switzerland ranked first among all institutions. It's noteworthy that for top 10 institutions there were six belonged to the USA was coincided with the country analysis of national level productivity. However, the most cited journal paper came from the Czech Republic of Eastern Europe which capital Prague has around one hundred places accepting Bitcoins as the payment for goods and services, such as having a lunch or staying in a hotel. In addition, among the top 10 cited journal papers, only one country came from South America (USA) others all came from Europe and topics were all related to the Bitcoin. Thus, it also showed that Europe countries had paid more attentions about Bitcoin and related issues.

Moreover, the analysis of author productivity by investigating the top 10 most productive authors of journal papers and applying Lotka's law were included. Bouri, E., from the USEK Business School of Lebanon published the most articles. However, Csabai, I., Posfai, M. and Vattay, G from Department of Physics of Complex Systems, Eötvös Loránd University of Hungary and Kondor, D., from Massachusetts Institute of Technology, USA whom published two papers together were the most productive authors. It also showed that collaborative publishing is a recent phenomenon and has steadily increased.

Consistently with the study of Lotka and observations in other fields, the author productivity analysis of journal papers and all publications in this study indicated that a few number of productive authors contributed to a significant discipline over time.

Overall, the present findings of this research review the literature scattering and author productivity of current Blockchain researches regarding several perspectives of bibliometrics analysis. However, this research does not look into the changes with technical attributes such as the mechanisms of security or privacy from different fields. For future work, more features and data can be added to evaluate the pathway from multiple viewpoints especially the changes of technologies in Blockchain and related areas.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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