

# The Information Society

## An International Journal

ISSN: 0197-2243 (Print) 1087-6537 (Online) Journal homepage: <http://www.tandfonline.com/loi/utis20>

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To cite this article: Mark Holub & Jackie Johnson (2018) Bitcoin research across disciplines, The Information Society, 34:2, 114-126, DOI: [10.1080/01972243.2017.1414094](https://doi.org/10.1080/01972243.2017.1414094)

To link to this article: <https://doi.org/10.1080/01972243.2017.1414094>



Published online: 08 Mar 2018.



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PERSPECTIVE



## Bitcoin research across disciplines

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### ABSTRACT

Over the last few years, research on Bitcoin and other cryptocurrencies has snowballed across many disciplines: technical fields, economics, law, public policy, finance, accounting, and others. As the uses of blockchain technology behind Bitcoin expand, more disciplines will be drawn to its study and the research will greatly expand. This paper provides an assessment of the current state of the literature. From a comprehensive search of the literature that resulted in an original sample of 13,507 results, a final sample of 1,206 papers on Bitcoin are categorised and mapped across six disciplines.

### ARTICLE HISTORY

Received 17 October 2017  
Accepted 3 December 2017

### KEYWORDS

Bitcoin; blockchain; cryptocurrency; digital currency; research; literature

On entering just the simple search term ‘Bitcoin’ one can see how the research on Bitcoin and other cryptocurrencies has snowballed across many disciplines. Initially, the focus was on the technology. With the entry of Bitcoin into the realm of market transactions, the economists, legal scholars, public policy researchers, and others started grappling with the peculiar issues it raises: Whether or not it is a currency? Whether or not it should be regulated? As the price of Bitcoin rose and the number of transactions involving payments in Bitcoins increased, the finance and accounting researchers were pressed on questions regarding standards. As the uses of blockchain technology behind Bitcoin expand, more disciplines will be drawn to its study and the research will greatly expand.

This paper provides an assessment of the current state of the literature. From a comprehensive search of the literature that resulted in an original sample of 13,507 results, a final sample of 1,206 papers on Bitcoin are categorised and mapped across six disciplines.

The rest of the paper proceeds as follows. The following section explains our search methodology. The next explains the category formation process. The subsequent spotlights innovative papers. The last section offers concluding thoughts.

### Literature search

For a comprehensive search of the literature on Bitcoin, we drew on the following resources:

- the major bibliographic databases (including component databases);

- search facilities provided by major journal publishers; and
- the key research repositories of unpublished work – working papers and conference papers not published in conference proceedings.

These resources differ in size and scope, and in the options they offer for search fields (e.g., title, abstract, keywords, peer-reviewed, subject, full text, etc.). Our search considers papers published or completed during the 2011 – 2016 period.<sup>1</sup> We do not restrict our search to works in English. Although some databases provide an option to limit searches to peer-reviewed content, we do not use this feature. We discuss this further in a later section.

### Databases searched

A list of the specific resources searched is presented in Table 1. The main resources in each group are described below.

### Bibliographic databases

The main bibliographic databases used are *EBSCOhost* [1],<sup>2</sup> *Proquest* [2], *Web of Science* (Thomson Reuters) [3] and *Scopus* (Elsevier) [4].<sup>3</sup> *EBSCOhost* is by far the largest database, comprising 47 individual databases. *EBSCOhost* includes *Academic Search Premier*, *Business Source Complete*, and *EconLit with Full Text*. The next largest database, *ProQuest Research Library*, consists of 18 individual databases, including *ABI/Inform Collection*,

**Table 1.** Literature database search results.

ID	Database	Fields searched	Raw results	Refined results
1	EBSCOhost Research Databases	Title, Subject terms, Abstract	8,957	1,186
2	ProQuest Research Library	Title, Subject heading, Abstract	1,754	635
3	Scopus [Elsevier]	Article title, Abstract, Keywords (All fields searched together)	586	501
4	Web of Science [Thomson Reuters]	Title, Topic, Research area	467	422
5	IEEE Xplore Digital Library (Computer Science and Engineering)	Document title, Abstract, Index terms (Metadata search)	114	114
6	Directory of Open Access Journals [DOAJ] [Lund University]	Basic search field only	44	44
7	HeinOnline databases (Law)	Article title and description	112	112
8	IngentaConnect	Article title, Keywords, Abstract (All fields searched together)	82	82
9	JSTOR	Title, Abstract, Caption	5	4
10	SpringerLink [Springer]	Basic search field only	721	711
11	ScienceDirect [Elsevier]	Abstract, Title, Keywords (All fields searched together)	86	55
12	Wiley Online Library	Article title, Abstract, Keywords	29	13
13	Taylor & Francis Online Journals	Title, Keywords (Fields searched individually)	12	12
14	SAGE Journals Online	Title, Keywords, Abstract (individual searches)	3	3
15	Oxford Journals	Title, Keywords, Abstract (individual searches)	5	5
16	Cambridge Core	Basic search box (articles and books)	3	3
17	Emerald Insight	Content item title, Abstract, Keywords	7	7
18	SSRN	Title, Abstract, Keywords	198	198
19	arXiv [Cornell University] (Sciences)	Title, Abstract, Subject description	116	116
20	IDEAS [ideas.repec.org]	Abstract, Keywords, Title, Author (Whole record search)	206	206
Total papers			13,507	4,429

*Periodicals Archive Online*, and *ProQuest SciTech Collection*. Together, the four largest bibliographic databases ([1] to [4]) provide over 60% of our search results. The remaining bibliographic databases – *IEEE Xplore Digital Library* [5], the *Directory of Open Access Journals (DOAJ)* [6], *HeinOnline* [7], *IngentaConnect* [8], and *JSTOR* [9] – account for an additional 8% of search results.

### Publisher databases

The main publisher database is *SpringerLink* [10], which alone contributes to 16% of the search results.<sup>4</sup> The other publisher databases – *ScienceDirect* [11], the *Wiley Online Library* [12], *Taylor and Francis Online* [13], *SAGE Journals Online* [14], *Oxford Journals* [15] and *Cambridge Core* [16] and *Emerald Insight* [17] – collectively account for about 3% of all search results.

### Research repositories

To examine as yet unpublished work, we access three large research repositories: *SSRN (Social Science Research Network)* [18]; *arXiv* [19] from Cornell University, which covers research papers in Physics, Mathematics, Computer Science, Quantitative Biology, Quantitative Finance and Statistics; and *IDEAS* [20], which provides access to *RePEc (Research Papers in Economics)*.<sup>5</sup> About

12% of our search results come from these research repositories.

### Search specification

To increase the relevance of results, we limit our search (where possible) to papers with ‘Bitcoin’ in the title or abstract or subject/keywords, rather than allowing for full text searches. The main bibliographic databases (*EBSCOhost* [1], *ProQuest* [2] and *Scopus* [3]) can be searched in this way. In other resources, we can only search specific fields individually, later having to combine the results (e.g., *SAGE Journals Online* [14], *Oxford Journals* [15]). In resources such as *IngentaConnect* [8], we are not able to specify the fields to be searched and perform a search of all fields at once. [Table 1](#) provides details of the fields searched.

The bibliographic databases differ in their coverage and classification of paper type. We seek to include the following paper types: published articles, conference papers and working papers, papers in published collections, and technical reports. In the various databases, the descriptions for these desired source types include: academic/scholarly articles, articles in journals, and articles in trade journals; conference and meeting papers; book chapters; and reports/technical reports. We exclude papers from the following sources: books and ebooks about Bitcoin generally (e.g., its origins and development, how it works), book reviews, magazines,

newspaper articles, editorials, reference works, conference proceeding summaries, dissertations (few were listed), Internet-related items (blogs, podcasts, websites), and miscellaneous other items (e.g., letters).

The fourth column in Table 1 ('Raw results') is the total number of results found from each search. The final column ('Refined results') shows the number of results having the desired paper type, which we downloaded for further examination. For the *EBSCOhost Research Databases* [1], the total of 8,957 reduces to 1,186 when results for sources like magazines and newspapers are excluded. For other databases (e.g., *HeinOnline* [7], *IngentaConnect* [8], and databases [13 through 20]), all results are of the desired type.<sup>6</sup>

This process reduces the original count of 13,507 papers to 4,429 across all 20 databases.

### Papers removed

We next proceed to apply a set of selection criteria as detailed in Table 2. We begin by eliminating duplicate references to the same work. This process involves multiple stages: searching for and analysing potential duplicates electronically, manually inspecting entries for similarity, and examining working papers that have been updated or subsequently published. The removal of duplicates reduces our collection by 1,289 papers.

Despite requesting only certain paper types when searching the databases (e.g., journal-only periodicals and chapters in conference proceedings), the results often include non-journal serials (such as magazines,

newsletters), and books and book reviews. Some of the results are works without an author. We manually remove all works without an author (508) and papers that are not of the desired type (e.g., book reviews, interviews, news briefs) (58).

We next undertake a formal analysis of paper type. The bibliographic and publisher databases differ in their classifications of the type of work published. The 'Article' type is used widely. To ensure consistency in the classification of the results, we assign each paper one of six paper types: journal article, paper in edited book (*In collection*), paper in published proceedings (*In proceedings*), book chapter, article in other serial (*Other serial*), and unpublished paper.

To assist with the classification of articles in serials/periodicals, we consult *Ulrichsweb Global Serials Directory* to determine the correct serial type for each entry. Non-journal type publications such as magazines and newsletters are removed. This reduces our collection by 877 papers. In the "Collection Summary" section, we also collect information from *Ulrichs* on content type (academic/scholarly, trade publication, etc.) and whether the publication is refereed.

As noted earlier, some of the bibliographic databases do not allow us to limit the search to the title, abstract or keywords, and some databases appear to use full record searches by default. This means that articles merely including a reference to Bitcoin in the text, without a focus on Bitcoin, appear in the results. The most practical way of dealing with these papers is to examine the search results and exclude those that do not include 'Bitcoin' in the title, abstract or keywords. This is particularly relevant for the *SpringerLink* database, which initially contributed 711 papers to our collection. To ensure we do not discard papers simply because no abstract is provided, we separately source abstracts for all papers where possible.<sup>7</sup> This step results in the removal of 540 records, 509 of which come from the *SpringerLink* database.

We retain all papers in languages other than English where an abstract is provided in English. Papers without an English abstract are excluded, as their content type is not evident and they cannot be readily categorised. Of 94 papers in a language other than English, 20 papers are excluded for not having an English abstract and three papers are removed because no abstract could be located. This leaves 71 papers non-English articles in our collection.

A final set of 23 papers have to be deleted as they: have irrelevant content (14), have missing or incomplete details (8), or are outside the time range (1). Following the application of all removal criteria, we are left with 1,111 papers for consideration.

**Table 2.** Application of removal criteria.

Number of papers at start		4,429
Less:		
Duplicates	1,289	
Papers without an author	508	
Papers not of the desired type <sup>†</sup>	58	
Papers in non-journal periodicals	877	
Entries in SpringerLink where 'Bitcoin' is not in the record	509	
Other entries where 'Bitcoin' is not in the record	31	
Papers with details in a foreign language (no English abstract or title)	20	
Papers with details in a foreign language (no abstract located)	3	
Papers published outside time range (2011–2016)	1	
Papers with irrelevant content	14	
Papers with missing or incomplete details	8	3,318
		1,111
Add:		
Papers of interest found through other sources		95
Number of papers remaining		1,206

<sup>†</sup>Papers that are not research articles (e.g., book reviews, interviews, news briefs, etc.).

## Papers added

Before finalising our database, we consult two other compilations of Bitcoin-related research. The first is a compilation by Brett Scott that covers the 2011 – 2015 period.<sup>8</sup> We reconcile our database with Brett Scott's list and include any additional papers meeting our criteria. This results principally in the addition of working papers not contained in the SSRN and IDEAS repositories. The second source we examine is the cryptofinance research paper collection of Smith + Crown, which presents articles by title over a series of webpages.<sup>9</sup> Although we are not able to easily extract bibliographic details for comparison, a basic 'first pass' text match by title reveals we have 57% of the papers listed there.

We do not specifically examine resources such as Google Scholar, ResearchGate and Academia.edu, due to the difficulty of obtaining each entry's details and formally compiling and extracting bibliographic data.

In conducting our searches, we also come across other papers that we consider important to Bitcoin research. Some of these, typically unpublished papers such as the literature review by Morisse (2015), are directly related to Bitcoin but are not covered by the resources noted above. Others are papers on the blockchain or cryptocurrencies generally, which are not identified in our searches because 'Bitcoin' does not appear in the searched fields (e.g., Yermack (2017)). In total, we collect 95 relevant papers from other sources. This increases our collection to a grand total of 1,206 records.

## Collection summary

The proportion of the six paper types in our collection of published and unpublished research on Bitcoin is illustrated in Figure 1 and detailed in Table 3.

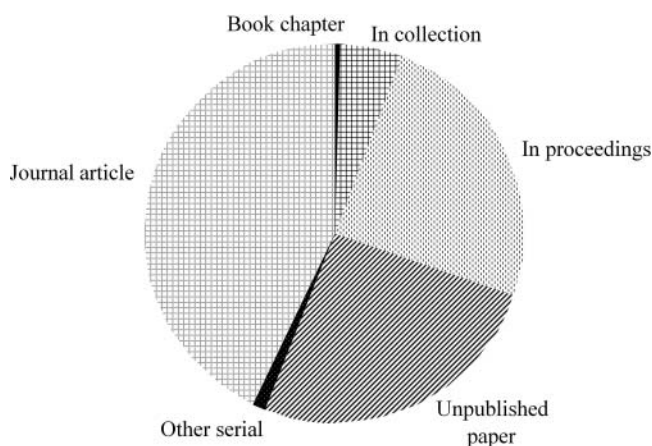


Figure 1. Proportion of paper types, 2011–2016.

Table 3. Paper type by year.

Paper type	2011	2012	2013	2014	2015	2016	Total	%
Book chapter	0	0	0	2	3	1	6	0%
In collection	0	0	2	1	28	33	64	5%
In proceedings	0	5	13	70	88	120	296	25%
Unpublished paper	4	4	19	75	75	131	308	26%
Other serial	0	0	0	7	1	6	14	1%
Journal article	1	6	38	121	158	194	518	43%
Total	5	15	72	276	353	485	1,206	100%

Journal articles make up the bulk of the collection (43%), with papers in published proceedings and unpublished papers each accounting for approximately a quarter. To consider the published periodical papers further, we refer to the serial type, content type and refereed status from the *Ulrichs Global Serials Directory*. Of the 532 papers comprising journal articles and other serials, 78.2% are in academic/scholarly publications, 9.4% are in trade periodicals, 1.1% are in government or consumer publications, and 11.3% are in serials not found in *Ulrichs* (10.7%) or have no classification details (0.6%). The details we collect from *Ulrichs* on refereed status indicate that of the 532 articles from journals and other serials, 57% are in peer-reviewed publications.

A breakdown of paper type by year is presented in Table 3. As can be seen from the table, the research output on Bitcoin at least trebled each year from 2011 to 2014. Unpublished papers account for 25% of the total research output over the six-year period. Output has continued to grow strongly for papers in published conference proceedings (*In proceedings*) and journal articles.

Over the total period, from a baseline of five papers in 2011, total research on Bitcoin has grown to 485 papers by 2016, a meteoric rise matching the rise in the Bitcoin price itself.

## Categorisation of papers in collection

The next step involved categorising the papers in our collection by research focus. On reading a sample of abstracts and full articles, it becomes evident that the papers fall into the following broad categories: Technology, Economics, Finance, Regulation and Taxation. We later come across papers in Accounting and, even though they are few in number, we treat these papers under the separate subject area of Accounting. We also note a number of papers that consider broader aspects of politics, philosophy and ethics, and which do not fit neatly into one of the existing categories. We adopt a single category for these papers, which we call Critical Thought.

We also come across papers that are unrelated to Bitcoin or not directly focused on Bitcoin. Of the original



1,206 papers, there are 289 that we classify as Not Applicable. These papers are typically related to such issues as:

- various frauds and scams;
- use of the Internet to purchase drugs;
- e-commerce in general;
- money transfers;
- general discussion on the past, present and future of the financial sector;
- shift to cloud;
- use of the mobile network;
- bio-security; and
- actions and needs of the on-line community.

A significant number of technical articles are deemed to be not applicable because they focus on the development of the blockchain well beyond its original use as a permanent record of transactions, which is beyond the scope of this paper and better discussed at a technical level. Both Yli-Huuma et al. (2016) and Morisse (2015) focus on technical aspects in their reviews of blockchain and Bitcoin from the perspective of technology and information systems research. Removing the papers that are not directly focused on Bitcoin leaves 917 papers for further analysis.

### Consideration of sub-categories

Having identified seven main categories of Technology, Economics, Finance, Regulation, Taxation, Accounting, and Critical Thought, we next read through the article abstracts to develop sub-categories. It becomes very clear at this stage how important the abstract of a paper is in giving the reader a clear indication of the focus and

contribution of the paper. We begin developing a list of descriptors that continues to grow as new topics emerge. We then identify broader groups for these descriptors, which comes to represent formal sub-categories that we use to categorise each article. For example, we use the sub-category 'Bitcoin protocol' to cover the Bitcoin system, network, the blockchain and the distributed ledger. Articles providing an overview of Bitcoin also come under this sub-category.

Each author categorises the papers and any differences are then resolved. We supplement and refine sub-categories as we go and end up with the final set shown in Table 4. For example, the sub-category 'Bitcoin adoption' covers Bitcoin adopters, users and start-ups. 'Bitcoin price characteristics' covers Bitcoin returns, exchange rates, price modelling and other data analyses. 'Bitcoin & virtual currency legality' covers the legal framework, exchange regulation, public policy issues and governance. 'Taxing virtual currencies' considers the general question of how to tax virtual currencies as well as specific commentary on taxing virtual currencies as property and under value-added tax (VAT) regimes. 'Accounting' generally covers accounting standards and financial accounting.

Although the sub-categories and main categories are naturally related, we do not restrict our classification to a unique category-sub-category combination. It is possible for a sub-category to appear under any major category. For example, 'Bitcoin adoption' appears under Technology, Economics, Finance, Accounting and Regulation, while 'monetary system' appears solely under Economics. Our paper thus differs from Liu (2016), who uses

Table 4. Categories used.

Sub-category	Main category						Total
	Technology	Economics	Finance	Accounting	Tax	Regulation	
Accounting				8			8
Bitcoin & VC* legality						104	106
Bitcoin adoption	21	33	17	1		2	74
Bitcoin mining	39	7					46
Bitcoin price characteristics	2	30	50			1	83
Bitcoin protocol	111	7	1			1	120
Bitcoin threats	58	5	1				64
Blockchain adoption	26	9					35
Contractual aspects						19	19
Criminal aspects						28	28
Exchanges		2	1			1	4
Monetary system		53					53
Payments system	1	70	1	1			73
Risk	2	4	2				8
Tax issues					5		5
Taxing VCs*					34	1	35
Virtual currencies	14	6	3				23
Total	274	228	76	10	39	157	784
Critical Thought							133
Total							917

\*VC = virtual currency

**Table 5.** Main Categories by Year.

Main category	2011	2012	2013	2014	2015	2016	Total	%
Technology	2	4	16	54	70	128	274	29.9%
Economics	0	3	11	55	69	90	228	24.9%
Finance	0	1	1	13	25	36	76	8.3%
Accounting	0	0	0	4	4	2	10	1.1%
Tax	0	0	5	13	10	11	39	4.3%
Regulation	1	3	12	53	49	39	157	17.1%
Sub-total	3	11	45	192	227	306	784	85.5%
Critical Thought	2	1	7	29	42	52	133	14.5%
Total	5	12	52	221	269	358	917	100.0%

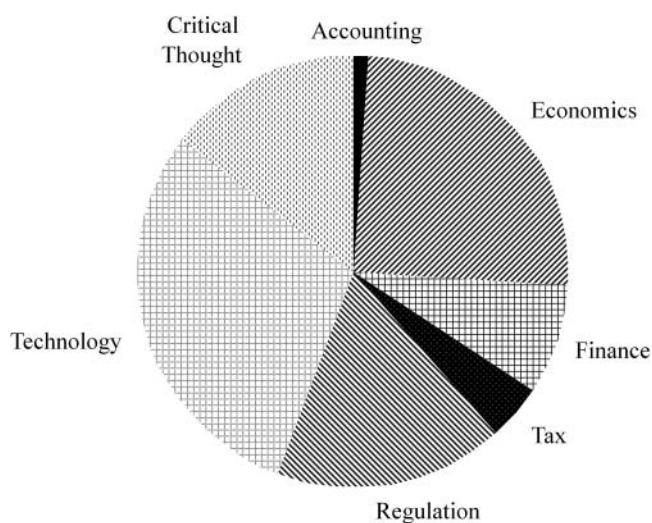
sub-categories that are mutually exclusive. Our paper, being multidisciplinary, considers Bitcoin research from differing perspectives.

Table 5 shows the proportion of papers in each main category and the interest areas over time. The majority of papers fall into Technology, followed by Economics and Regulation. Interest is growing in Finance, Accounting and Tax, which together currently make up 13.7% of the total, but are expected to grow as interest in Bitcoin and its uses increases. In the next section we discuss a selection of papers from each of the main categories.

### Interesting and innovative papers

In this section we highlight what we believe are the most interesting and innovative papers, in order to provide starting points for future research. There is no artificial limit placed on the number of papers to include.

From Figure 2, which shows the proportion of papers over the six-year period, it is easy to see the dominance of Technology and Economics. At this stage, Accounting is barely on the map. No doubt the interest will increase as businesses start using Bitcoin and other cryptocurrencies.

**Figure 2.** Proportion of Paper Categories, 2011–2016.

Governments will also begin to put in place regulations for use of Bitcoin and other cryptocurrencies.

### Critical thought

Most of the Critical Thought articles focus on one or more of the following issues:

- Bitcoin's role in providing an alternative to a centralized authority.
- Bitcoin as a currency that is detached from its expected value.
- Does the Bitcoin mean the end of fiat currencies?
- Financial innovations enabled by Bitcoin and associated blockchain technology.
- Modern society and its fascination with electronic money in all its forms.
- The macro-economic impact of virtual currencies.
- Disruption of the current norms by Bitcoin.
- The pros and cons of Bitcoin and the history of money and its substitutes.
- Can we trust virtual currencies?

De Filippi and Loveluck (2016) examine the control mechanisms of Bitcoin and point out that its use is governed not just by its technical protocol but also the pressure exerted by its developer community and other stakeholders. In effect, Bitcoin operates within a 'highly technocratic' structure.

Drawing on the history of previous substitutes for US legal tender, Middlebrook and Hughes (2016) gauge the likely regulation of the virtual currencies. Although the US has a history of alternative currencies, from notes issued by private banks, canal companies and railroads to trading stamps, it has a hostile and suspicious attitude to the use of virtual currencies and has prosecuted unlicensed 'money transmitters' except when transactions cover small amounts. In 2007 owners of E-gold, an organisation which allowed individuals to make relatively anonymous payments in gold or 395 other precious metals, were indicted for money laundering and operating as an illegal money transmitter. Recently Bitcoin exchanges have attracted the attention of the Financial Crimes Enforcement Network (FinCEN) and a number of them have been indicted for money laundering and illegal money transmission. Their prognosis is to expect a continuing antagonistic response from the federal and state governments.

### Technology

The papers in this category, which is by far the largest, focus on: the behaviour of mining pools; the development and potential use of Bitcoin's blockchain; privacy

of Bitcoin users; security of the Bitcoin network; the development of other cryptocurrencies; and users of Bitcoin.

Miners play a key role in validating and recording transactions and are expected to act honestly. However, some may deviate from honest behaviour for a profit and there are no penalties for such behaviour. Both Courtois and Bahack (2014) and Sapirshtein, Sompolinsky and Zohar (2015) focus on the 'selfish mining strategy' wherein a miner or mining pool does not publish and distribute its solution to the most recent block in the Bitcoin network, but continues to mine and thereby maintain a lead in solving the next block. They both discuss the impact and payoff of withholding blocks, even for a small amount of time. Courtois and Bahack find no evidence that rogue strategies have been applied but Sapirshtein, Sompolinsky and Zohar conclude that there are always mining strategies that earn more than honest mining.

The Bitcoin community has not only individual miners, as it did in its early days, but also mining pools and Bitcoin currency exchanges. They are now of considerable size and thereby more visible and susceptible to denial-of-service (DoS) attacks.<sup>10</sup> Capturing details of distributed denial-of-service (DDoS) attacks is difficult but Vasek, Thornton and Moore (2014) employ a novel approach that draws on reports of DDoS attacks posted on the *bitcointalk.org* forum. They identify 142 posts between February 2011 and October 2013 that describe distinct attacks. They find that attacks have changed over time. Initially the mining pools were the main targets, large pools being attacked more often than small pools. Later came attacks on currency exchanges and to some extent gambling websites. McGinn et al. (2016) detail a specific attack in 2015 over disagreement on the 1 MB limit on the size of a block. The perpetrators set out to demonstrate the need for a large block size by artificially increasing the data rate, by generating a large number of very small transactions. Their actions caused delays in processing all transactions.

Currently it is estimated that there are over 1000 altcoins<sup>11</sup>. Why develop alternatives? What makes them attractive over and above Bitcoin? Hayes (2015b) suggests that it is the arbitrage opportunities that arise from cryptocurrency-to-Bitcoin conversions that induce miners to spend time and resources to mine alternative coins. With Bitcoin being the only real option for transactions in the real world, it is the conversion rate into Bitcoin that is determinative of whether or not it is profitable to mine an alt coin. Hayes finds from real world observations that most of the time it is not more profitable to mine altcoins. Yet, we find they still persist and new

coins enter the market place all the time. The interest in Ethereum and Ripple and the increase in their prices since his 2015 study suggest that his observation may be time dependant and there is a need for new studies.

Sat et al. (2016) investigate the potential for laundering money through the use of cryptocurrencies. As Bitcoin accounts do not contain client identifiers and there is no central authority to provide details, identification of illegal use is difficult. Further obscuration can be achieved by utilizing a mixing service where funds from a number of clients are combined and used for further transactions. Sat et al. investigate transactions on the website *blockchain.info* with the intent of tracking specific transactions to a single client. They find 98 transactions that appear to be directed at breaking down large amounts into smaller amounts to avoid detection. But are unable to say more, as the trail becomes blurry after funds are mixed. They offer suggestions for further analysis. Ziegeldorf et al. (2016) point out the problem with the type of analysis proposed by Sat et al., which enables reconstruction of a Bitcoin owner's address, raising issues of privacy. They discuss the issues of user security and anonymity when using mixing services: the service providers themselves may not be trustworthy, may steal the Bitcoins in their trust, and may retain details of the inputs in each mix. They propose a mixing service that runs on a distributed protocol and offers generated escrow addresses from which funds can be redeemed.

Although much has been made of the benefits of Bitcoin's blockchain technology in finance, Ammous (2016) notes some major obstacles to its use. In the banking sector recording of every transaction by every member of the network is very costly in terms of resources. The data storage costs and computational burden on network members will grow exponentially as transaction numbers grow, so unless it is a closed network, members may not be prepared to commit the necessary resources unless the financial rewards are significant. Ammous also points out that as blockchain technology moves to the financial networks, anonymity will not be possible because of the need for regulatory compliance. Lastly, procedures to reverse or delete transactions after mistakes would negate the whole point of the blockchain. Ammous notes that, so far, the only successful application of Bitcoin's blockchain technology is the recording of cryptocurrency transactions. Commercial applications are still at the prototype stage.

### **Economics, finance and accounting**

Next in importance, making up approximately 34% of the total are papers relating to economics, finance and accounting.



## Economics

Of the 228 papers classified as Economics, approximately 55% relate to Bitcoin's impact on payment systems, the monetary system, monetary policy or governance. A few focus on mining production costs as a factor in the price of Bitcoin. Others focus on the relationship between Bitcoin and various exchange rates and the economic and political situation in a range of countries. Some analyse the characteristics of Bitcoin users. Others explore the issues in more general terms offering observation on cryptocurrencies rather than just Bitcoin.

Much of the early research is directed at the question whether or not Bitcoin is a currency. If it is not a currency, then what is it? Yermack's (2013) analysis of the characteristics of Bitcoin prices leads him to conclude that Bitcoin resembles a highly speculative investment – not a currency. While Bitcoin is increasingly accepted as a medium of exchange, it performs poorly as a unit of account or a store of value because of its high volatility. Yermack also cites other non-currency like attributes, such as not being able to deposit it in a bank, but this limitation has since been removed by at least one bank. Norway's largest Internet-based bank has added a new feature tethering Bitcoin accounts to the company's web bank platform. Bank customers can now access Coinbase accounts alongside their savings and checking accounts.<sup>12</sup> Whether or not Bitcoin is a currency may be a moot point as more and more companies, organisations and businesses now accept it as a legitimate payment. For example, 300,000 businesses in Japan alone are signing on to accept Bitcoin.<sup>13</sup>

Instead of making a case one way or other about Bitcoin's status as a currency, Shaw (2016) sets out to understand how the Bitcoin community views it, using an impressive data set of 235,000 messages relating to the role of Bitcoin on *Bitcointalk* and *r/bitcoin*. Shaw finds that the community members are aware of Bitcoin's position and they talk of Bitcoin as a medium of exchange, an investment asset and a store of value. Shaw concludes, that with the increase in trading volume, number of users and the acceptance by businesses as a money substitute, the issue becomes whether time will determine the ultimate status of Bitcoin – will it become a real currency or just an innovative technology of limited financial consequence.

Whether Bitcoin is currency or not, central banks are concerned with the increasing acceptance of Bitcoin. Sauer (2015) points to central banks' concerns over the risks that Bitcoin may bring to financial stability. Furthermore, since Bitcoin mining is itself the creation of money, even if Bitcoin partially substitutes for a national currency, the central bank may have to adjust its money supply to respond to changed demand. This

in turn can impact on, at least in the short term, the bank's ability to influence interest rates and monetary policy.

Caytas (2017) provides an excellent discussion of the benefits of Bitcoin's blockchain technology in enabling a real-time clearing and settlement system. For example, in the US, settlement for equities, bonds, municipal securities, and mutual funds is typically T+3 (within three business days after the transaction date), and government securities, options on future contracts, and listed options T+1. The European standard for forex spot markets is T+2, but the target is real-time (or near real-time) clearing and settlement. While countries are striving for near real-time clearing, real-time settlement is still some way away. Blockchain technology could enable the speed and security that financial markets seek. Security would also be enhanced with non-acceptance of ex-post corrections to transactions data on blockchains, which would forestall forgeries, manipulation or the sale of the same asset to more than one party. Correspondingly, the cost of financial transactions would be significantly reduced, reducing overall costs to financial institutions. Blockchain technology is still in its infancy, with no global technical and legal standards, but even so Caytas sees this technology as the way forward.

So, what is driving the prices of Bitcoin and other cryptocurrencies? Hayes (2015a) points to three main drivers: the production costs of mining coins, the rate of coin production, and the algorithm. He does recognise that other factors such as a speculative premium and the tendency to hoard coins may also influence the price at any given time. Reduction in the number of coins in circulation will also have an impact on the price, but he finds the number out of circulation difficult to quantify and measure. Kim et al. (2016) use comments on online cryptocurrency forums to formulate a model for predicting fluctuations in the price and trade volume of Bitcoin, Ethereum and Ripple. They find that positive comments affect price fluctuations for Bitcoin but it is negative comments that affect price fluctuations for Ethereum and Ripple.

Yelowitz and Wilson (2015) take a different approach, using Google Trend data to study the clientele driving the interest in Bitcoins. They identify following proxies for interest of four groups in Bitcoin:

- computer programmers attracted by the complexities of mining and the prospect of getting rewarded for their technical capabilities;
- investors and speculators attracted by the possibility of significant financial rewards;
- those involved in illegal activities attracted by the anonymity of Bitcoin; and
- libertarians attracted by absence of regulations.

Analyzing Google Trends US data from January 2011 to July 2013 they find that enthusiasm for computer programming and illegal activity drive interest in Bitcoin but find little evidence for political or investment motives. Bohr and Bashir's (2014) profile of Bitcoin users also includes a political dimension. They find that users are attracted to Bitcoin because it operates outside of government control.

Viglione (2015) finds that pricing, in particular the premium that appears to be paid in some countries, is related to the country's political situation. His research is important for its innovative approach in using the price of Bitcoin as a proxy for disaster insurance. He finds that Bitcoin, as a financial asset with minimal co-variance with other financial assets in the local economy, is attractive as a hedge against the risk of loss in a politically volatile environment.

### Finance

Finance papers tend to be more traditional in their approach with a significant number focusing on Bitcoin's high price volatility and price differences across exchanges.

Pieters and Vivanco (2016) observe that Bitcoin trades at different prices in 11 Bitcoin exchanges they study. They find statistically different price patterns in exchanges that adhere to Anti-money Laundering (AML) and Know Your Customer (KYC) policies and those that do not even require any identification. They also find that trading volume and exchange fees influence Bitcoin prices.

Now with social media, chat rooms and other Internet forums where information (true or false) can be exchanged at minimal cost without delay, Kristoufek (2013) analyses the price dynamics of Bitcoin using the search queries on Google Trends and Wikipedia as proxies for investor interest. He observes a strong correlation between Bitcoin prices and search queries. Moreover, there is a marked asymmetry in the relationship between interest and price above and below short-term trend. While prices are above short-term trend, with increased interest there is a pronounced increase in price, which can lead to a price bubble. When prices are below short-term trend, with increased interest there is a decline in prices.

A similar approach is used by Garcia et al. (2014) who also use social signals to analyse Bitcoin prices; a modern day take on investors' herd mentality. They use four signals to examine price variation: exchange prices, social media communication, growth in user base, and the volume of information searches. They find that spikes in searches, perhaps linked to external events, precede price declines. They also find that surges in Bitcoin prices are

largely due to increased public attention, in particular entry of new users into the market. Bouoiyour and Selmi (2015) and Bouoiyour and Selmi (2016) find that Bitcoin prices are driven more by negative rather than positive shocks. However, although Bitcoin is known for its high price volatility, both studies find its price has stabilised following a five-year period (2010–2014) of high volatility. We expect there will be more to come on this issue given the actions of the Chinese government with regard to Bitcoin trading in the first half of 2017.<sup>14</sup> It is a case of 'watch this space'.

Osterrieder, Lorenz & Strika (2016) and Osterrieder and Lorenz (2016) assess the risk of using cryptocurrencies. They focus on the top six cryptocurrencies: Bitcoin, Litecoin, Dash, Monero, Ripple and MaidSafeCoin. They find the returns on cryptocurrencies to be more volatile and riskier than fiat currencies, equities and commodities. Apart from Bitcoin and Litecoin, the others are only slightly correlated with each other, with Ripple showing the lowest correlation with the other five cryptocurrencies. So, while risk levels are not consistent, they tend to be cryptocurrency dependant.

### No accounting for Bitcoin

Accounting research has come late to the study of Bitcoin and its impact. This is not unexpected as in 2011 one Bitcoin (BTC) was trading at only US\$1.00. When searching for Bitcoin related papers, we found only ten in accounting. None of them appeared before 2014, when Bitcoin was trading at around US\$300/1BTC. With Bitcoin trading at US\$970/1BTC at the end of 2016, accounting for its use in an organisation's financial statements is now a serious and pressing issue. We now cover the current issues facing the accounting profession: the need for standards, the need for auditors to understand the risks involved, and the issues facing treasury managers with regard to the acceptance of any form of virtual currency.

Tan and Low (2017) point out that although tax regulators are providing tax rulings on Bitcoin and virtual currencies in general, the accounting standard setters have been slow to act. This is proving difficult for accountants looking for guidance on how to account for virtual currencies, particularly in the US where the Internal Revenue Service (IRS) for tax purposes considers virtual currencies to be property – not currency. Accounting standard setters need to provide guidance and some authoritative interpretation on whether Bitcoin and other virtual currencies are financial assets or currencies so that there is a consistent approach amongst accountants and auditors.

Analysing and assessing the risks organisations take in accepting cryptocurrencies should be part of the risk

assessment process performed by the organisation's internal auditors. Hoelscher (2014) also points out the need for communication between the internal and external auditors to ensure that transactions are accounted for appropriately in an organisation's financial statements as well as conforming to the relevant tax authority's guidelines.

Smith and Weismann (2014) look at Bitcoin from the vantage point of the treasury manager. Given that Bitcoin is gaining acceptance from both brick and mortar and online merchants and the regulations, which could mitigate risks, are not yet in place, organisations must, at present, make their own decision: do the commercial benefits outweigh the risks?

### How to tax and regulate the new cryptocurrencies?

With the increase in size of the cryptocurrency markets governments are facing the issues of how to regulate and tax these new entrants in the financial market place.

#### Regulation

Of the 917 relevant papers, 157 relate to the regulation of Bitcoin, cryptocurrencies, and virtual currencies. Most governments have not concentrated on regulating just Bitcoin, though that was the catalyst. They realise the importance of framing legislation to encompass all non-fiat currencies: their recognition, production, use and conversion.

Some papers concentrate on just a specific aspect of the law, such as bankruptcy, contract, property, and securities. Others focus on the criminal aspects, such as use of cryptocurrencies for money laundering, financing terrorism, and other criminal activities. The bulk of the papers, two thirds, discuss various aspects of governance, public policy and the legal framework under which governments should or should not regulate and control Bitcoin and other cryptocurrencies. Kaplanov (2012) argues that Bitcoin activities, in the US in particular, fall outside of banking, money transmission and securities laws. He makes a compelling argument for treating Bitcoin transactions as transactions using a community currency (e.g., barter contract), which are accepted within a community according to the rules of its own system. In effect, Bitcoins should "receive full contractual authority without being bound by federal securities regulations" (p. 114).

With Bitcoin still viewed as playing a minimal role in the global economy, De Filippi (2014) does not see Bitcoin regulation as a pressing issue for governments. Any harsh regulation based on worst-case scenarios could

easily stifle the opportunities such an innovation offers. Borroni (2016) sees a need to hold an international conference to draft a multilateral agreement under the auspices of the International Monetary Fund (IMF). Brito, Shadab & Costillo's (2014) anticipate that the next wave of Bitcoin regulation will bring securities, derivatives, and gambling under regulatory purview. Bryans (2014) argues that current anti-money laundering regulations do not cover the entirety of Bitcoin use. Luu and Imwinkelried (2016) examine two methods used by data forensic experts to penetrate anonymity of Bitcoin – traffic analysis and transaction graph analysis. They find both methods insufficient to provide evidence in a court of law.

These papers point to a regulatory system in transition and caution against overregulating a potentially valuable addition to the global payment and financial systems.

#### A taxing question

The academic literature focuses on: How to tax cryptocurrencies – tax mining or transactions? Are cryptocurrencies a currency, an asset or just a barter system? Are people using cryptocurrencies to hide income, be it from legal or illegal sources? So, what should governments do about it?

Bal (2015) provides an excellent overview of the present tax conundrum. How, when and where governments tax Bitcoin or any cryptocurrency? Is it through taxing income or consumption? If income is taxed is it all income regardless of its source as in the US, or are there only specific categories that are taxed. If governments move to taxing consumption then they need to decide what is taxable. The governments also face the challenge of detecting non-compliance when transactions are anonymous in a multijurisdictional setting. Bal finds that national approaches vary; for example, in Holland general income tax rules apply to taxpayers earning their profits in Bitcoin, Canada taxes transactions, Finland taxes the profits made when Bitcoins are exchanged for fiat currency as capital gains and the value of Bitcoins generated through mining are subject to income tax. Moreover, governments are continually changing their policies. Emery (2016) finds the Australian situation is also unclear with Bitcoin falling outside the current definition of any particular asset class as far as the Australian Taxation Office is concerned.

Akins, Chapman and Gordon (2014) and Wiseman (2016) look at the taxation issues raised by the Bitcoin in the US. Taxation of Bitcoin as property favours investors who have a lower tax rate on investments and with fewer transactions, which makes compliance easier. Wiseman

**Table 6.** Dissemination avenue for cited papers.

Dissemination Avenue	Cited Papers	%
Journal articles	23	53.4%
Unpublished papers	12	27.9%
In Collection	2	4.7%
In Proceedings	4	9.3%
Other Serial	2	4.7%
Total	43	100.0%

believes that such taxation makes it extremely difficult to use Bitcoin for everyday purposes, as it almost impossible for users to comply and the IRS to police. In effect, with this attitude the US is actively discouraging usage of Bitcoin as a form of currency. Pittman (2015) looks at how US charities handle Bitcoin donations. With the IRS classifying Bitcoin as property for taxation purposes, the market price of any donation has to be determined. The question then is when and how to determine the fair value of a Bitcoin donation – when the charity uses it or when it is donated? Pittman points out that the donor could claim a tax deduction at the market price at the time the donation is made, but Bitcoin is so volatile that by the time the charity receives the donation, which may be by way of crowd funding, the market price may be very different. Pittman recommends using the ‘stock valuation model’ but organisations will need comprehensive guidance on determining a fair market price.

Marian (2013) notes that at the same time as Bitcoin has increased in value and popularity we have seen governments around the world cooperating in the battle against tax evasion, putting more pressure on financial institutions to collect and provide information about account holders. But then, cryptocurrencies possess the same characteristics as tax havens – transfer and storage of funds with anonymity preserved, and they offer a bonus – no need for an intermediary financial institution to transfer the funds. Marian believes that cryptocurrencies have the ability to defeat any global anti-tax haven initiative.

## Conclusion

The arrival of Bitcoin has certainly caused a stir in academic circles. The initial interest was, of course, technical but with Bitcoin prices increasing substantially, interest soon spread to its likely impact on countries’ monetary systems. Economists’ early discussions centred on whether or not Bitcoin is a currency, a moot point as Bitcoin users have already decided this for themselves. Finance got engaged later when there was enough data to analyse prices and returns. Governments, though late in recognising the importance of Bitcoin are now considering both regulation and taxation of Bitcoin. Accountants are now looking to the accounting

standard setters for guidance as businesses have started accepting payments in Bitcoin.

As can be seen in Table 6, only about half the papers cited here have been published in journals; many are unpublished working papers. With the Bitcoin landscape changing daily, ideas and research need to reach the target audience faster than the traditional journal route allows, so researchers will need to use sites that allow working papers to be listed.

It is clear that the future of Bitcoin research will not be limited to any particular discipline. Wherever Bitcoin appears to have a role in a domain of interest, academic interest will follow. The research papers we include here are intended to provide a starting point, from whatever discipline you approach the issue.

## Notes

1. We include the most recent version of working papers subsequently revised or published, so some publications bear the date 2017.
2. Numbers in square brackets refer to the database IDs in Table 1.
3. Liu (2016) sourced the articles for his co-word analysis of Bitcoin exclusively from the Scopus database.
4. However, as explained in a later section, many of the search results from *SpringerLink* have to be discarded.
5. We do not specifically examine *Econpapers* due to the substantial overlap with *IDEAS*.
6. Despite selecting desired types, other types nevertheless appear in the results. These are considered in the next section.
7. This is especially important for the “Categorisation of Papers in Collection” section, where we assign each entry to a category. For papers that do not have an abstract – such as articles in law journals – we refer to the article’s introduction to determine the focus of the article. The *SpringerLink* database does not provide abstracts, and here papers not indicating ‘Bitcoin’ in the resulting downloaded entry record are discarded.
8. ‘An Epic List of Bitcoin Research’: <https://docs.google.com/spreadsheets/d/1VaWhbAj7hWNdiE73P-W-wrl5a0WNgzjofmZXe0Rh5sg/edit#gid=0> (accessed August 5, 2017).
9. Smith + Crown published research repository: <https://www.smithandcrown.com/research-search/> (accessed August 5, 2017).
10. These attacks are designed to prevent legitimate users from accessing a desired service. With a distributed denial-of-service (DDos) the incoming traffic flooding the victim’s site comes from multiple sources, making it impossible to stop by blocking a single IP address.
11. On the website *coinmarketcap.com* there were 1,017 altcoins listed on July 29, 2017.
12. ‘Norway’s Largest Online Bank Integrates Bitcoin Accounts’, by Jamie Redman, May 15, 2017 <https://news.bitcoin.com/norways-online-bank-bitcoin-accounts/> (accessed May 28, 2017).
13. ‘Bitcoin going mainstream as Japanese business signs on’, *Nikkei Asian Review*, May 23, 2017.



14. On January 11, 2017, the People's Bank of China (PBOC) announced it is going to be carrying out inspections on Bitcoin enterprises in the country. <https://cointelegraph.com/news/chinas-central-bank-is-raiding-bitcoin-operators-bitcoin-price-is-tumbling> (accessed December 3, 2017)  
On January 26, 2017, the PBOC announced it will continue its investigation into the country's Bitcoin exchanges focusing on payments and settlement, money laundering, foreign currency exchange, and information and fund security. [http://www.chinadaily.com.cn/bizchina/2017-01/26/content\\_28057727.htm](http://www.chinadaily.com.cn/bizchina/2017-01/26/content_28057727.htm). (accessed December 3, 2017)  
The PBOC continued putting pressure on Bitcoin Exchanges in China during 2017, influencing Bitcoin trading in China.

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