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Are we contributing? The who, when, where, & what of the Blockchain research landscape

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Short Paper

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Abstract

This short paper presents a comprehensive systematic and bibliometric analysis of blockchain technology. It extends beyond the information systems field, to include management, finance, economics, and others, to assess the true reach and impact of the technology. We present a summary of the who, when, where, and what of blockchain research. Informed by these findings we continue to explore how researchers are contributing and whether we (as researchers) are indeed advancing and contributing to theory and/or practice. We present some of the early findings and look forward to presenting the completed analysis at the conference.

Keywords: Blockchain, Literature Review, Bibliometric Analysis, Distributed Ledger

Introduction

Blockchain research has grown exponentially since the 2008 publication of 'Bitcoin: A Peer-to-Peer Electronic Cash System' (Nakamoto 2008). In 2016, the first blockchain literature review was published, reviewing 41 papers (Yli-Huumo et al. 2016), of which over 80% of papers focused on Bitcoin systems. Literature reviews can fit into one of three types: first, literature reviews for the purpose of scholarly publication, second, stand-alone literature reviews, and third, literature reviews that serve as an anchor for an academic thesis (Okoli and Schabram 2010). Risius and Spohrer (2017) present a stand-alone literature review with the intent to provide a comprehensive potential research framework. The literature review of Yli-Huumo et al. (2016) defined blockchain anchored on the technical architecture of the Bitcoin Blockchain, while Risius and Spohrer (2017) defined blockchain more broadly and highlighted the changes in the technical architecture since the emergence of Ethereum and other such applications. Another often referenced literature review from Wang et al. (2019) presents their literature review for the purpose of scholarly publication, defining blockchain based on its use within supply chain environments. Wang et al. (2019) anchor to the Bitcoin blockchain definition but do introduce permissioned and permissionless access controls.

Risius and Spohrer (2017) and Wang et al (2019) are two of the most widely cited literature reviews on blockchain technology. Risius and Spohrer (2017) and Wang et al (2019) were fortunate to have a review

cycle of eight (8) months each, as some review cycles within information systems can be significantly longer. Still, the definitions were outdated and do not accurately represent how the technology was been enacted within the industry. Subsequent literature reviews and research are anchored in the work of Yli-Huumo et al. (2016), Risius and Spohrer (2017), and Wang et al (2019), and, as such, are making assessments of technology suitability against an outdated definition, even if accounting for publication review cycle lags.

As this research began, it was never the intention to problematize the research (Alvesson and Sandberg 2011), feeling there were plenty of research opportunities. However, research must build from firm foundations. At this point, it is beneficial to reflect and confirm "what is blockchain?". Additionally, researchers often reference case studies (for example, R3 Corda (Grover et al. 2019) or De Beers Tracr (Roeck et al. 2020)) as blockchain solutions. We present in this paper the argument that such solutions should not be defined as blockchain solutions. Subsequently, one of our research questions seeks to define "what is blockchain technology?".

Our research is also based on the call for research covering themes of design and features, measurement and value, and management and organization. 2008-2017 was dominated with design science research (both conceptual and prototype solutions) and there was a lack of empirical research (Risius and Spohrer 2017). We assess how well we, as researchers, have heeded the call by using theories from Gregor (2006) and O'Leary (2008) to frame our bibliometric literature review. Our literature review highlights that researchers' must re-baseline their understanding of blockchain technology (what) and provide more clarity and accuracy to the discourse. We welcome the diversity of researchers (by location (where) and by discipline (who)) who also contribute to this discourse. We would welcome increased multi-disciplinary collaborations to ensure technology features are being applied appropriately to business problems, rather than research being diverse yet siloed within a discipline. We also welcome the wide variety of prototype solutions (what) common in the early stages of emerging technology research (when) (O'Leary 2008). These prototype solutions are often motivated by stating blockchain is unable to perform suitably to solve the business problem. We agree with these researchers and with Fridgen (2018), that blockchain cannot solve every business problem. We present that many solutions may be better suited to distributed ledger solutions or distributed systems rather than blockchain solutions. We call to researchers to improve their accuracy in the discourse about the technology.

This short paper presents a comprehensive review of blockchain technology research using both bibliometric and systematic methods. We also demonstrate how researchers can't yet answer the call for empirical research and that researchers have not yet answered the call for research in many of the areas suggested by Risius and Spohrer (2017). To access the call regarding multidisciplinary research, our literature review extends beyond the information systems field, including management, finance, economics, and others. The remainder of the paper is structured as follows: First, we discuss the methodologies used for the literature review and analysis, including the tool used to aid the process. Subsequently, we present a summary of the who, when, where, and what of blockchain research and demonstrate that the research is still in an embryonic state. Next, we provide a brief statement on the next steps. And finally, we provide some initial conclusions and future research opportunities.

Methodology

A systematic process (as outlined below in Figure 1) was undertaken to select suitable literature to answer the research questions of who, when, where, and what we contribute. Steps 1.0 to 5.0 findings are presented below within the discussion section. A total of 1260 highly ranked academic journals[1] were selected with the intention of a bibliometric analysis[2]. An advanced search was undertaken using Web of Science using the sole term "blockchain" listed within the abstract and matching with the ISSN (and eISSN) numbers for the selected high-quality, peer-reviewed journals. A total of 1178 articles were identified and extracted from 277 unique journals. A comparative extract was taken from Scopus. Web of Science provided a larger and more comprehensive (and higher quality) dataset than Scopus.

[1] Journals were selected based on their ranking by the Australian Deans Business Council.

[2] The chosen tool was Biblioshiny, an R-developed application. Version 3.2.1 released on 21 February was used.

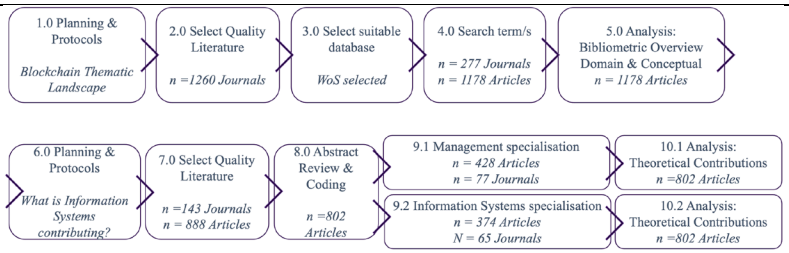


Figure 1: Meta-analysis process, using systematic and bibliometric methods

Bibliometric analysis can provide both domain and knowledge structure analysis of large volumes of research (Aria and Cuccurullo 2017). The maturity and user-friendliness of these tools are varied. VOSViewer and BibExcel are widely used tools (Lardo et al. 2022; Lombardi et al. 2021). Aria and Cuccurullo (2017) have developed and continue to update a comprehensive, Apple Mac compatible, user-friendly and open-source bibliometric tool, Biblioshiny, which is based on R bibliometrix library packages. Aria and Cuccurullo (2017) present in their paper the strengths and weaknesses of commonly-used bibliometric tools, as well as provide a comprehensive breakdown (and each mathematical computation) of each functionality provided within Biblioshiny. Due to brevity requirements, we encourage reading the Aria and Cuccurullo (2017) paper, as well as supporting documentation provided at bibliometrix.org.

Step 6.0 (from Figure 1) was informed by two papers, one from a theoretical perspective (Gregor 2006) and one from an industry perspective (O'Leary 2008). O'Leary (2008) suggests reasons why we still may have to wait to see any empirical research on blockchain technology. Gregor (2006) was chosen as a framework to help answer "Are we contributing?", as it is a highly cited papers that provides a categorisation framework for how researchers can contribute to theory. Risius and Spohrer (2017) state that between 2008 and 2016 there is significant Design and Action research. They also call for empirical research to be undertaken. O'Leary (2008) presents a complementary framework tailored for emerging technology research which suggests that certain contributions may only be possible as the technology emerges and progresses along the Gartner Hype Cycle™. Accordingly, O'Leary provides a framework that explains why is may not be possible to yet produce empirical research. Step 7.0 selected a subset of articles (888 articles) from the fields of Information Systems and Business & Management were extracted from the larger dataset. Abstracts were reviewed for relevance, resulting in a final dataset of 802 articles. Information Systems articles resulted in 374 articles from 65 unique journals and Business & Management articles resulted in 428 articles from 77 journals. Step 8.0 refers to the coding of the shortlisted articles and is outlined in further detail below.

Discussion

Who, when, and where are we contributing?

The top 15 authors all refer to the original paper written pseudonymously by Satoshi Nakamoto (Nakamoto 2008). The top 15 authors are Professor Tsan-Ming Choi, Professor Angappa Gunasekaran, Professor Kim-Kwang Raymond Choo, Professor Joseph Sarkis, Professor George G.Q. Huang, Associate Professor Li Zhi, Professor Samuel Fosso Wamba, Professor Yogesh K Dwivedi, Assistant Professor Tsung-Ting Kuo, Professor Maciel M. Queiroz, Professor Nils Urbach, Assistant Professor Yan Chen, Professor Gilbert Fridgen, Professor Marijn Janssen, and Professor Akhil Kumar. Each of these authors (based on their Google Scholar profiles) come from a variety of research fields (law, supply chain operations, and one is even a medical doctor), and only a few researchers are from the Information Systems discipline.

The first academic paper published within our dataset was published in the Duke Law Journal discussing the abundance of research on bitcoin but highlighting the lack of necessary progress in the areas of blockchain and regulation (Kiviat 2015). Currently, that call has not been heeded, even with the exponential growth of research. Business Law journals over the past six years have totalled an additional 53 articles, while Information Systems journals have published 404 articles.

We have answered who is publishing and are impressed with the variety and widespread diversity of research. Now, we will address the 'When and Where we are contributing?' Figure 2, below, provides a summary of the twenty (20) journals that are publishing the most blockchain research. 530 (45%) of 1178 articles are published in twenty (20) journals. 2022 only contains partial data (up to March 2022), but growth so far has been consistent and exponential since 2017. The journals with the most publications are predominately from two scholarly fields, Information Systems (9 journals) and Business & Management (8 journals). Also represented are Accounting, Auditing & Accountability, Banking, Finance, & Investment, and Commercial and Contract Law (with one journal each). Risius and Spohrer (2017) call for multi-disciplinary research. Predominately the research is diverse and broad but siloed. There would be new insights offered by a multi-disciplinary approach.

Journals	2017	2018	2019	2020	2021	2022	Grand Total
INFORMATION PROCESSING & MANAGEMENT				4	45	4	**53**
IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT				34	14	5	**53**
INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH			3	15	24	7	**49**
COMPUTERS & SECURITY		1	11	18	14	3	**47**
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	2	1	3	13	25	2	**46**
JOURNAL OF CLEANER PRODUCTION			2	11	26		**39**
INTERNATIONAL JOURNAL OF INFORMATION MANAGEMENT		2	3	22	5		**32**
COMPUTERS & INDUSTRIAL ENGINEERING			10	3	13	2	**28**
ANNALS OF OPERATIONS RESEARCH				1	11	11	**23**
JOURNAL OF ENTERPRISE INFORMATION MANAGEMENT			1	6	11	1	**19**
INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS			1	7	11		**19**
COMPUTER LAW & SECURITY REVIEW	2	5	3	3	2		**15**
PERSONAL AND UBIQUITOUS COMPUTING				2	12	1	**15**
JOURNAL OF EMERGING TECHNOLOGIES IN ACCOUNTING	2		6	4	2		**14**
ELECTRONIC MARKETS				11	2	1	**14**
INDUSTRIAL MANAGEMENT & DATA SYSTEMS		2	4	2	4	1	**13**
INTERNATIONAL JOURNAL OF INFORMATION SECURITY			2	4	7		**13**
JOURNAL OF RISK AND FINANCIAL MANAGEMENT			2	4	7		**13**
ENTERPRISE INFORMATION SYSTEMS			2		10	1	**13**
SUPPLY CHAIN MANAGEMENT-AN INTERNATIONAL JOURNAL		1	2	6	2	1	**12**
Grand Total	**6**	**12**	**55**	**170**	**247**	**40**	**530**

Figure 2: Journal publication counts by year

What are we contributing?

We have answered who, when and where are we contributing, the question now arises: 'What are we contributing'? Using bibliometric analysis software, Figure 3 provides a thematic evolution across four (4) time slice periods for all 1178 articles[3]. Between 2015 and 2018 themes such as financial markets, digital currencies, distributed ledgers, future research, and supply chain topics were dominant. 2019 saw supply chain, smart contracts, initial coin offerings, and blockchain adoption themes emerge. 2020 saw the continuation of smart contracts and supply chain themes, with design science emerging as a dominant theme. 2021 sees smart contracts and supply chain research dominate, with a re-emergence of initial coin offerings, and systematic literature reviews becoming dominant. 2022 has, thus far, seen continued research in the areas of supply chain and smart contracts, with new themes emerging in the areas of business models, artificial intelligence, food safety, access control, and financial markets.

The thematic evolution shows the science that is emerging or declining. For example, future research is identified as a theme in 2015-2018. From there, the theme evolves to research in supply chain, which in 2020, returns to the topic of future research, which then splits into four themes in 2021 (supply chain, blockchain technologies, systematic literature reviews, and initial coin offerings). Another theme is 'blockchain technology', which seems obvious since this was the search term. However, what is interesting is the theme of 'distributed ledger technology' in 2015-2018. Much of the research in this period struggled to define blockchain technology (as did the industry), vacillating between the terminology of distributed ledger and blockchain regularly and even erroneously calling them synonyms (Klimos 2018). However, since 2019 blockchain technology has remained the dominant theme and term used, even though researchers are finally starting to correctly define the difference between blockchain and distributed ledger technology (Pedersen et al. 2019). Further, researchers have started to identify cases that are more likely to be called 'blockchain inspired' (Babich and Hilary 2020). Due to the velocity of change within the technology stack, we looked to non-traditional, yet reputable instiutions, such as the National Institute of

[3] Analysis settings were Field: Abstracts, N-grams: Bigrams, no terms or synonyms were excluded, using 4 time slices.

Standards and Technology (NIST), to help provide a definition of 'What is blockchain?' that we considered most accurate and aligned with blockchain technology. As such we provide the definition below:

> Blockchains are *distributed digital ledgers* of *cryptographically signed transactions* that are *grouped into blocks*. Each block is *cryptographically linked* to the previous one (making it *tamper evident*) after validation and undergoing a *consensus decision*. As new blocks are added, older blocks become more difficult to modify (creating *tamper resistance*). New blocks are *replicated* across copies of the ledger within the network, and any conflicts are resolved automatically using *established rules*. (Yaga et al. 2018, p. 1 emphasis added).

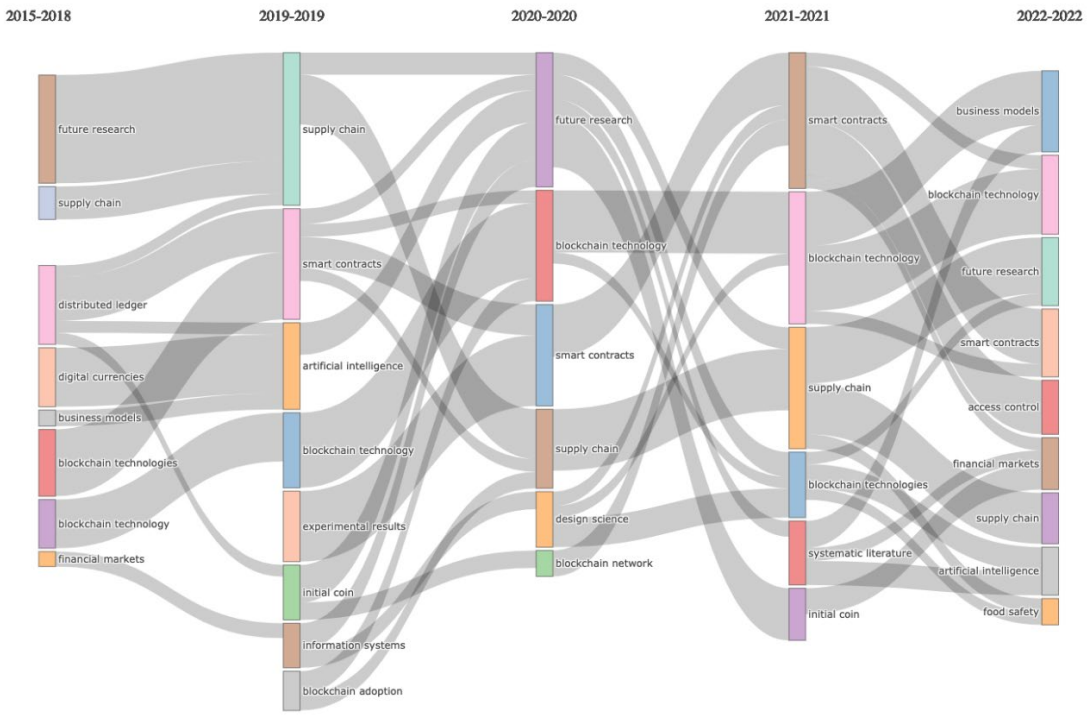


Figure 3: Thematic evolution of research

Beyond what is blockchain – how are we contributing?

Our main research question of 'What is blockchain?' is answered. Informed by these findings we continue to explore how researchers are contributing and whether we (as researchers) are advancing, contributing, and whether research is aligned to this definition

Similar to Risius and Spohrer (2017) and using the Gregor (2006) theoretical framework, analysis of the data suggests that **Design and Action** research is rising with research publications reaching a cumulative total of 301 publications compared to **Explanation** research having a cumulative total of 240 articles. The research commonly takes one of two paths. Option 1 is where researchers "test" whether blockchain solutions could be applied to a specific context and option 2, highlights weaknesses in the current technology and then proposes a way to "fix" the problem. Examples of option 1 solutions include smart metering and peer-to-peer energy trading (Singh et al. 2021), while option 2 type solutions, recommend Elliptical Curve Cryptography (ECC) over other algorithms, to create trust between potentially untrusted parties (Sarfaraz et al. 2021).

Option 2 is how blockchain technology began. One might suggest that 'Satoshi Nakamoto' is a design and action researcher from academia. They released an eight (8) page paper to present their conceptual model to solve the double-spend problem, which current combinations of technologies could not solve (Peters et al. 2015). And then months later present a working prototype, demonstrating a novel combination of

existing technologies to enable digital currencies to work. Since that time, others have critiqued the solution (Yu et al. 2019), saying what is good and bad about the technology and where it can and cannot be applied.

Several prototypes (Chanson et al. 2019) focus on issues of privacy, security, and trust of a permissionless, open architecture, with Proof-of-Work (PoW) consensus protocols and state lack of suitability with the context. Two issues are found with this approach. One, the new prototype technology stack is altered so significantly it may not adhere to the definition of a blockchain, or two, alternate technologies are not considered alongside the blockchain option. For example, solving the issue of fake checks (or cheques) in the US (Hammi et al. 2021). The banking industry solved the issue of fake checks/cheques in Australia by moving to digital banking. Personal checks/cheques have been phased out completely. Bank checks/cheques still exist for such transactions as car and house settlements where timely assurance of funds is required before handing over the title to a high-value property item. In this context, researchers might contest that a blockchain solution may have a specialised role in settlements for high-value items, such as car and/or house purchases, but certainly not to solve the fake check/cheque issue. Highlighting an absence of testing all technology options available to organisations.

Another example is the location of Electronic Vehicles charging stations research (Fu et al. 2020). While the research demonstrates solving this problem successfully with blockchain technology, other technology solutions may also solve this. Again, in Australia, the Australian Competition & Consumer Commission (ACCC) monitors fuel prices throughout Australia and sites like Petrolspy use data gathered by the regulator to offer high accuracy fuel prices to the public and google map queries can help you locate nearby EV charging stations. In this context, some contest that a blockchain solution brings no value to what can be solved through a (potentially cheaper) centralised database solution. Which raises the spectre of whether blockchain solutions are necessarily the optimum solution for every or, perhaps, most business problems, and whether proffered blockchain solutions are, indeed, blockchain solutions at all. This finding also supports the lack of research for the assessment of value creation and measurement of blockchain solutions (Risius and Spohrer 2017) and provides future research prospects.

The first **explanation and prediction** article sought theory building, using fuzzy-set Qualitative Comparative Analysis (fsQCA), to identify the "nonmonetary causal factors and informal financial practices [that] play a major role in habits of the financially excluded" (Larios-Hernández 2017, p. 865). A more recent paper (Chowdhury et al. 2022), sought to explain and predict blockchain technology adoption within an Operations and Supply Chain management context using a combination of risk management theory (VUCA - volatility, uncertainty, complexity and ambiguity) and Technology Acceptance Model (TAM). This study (and many other supply chain studies like it), highlight specific supply chain solutions. Reflecting on the blockchain definition provided from NIST, there is the potential for these supply chain exemplars to be "blockchain-inspired" rather than actual blockchain solutions, akin to the dot.com era (Cooper et al. 2001). We draw particular attention to Tracr, a solution built for the provenance tracking of diamonds. Tracr is built on Ethereum through a joint project with BCG Digital Ventures and De Beers. Reviewing various marketing materials on De Beers website and various other searches resulted in determining that the solution is a permissioned solution, only allowing authenticated users to join (Sharma 2018). This variation does not negate the solution satisfying the definition of a blockchain (Yaga et al. 2018). However, a BCG Digital Venture representative is quoted as saying "it keeps data private and allows participants to selectively share data with only those that they want to." (Sharma 2018). This variation now negates the technology complying with the definition from NIST (Yaga et al. 2018). There is also potential for this statement to suggest that the solution may not even comply with the definition of a distributed ledger. As researchers, we must be vigilant and careful regarding what is, and what is not, blockchain technology. This provides again, future research opportunities to identify and describe the trade-offs of different blockchain features (Risius and Spohrer 2017), but to take it further by including a broader analysis of when business problems and opportunities are just not suited for blockchain features. **Analysis and Explanation** articles are necessary for setting the foundations of research and this research can be a foundation from which further research about blockchain, distributed ledger technology, and blockchain-inspired solutions can stem.

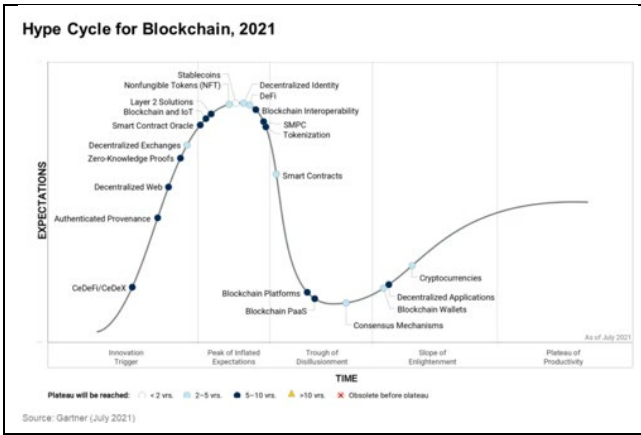
Conclusion

Risius and Spohrer (2017, p. 404) highlight that research was "conceptual, prototyping, and analytical papers, often [focused] on cryptocurrencies". Unfortunately, our research suggests that research has not

progressed much further. This research also sought to answer the challenge of Risius and Spohrer (2017) and sought to gain a deeper understanding of how researchers were contributing beyond the thematic analysis, and whether any of the suggested research areas were addressed. We have presented a summary of the who, when, and where of blockchain research. We have also defined what constitutes a blockchain. Informed by these findings, we recommend a challenge to researchers to confirm solutions that are claiming to be blockchain solutions before declaring positive (or negative) use cases.

O'Leary (2008) offers a research strategy for emerging technologies. O'Leary (2008) presented how research and research styles can vary depending on the technologies placement on the Gartner Hype Cycle™. Blockchain did not appear on the curve until 2016. 2018 saw blockchain begin its descent into the Trough of Disillusionment, where it is predicted that research will focus on the limitations of the technology and provide findings from behavioural studies as to what went wrong. In 2021 (shown in Gartner Hype Cycle™ Figure 4 on the left), Blockchain PaaS is well in the depths of the Trough of Disillusionment, suggesting that case study research will be prevalent. O'Leary (2008) predicts six stages that research will follow as the technology progresses through the various stages of the Gartner Hype Cycle™ (also shown in Figure 4).

All articles are yet to be coded against this framework. In Figure 4, Authenticated Provenance is in the Innovation Trigger stage on the 2021 Hype Cycle, which suggests that supply chain provenance prototypes may be evident within research in 2021 or 2022 (if accounting for publication lags). We will explore this further once the data is codified, but the earlier thematic evolution suggests that there will be an alignment of research outcomes and the Gartner Hype Cycle™ as predicted. We suggest that certain research will be seen to be more represented at different stages of the Gartner Hype Cycle™ as the technology evolves. We are keen to continue our analysis against the Gartner Hype Cycle™ and to confirm how researchers are contributing and indeed determine if researching as predicted.



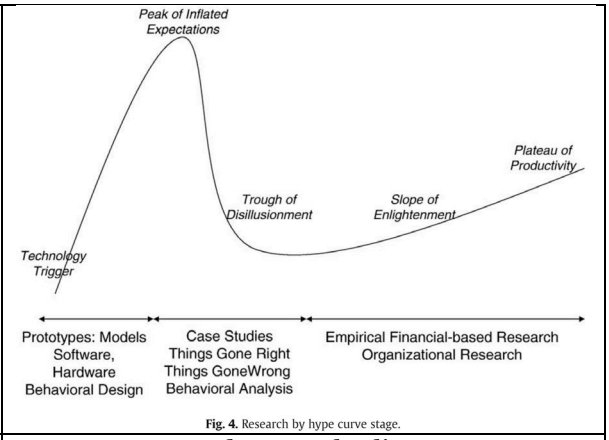


Fig. 4. Research by hype curve stage.

2021 Hype Cycle Source: Litan(2021)	Expected Research Alignment Source: O'Leary (2008)

Figure 4: Gartner Hype Cycle™ and research alignment

There are ample gaps in the blockchain research landscape. Finding the novel space that adds value, provides a unique contribution to theory and practice, and at the right time is certainly more challenging. In this paper, we have answered 'who' is contributing to the research. We have also answered 'when' researchers are contributing. There is a certain feeling of frenzy within some of the research. Potentially, that may be coming from the design and action researchers, who seek to identify and solve perceived problems (and publish their research) ahead of their entrepreneurial competitors. We have also answered 'where' researchers are contributing. We also looked at the future research suggestions from Risius and Spohrer (2017), of which, we still believe the research in all these six (6) areas are still lacking. As we progress from 2017 to 2022, we echo Risius and Spohrer (2017) and further encourage researchers to three (3) things; 1) Accurately define the technology they are studying, 2)Progress beyond Action and Design research, and 3) Provide value and measurement frameworks that extend beyond the technology stack of blockchain.

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