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PERSPECTIVES FOR THE IMPLEMENTATION OF BLOCKCHAIN TECHNOLOGY IN THE SUPPLY CHAIN:

RESEARCH, TRENDS AND FUTURE

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Authors' Notes

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Abstract

The rise of new technologies is pushing companies to a new digital era. Among all technologies, one that has been gaining prominence is blockchain, which has potential for improving processes and enhance business models in supply chain. The implementation of blockchain technology in the supply chain is promising as it can bring benefits to everyone involved in the chain, among them, highlight for reliability, security, transparency, traceability and authenticity of information. Nonetheless, its application is still in the initial phase and this paper aims to shed light on the current research, trends and future related in the literature. Through an RSL (Systematic Literature Review) is identified how recent and innovative are studies published about the subject, as well as how researchers and universities are working on that around the world. The conclusion is that the issue has been attracting attention from academics, with researches dispersed in several countries and universities around the world, with growth potential. It was also identified a few papers with a high impact factor or cited many times, while these usually brings features as security, transparency and sustainability. Despite the advantages and potential, there is still a lack of empirical studies, characterizing a good gap for potential future research.

Keywords: blockchain, supply chain, implementation

1 Introduction

The rise of new technologies is making companies rush to bring them to their reality. In the current digital era, one field that has been affected is the supply chain, which brings possibilities to develop new business innovation models. Among all technologies, one of the most promising is blockchain, which according to Helo and Hao (2019) has tremendous potential for improving processes and enhancing business models in supply chain.

The blockchain technology can be defined as a ledger that records transactions between parties in a verifiable and permanent way (Perboli, Musso and Rosano, 2018). This technology can also be understood as a decentralized distributed accounting and data storage technology (Gromovs



and Lammi, 2017). The great advantage is that this technology works as a distributed and immutable ledger that holds a permanent record of transactional data, which is managed by the peers in the network, eliminating the middleman (Harshavardhan Reddy, Aravind Reddy and Sashi Rekha, 2019).

The possibility to change the way traceability is conducted in all sectors where technology can be used, represents a great promising potential of using blockchain. Moreover, the use of blockchain technology may be an excellent solution to ensure reliability, transparency and security (Figorilli *et al.*, 2018; Grest *et al.*, 2019). According to Kshetri (2018), one of the blockchain's most promising non-financial applications is in the supply chain. Indeed, this technology has the potential to overcome collaboration and trust issues in a supply chain, and it still improves the supply chain performance, through minimizing negative effects of information asymmetry and discouraging enterprises from misconduct, such as counterfeiting data (Longo *et al.*, 2019).

The use of blockchain based on supply chain allows the creation of shared, secure, decentralized ledgers and secure networks (Saberri, Kouhizadeh and Sarkis, 2019). All these advantages help to reduce fraud and errors, mitigating risks, in addition to bringing data transparency and privacy (Vinay Reddy, 2019). Furthermore, integrating processes and making information transparent throughout the supply chain enables companies to employ actions in a collaborative way, providing better service to customer needs (Schrauf and Bertram, 2016).

Taking into account the fact that the theme is innovative and new, this paper aims to shed light on the current trends in the literature regarding blockchain applied to supply chain. It basically seeks to bring perspectives for this application based on the main authors, researches, trends and countries that relate the theme in the last 10 years.

2 Literature review

2.1 Blockchain Technology

Blockchain technology has emerged to support the cryptocurrency as a trustable distributed ledger. The first reference to this technology as a data structure consisting of a chain of blocks appeared in 2008 in the publication "Bitcoin: a peer-to-peer electronic cash system", by Satoshi

Nakamoto (Collomb and Sock, 2016). The essence of this technology is to share data between peer to peer network, what enables to register transactions without a third part. The blockchain is a chain of chronological blocks, where each block is identifying by its hash value and links to the previous block by referencing the hash of the previous block (Rouhani and Deters, 2019).

In a short time frequency, users who access the database are requested to approve the new blocks, cryptographically stamp and register them in a chronological order, thus giving rise to the blockchain (Nakamoto, 2008). The technology has appeared in order to guarantee trust between different parties. According to Gromovs and Lammi (2017), the fact of being a decentralized distributed accounting and a data security storage technology, allows the resolution of the business fraud and still offers more accurate decision information for each business area.

The adoption of blockchain technology may be great solution to provide reliability, transparency and security in other fields. The technology supports to increase profit and ensures the authenticity of the product in real time, providing accurate product information to customers and peers, what is possible through the tracking of the product back and forth across the chain (Harshavardhan Reddy, Aravind Reddy and Sashi Rekha, 2019). Indeed, these inherited features enhance blockchain as a suitable technology to optimize the adopted processing model in several domains, such as health, trade supply chain and food safety (Juma, Shaalan and Kamel, 2019).

As stated by Kumar, Liu and Shan (2020), the technology represents a paradigm change in terms of how business transactions are conducted and therefore has far-reaching implications. Although some experts consider that there is too much expectation about the blockchain application in industry, it is still in the first stages of commercialization and many others experts believe that there is a promising future for the application of this technology across industry (Pournader, Seuring and Koh, 2019). According to Bumblauskas *et al.* (2020) even though the potential for practical use of blockchain technology are still being understood, the potential results are promising.

2.2 Blockchain and Supply Chain Integration



Although there is no consensus among experts on the concept of supply chain a widespread definition comes from the council of supply chain management professionals – CSCMP (2013), which states, the supply chain connects many companies, encompassing all suppliers, service providers and customers through the exchange of materials and information in the logistics process, which begins in the acquisition of raw materials, ending in the delivery of finished products to the final customer. The issue is relevant for companies due to its scope and since the market competition became among supply chains. The material and information flow are under responsibility of all those involved in the chain, and its efficiently control becomes important success factor. According to Bowersox, Closs and Cooper (2006), aiming to conquer competitive advantage, the supply chain strategy seeks the company operational integration with customers and suppliers.

Usually, companies seek to build trusty by establishing a lasting relationship with their supply chain partners or through mutual investments in the supply chain (Wang *et al.*, 2019). However, in many cases, they do not trust each other and several companies are averse in providing or using information from their partners. Despite the possibility to have access to the supply chain partners' data, there is a problem of trust and it happens because they might mislead with inaccurate, wrong or counterfeit information that does not reflect the real data (Longo *et al.*, 2019).

Gonzhol *et al.* (2020), considers one of the challenges to the chain the link between a physical product and its digital record in order to authenticate the quality and origin of the product. Therefore, the challenge is to finding a manner to share information in a secure way, what enables any time, to check authenticity, origin and integrity of data. In this regard, blockchain technology fits as a solution to these concerns since it offers an unique and immutable record of data that can be checked by anyone who has the permission (Longo *et al.*, 2019). The interest of researchers moved to the application of blockchain technology to the supply chain, due to its potential of ensuring data immutability and public accessibility as well as increasing the efficiency, reliability, and transparency of the overall supply chain (Perboli, Musso and Rosano, 2018).

An important element to be considered is that in most companies involved in supply chain processes there is no sharing of the same information system, this leads to information replication or even information silos. In other words, the tracking data is separated between the parties and it is not possible to access the information of others directly. According to Betti *et al.* (2019), through blockchain technology, it is possible to build a shared, reliable information system that is not managed by a single entity, thus the data becomes available to everyone at each stage of the chain, bringing transparency to both companies and for consumers.

First of all, to apply blockchain technology to the supply chain, all actors must be involved. The best way of implementation starts based on requirements analysis and objectives that have emerged from different actors, considering the economic side and the customer satisfaction, aiming to create a business model capable of highlighting the returns of this solution (Perboli, Musso and Rosano, 2018). When well implemented, the technology can improve the quantity, quality and access to information, just as it might assure tracking and traceability across the supply chain. All these advantages help to reduce fraud and errors, mitigate risks and provide data transparency and privacy (Vinay Reddy, 2019).

Taking into account the perspective of the chain members by applying blockchain technology to their operations, it is possible to increase the visibility of all connected entities in the supply chain. According to Reyes, Visich and Jaska (2020), this promotes the establishment of a greater degree of trust between partners, since each member has a greater perception of the business processes of several partners. This new stage of transparency can benefit all participants of the supply chain through reduced delivery time and improved responsiveness. By enabling critical collaboration data records to be reliably maintained between stakeholders without intermediaries, this solution can enable unprecedented degrees of automation across organizational boundaries, which can have important implications for supply chain integration (Palm, Bodin and Schelén, 2020).

One element that is always under discussion in the supply chain, it is about the traceability of goods through the use of RFID tags. Products that contain this type of tag can be registered on the



blockchain and the information can be shared with all partners. This device is one of the best known which collaborates with the use of the internet of things (IoT). According to Gausdal, Czachorowski and Solesvik (2018), the IoT must connect devices to suppliers, anticipating demands and creating useful data.

The association between IOT and blockchain creates a powerful relationship between information and material flow, enabling to establish a link between the different stages of the supply chain. IoT devices can be deployed across the entire supply chain to capture comprehensive and consistent data across multiple parties and transmit the data to the blockchain. The captured data can answer the questions of where, when and what happened in the supply chain (Kayikci *et al.*, 2020).

Blockchain technology built into the IoT improves supply chain flow, transparency and efficiency. Furthermore, traceability, property registration and the encouragement of the use of smart contracts are potential results to avoid falsified information and unauthenticated products (Ahmadi *et al.*, 2020).

For Chang, Chen and Lu (2019) it is evident that there is a tendency to use the blockchain associated with smart contracts, and thus, revolutionize traditional thinking about business processes. These contracts are essentially stored programs that are executed when contractual agreements are conducted (Reyes, Visich and Jaska, 2020). Transactions managed through smart contracts are automated to execute pre-determined financial transactions to ensure that the contractual condition is met at the right time.

The application of smart contracts, IoT devices and blockchain technology in the supply chain strengthens transparency and trust among participants. A more transparent and automatic ecosystem is established, which improves the operational efficiency of the overall process in terms of cost reduction, time efficiency and system automation (Chang, Chen and Lu, 2019).

Another interesting contribution of this technology is in the context of the circular economy, that aims to maximize the product life cycle. Taking into account the main benefits of blockchain

applied throughout the entire chain, such transparency, decentralization and secure transaction process, besides being able to generate resources, reduce costs, improve efficiency and responsiveness, then these features might promote sustainable economic, social and environmental influences in the circular economy (Kouhizadeh, Zhu and Sarkis, 2019).

Despite the advantages explained in the literature regarding the use of blockchain technology in the supply chain, few organizations have implemented it. For Yang (2019), due to the relatively immaturity, its application faces ongoing challenges in terms of data management, scalability, interoperability, standards, and uncertainty in relation to government regulations. In any case, there is a big interest from companies and researchers seeking solutions for market inefficiencies, costs and delays, however, the fact of being in an early stage means that it will take time for blockchain be widely adopted.

3 Methodology

Thought a SLR (Systematic Literature Review) it was possible to provide insights based on a quantitative diagnosis of the literature. The study identifies key research topics, trends and interrelations among related researches. In other words, for a determine topic of study, the use of a RSL allows to find out methods used and results obtained, to identify the main authors, as well as the databases and means of publication used, making it possible to find update information from several laboratories, research centers scientific or even higher education institutions.

This work aims to clarify the current trends in the literature regarding the implementation of blockchain to the supply chain, through three steps: search for articles, analysis of them and summary of results. In order to search for the articles in an organized manner, it was established a research protocol, which has the function of setting the selection criteria for papers. Table 1 shows the protocol.

**Table 1***Search protocol*

Criteria	Description
Database	Scopus, Web of science
Keywords	"Supply Chain" AND "Blockchain" AND "Implementation"
Contain keywords	Title, abstract, keywords
Data range	2011-2021
Area	Engineering
Document Type	Article
Source type	Journal
Language	English

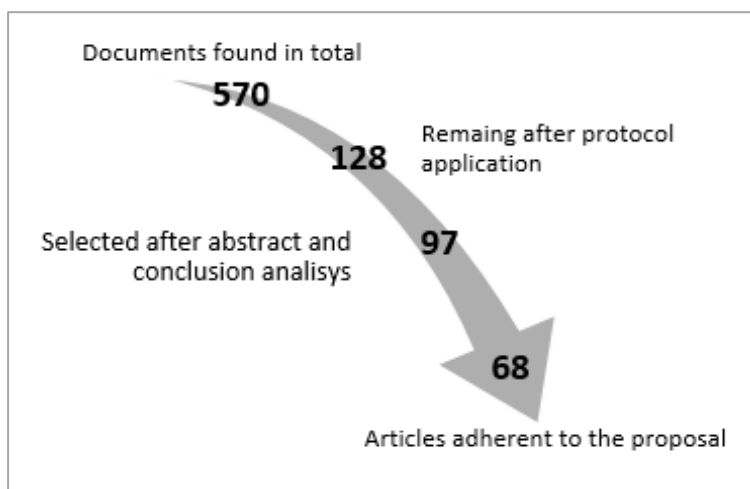
Source: Own elaboration

Based on the criteria to include and exclude papers searching in journals, it was possible to obtain 128 pertinent articles. Due to its relevance in the engineering field, the Web of Science and Scopus databases were chosen. Together they returned an amount of 128 papers, where 31 duplicate papers were identified, in other words, documents included in both databases. Finally, a reading of the abstract and conclusion of all documents were made, selecting only those documents that adhere to the proposed goal here, leaving only 68 papers. The process is shown in the Figure 1.



Figure 1

Article selecting process



Source: Own elaboration

4 Results

Performing an analysis of all abstracts, it was possible to verify that the most found concepts are Blockchain, Supply Chain, Supply Chain Management, Implementation, Technology, Analysis, Logistics, Challenges, Traceability, Security, Framework, Smart, Approach, among others. These main words are illustrated in Figure 2 in the form of cloud chart.

Figure 2

Cloud chart of the most frequently found words in abstracts



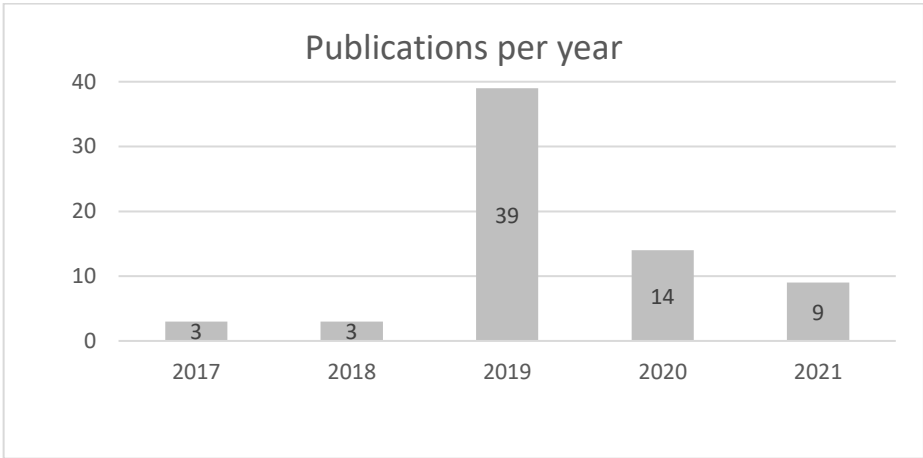
Source: Own elaboration using Pro Word Cloud



In the chart of the Figure 3, it is possible to realize that even searching in the last 10 years, researches related blockchain associated with supply chain implementation started only in 2017, showing how current the theme is. At the same time, it is possible to see how publications on the topic have grown, with a peak in 2019.

Figure 3

Number of publications per year

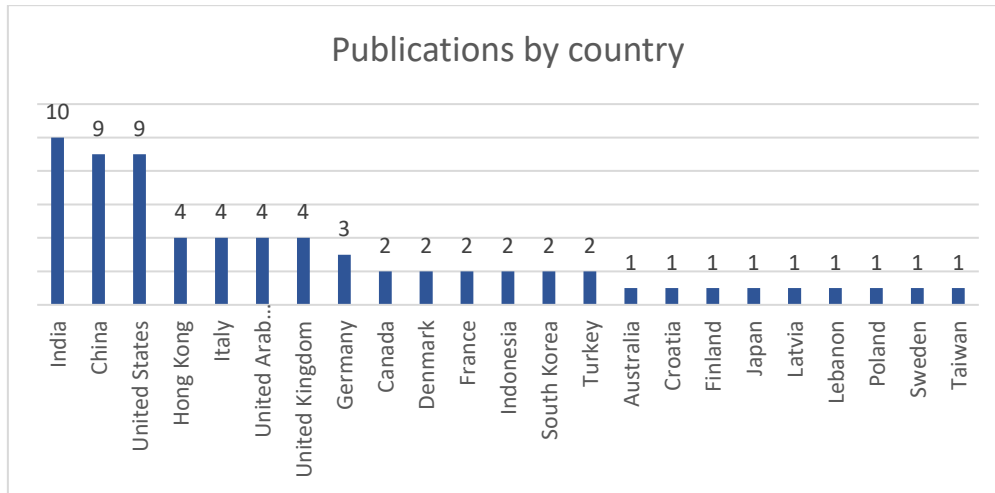


Source: Own elaboration

Figure 4 presents the contribution in number of papers published by country. There are many nations looking at this theme, however the leadership in number of publications is from India, with 9 publications, followed by China and United States, with 8 publications each. A trap here is about Hong Kong, in other words, the leadership could change if the dispute of Hong Kong being part of China is considered or not, since Hong Kong presented 4 publications.

Figure 4

Number of publications by country



Source: Own elaboration

Table 2 shows the amount of citations per article and year. It is possible to realize that the majority of the citation papers are related to the security issue. This makes a lot of sense, because it is one central advantage known when applying blockchain to supply chain. Other frequently cited articles take into account traceability, another well-known feature of the topic discussed here. Two other connected points present in the most cited articles are in relation to sustainability and transparency, topics that are very relevant lately.



Table 2

Amount of citations based on year of publication

Year	Article	Citation
	Blockchain's roles in strengthening cybersecurity and protecting privacy	107
2017	A Novel Blockchain-Based Product Ownership Management System (POMS) for Anti-Counterfeits in the Post Supply Chain	93
	When intrusion detection meets blockchain technology: A review	101
	A Blockchain Implementation Prototype for the Electronic Open Source	46
2018	Traceability of Wood along the Whole Supply Chain	46
	Blockchain in Logistics and Supply Chain: A Lean Approach for Designing Real-World Use Cases	41
	Blockchain in Industries: A Survey	94
	Blockchain technology and its relationships to sustainable supply chain management	84
	The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics	74
2019	Data quality challenges for sustainable fashion supply chain operations in emerging markets: Roles of blockchain, government sponsors and environment taxes	70
	A Decision-Making Framework for Blockchain Technology Selection	52
	Blockchain for Supply Chain Traceability: Business Requirements and Critical Success Factors	47
2020	System architecture for blockchain based transparency of supply chain social sustainability	40
2021	Implementation of Hybrid Blockchain in a Pre-Owned Electric Vehicle Supply Chain	71

Source: Own elaboration

On the other hand, Table 3 shows and takes into account papers according to the journal of publication and considers their respective impact factor, known as JCR (Journal Citation Reports). The *IEEE Access* journal was responsible for 20% of the publications here analyzed, followed by *International Journal of Production Research* and *Computers and Industrial Engineering*, with 16% and 12% respectively. In terms of relevance, the best evaluation is from the *IEEE Communications Surveys and Tutorials* with a significant impact factor of 25.249, followed by *Resources Conservation and Recycling* with 10.204.



Table 3

Major journals and number of papers published, organized by impact factor

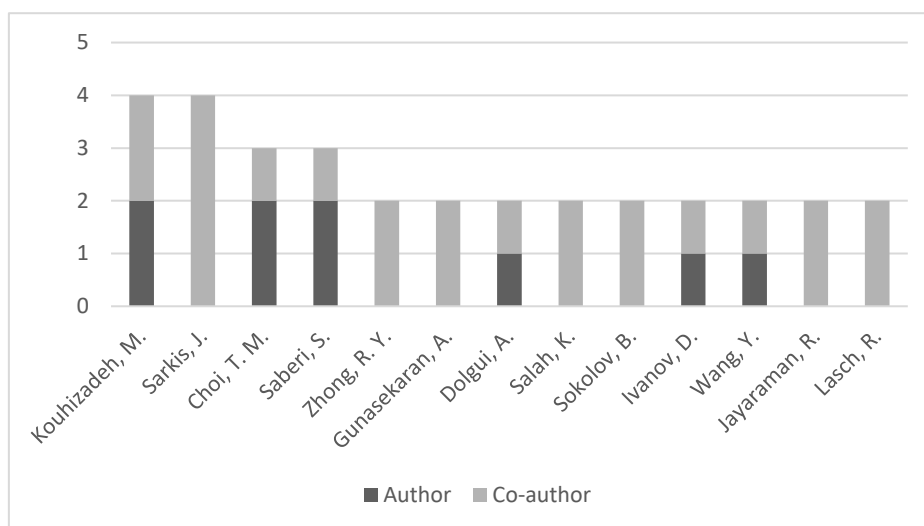
Journal	JCR (2020)	Publications
IEEE Communications Surveys and Tutorials	25.249	1
Resources Conservation and Recycling	10.204	1
IEEE Internet of Things Journal	9.471	1
International Journal of Production Research	8.568	11
International Journal of Production Economics	7.885	4
Automation in Construction	7.700	1
Journal of Manufacturing Technology Management	7.547	1
Journal of Cleaner Production	7.246	1
Production Planning & Control	7.044	2
Expert Systems with Applications	6.954	1
Transportation Research Part E: Logistics and Transportation Review	6.875	4
Computers & Industrial Engineering	5.431	8
Production and Operations Management	4.965	1
Industrial Management & Data Systems	4.224	1
Sensors	3.576	1
IEEE Access	3.367	13
Telecommunications Policy	3.036	1
Processes	2.847	1
IT Professional	2.626	1
Electronics (Switzerland)	2.397	1

Source: Own elaboration based on the Journal Citation Reports - JCR

Figure 5 brings in terms of quantity how the writers are involved in the theme. The direct authorship or co-authorship is considered. There are two people involved in 4 different papers, following of more two involved in other two works. Furthermore, nine authors are involved in at least two documents, while the remaining authors, 210 in total, contributed only with one publication.

Figure 5

Main authors and co-authors who contribute to the theme by number of articles



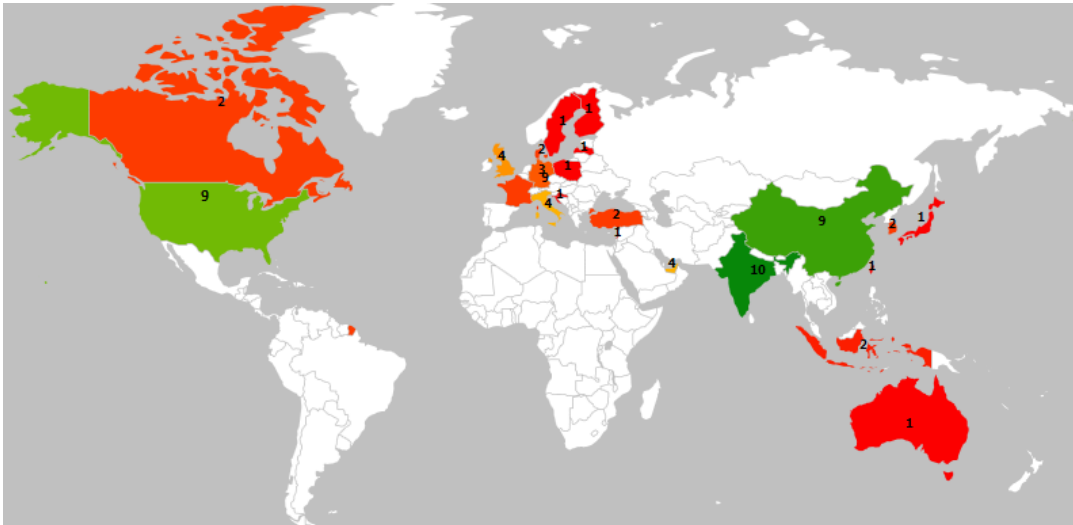
Source: Own elaboration

Regarding to academic institutes, most of them are associated with only one paper on the topic. However, emphasis on the university of Hong Kong Polytechnic University, which presented four papers, followed by Worcester Polytechnic Institute in United States with 3 publications. Other three institutions, Technical University of Dresden, the School of Information Systems at BINUS University and Cardiff University, which are respectively in Germany, Indonesia and United Kingdom, have three publication each. All others have a single publication each. This data endorses how the topic is recent with many publications spread across many institutes. Figure 6 illustrates the number of universities around the world by country.



Figure 6

Universities by publications around the world



Source: Own elaboration

5 Discussion of Results

Based on the data from the previous section, it is possible to raise some indicators on the dynamics and evolution of scientific and technological information.

The blockchain theme associated with supply chain implementation is very current as most of the research only started in 2017 reaching a peak in 2019. Even though it was found that the vast majority of authors still have only one article published. Very few authors have published more than one even so the relevance of the topic is significant considering that about 50% of the works on the topic of this research were published in journals with a high impact factor (JCR between 10,204 and 25,249).

The institutions that published the most are found in China, which leads in number of publications, followed by United States, Germany, Indonesia, and United Kingdom, that is, the ones that always publish more on other topics as well.

In most works, the main topic addressed is related to the issue “security”. This makes sense since it is the core motivation of blockchain applications in the supply chain. Other frequently cited articles consider traceability, sustainability and transparency, topics that are very relevant lately.

Through an analysis of the documents extracted from journals or conference proceedings, it is possible to verify that the theme has been gaining more and more attention, with an increase in the number of publications in recent years. The most important researches are distributed among several universities around the world, showing how the topic has been gaining relevance and the interest of researchers.

The supply chain has been consolidated as an area of significant importance in relation to the coordination and integration of activities between the company, customers, and suppliers. This integration is supported by an intense flow of information and depends on its sharing, reliability, and traceability in a secure way, allowing it to be possible to verify its authenticity and integrity at any time. These demands can be met using blockchain technology that presents promising potential to transform the supply chain with irrefutable benefits.

However, there is a lack of references in the literature, and a lack of practical applications of the blockchain technology in supply chains. There are still few studies published in journals with a high impact factor and that they are still little cited. The most cited articles that address blockchain and supply chain mainly deal with the issue of security, an intrinsic characteristic of blockchain technology. On the other hand, works published in journals with a higher impact factor approach the topic in the context of sustainability and transparency. The growing number of publications in several countries raises the alert for the topic.

In general, it is observed that, despite the advantages and potentialities of blockchain technology for the supply chain, there is still a lack of empirical studies, characterizing an important gap to be filled by future research.

6 Conclusions

Taking into account the last decade, the intention of this paper is to clarify what the academic community is publishing regarding the implementation of blockchain technology in the supply chain. To this end, information related researches, universities, authors, countries and trends are highlighted, bringing relevant data to the theme. Blockchain technology can be applied in many



areas, including the supply chain. Many benefits can be generated when this integration is achieved and the implementation is completed. This research brings up studies that enhance this trend and offers valuable insights for those who wish to advance and go deeper into the topic.

Other interesting evidence is how researches are dispersed in several universities around the world, exposing how this topic is proving to be of interest to many universities it was also possible to identify that there are few influential studies, in other words, few papers with a high impact factor or that are cited many times. In general, the most cited articles deal with the topic regarding security, feature that is brought by blockchain technology when implemented in the supply chain. On the other hand, papers with the greatest impact factor address the issue in the context of sustainability and transparency.

A relevant point is that the topic has been gaining attention in the academy, mainly for its promising potential to transform the supply chain. The growing number of publications in several countries lights up the alert for the theme. As presented in this study, when implemented the blockchain technology there is an irrefutable potential for the chain. Despite the advantages and potential, there is still a lack of empirical studies, characterizing a good gap for potential future research.

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