Blockchain technologies for sustainability in the agrifood sector: A literature review of academic research and business perspectives

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Technological Forecasting and Social Change

Abstract

In the realm of digital transformation, blockchain technologies are considered predominant for managing agrifood supply chains due to their contribution to traceability, safety, quality, transparency and scalability. Both academia and businesses are paying increased attention to the application of blockchain technologies in the agrifood sector, highlighting their potential to address sustainability issues. This paper aims to deepen the understanding of how blockchain technology is applied in the agrifood sector for sustainable supply chain management by investigating the link between blockchain, agrifood and sustainability, focussing on both professional and scientific sources. The article employs a content-based analysis methodology of both academic literature and professional documents like patents and business cases to delineate an up-to-date picture of the current scenario as well as to provide integrated insights regarding the opportunities and potentialities of blockchain technologies for agrifood sustainability. Our findings show that blockchain technologies play a crucial role in speeding up the digital transformation process of the agrifood supply chains and are considered essential for fostering the development of new sustainable business models. New research avenues and practical implications for businesses and policymakers are also presented and discussed.

Keywords. Blockchain; sustainability; agrifood sector; literature review; academic research; business insights.

1 Introduction

The exponential growth of advanced technologies has given rise to disruptions in all sectors, business models and management practices (Bagnoli et al., 2018; Bagnoli et al., 2019; Toniolo et al., 2019; Urbinati et al., 2019). The emerging digital transformation phenomenon has affected businesses, organisations and their supply chains (Mariani and Fosso Wamba, 2020). Previous studies have provided extensive pieces of evidence about the disruptive effects that new advanced technologies can trigger at the strategic level (Urbinati et al., 2019) and in business practices, processes, models and values (Appio et al., 2021; Guenzi and Habel, 2020; Klein et al., 2020; Ruzza et al., 2020; Secinaro et al., 2022a) as well as at a business performance level (Millán et al., 2021).

Due to these effects and with an aim to thrive in the new competitive scenario (Mariani and Fosso Wamba, 2020; Sjödin et al., 2020), businesses have been struggling to reconfigure and integrate cutting-edge technologies to create value, build trust and transparency and improve operations (Chirumalla, 2021; Mariani and Fosso Wamba, 2020; Sjödin et al., 2020; Tian et al., 2021).

One of the most cutting-edge technologies is represented by blockchain, which is reshaping the supply chain models, the relationships among different stakeholders and the consumption behaviour of society (Quieros and Wamba, 2019). While this technology is broadly applied in many contexts, such as manufacturing, finance, healthcare, real estate, art and culture, it is also considered a promising technology in the agrifood sector because of its potential to empower food traceability, safety and security, engender consumer trust, transparency and accountability, provide fraud prevention (Feng et al., 2020; Secinaro et al., 2022b; Calandra et al., 2022) and leverage the digitalisation process of the supply chain.

Some recent studies have focussed on an analysis of the opportunities and challenges provided by blockchain technologies (Dal Mas et al., 2020a; Massaro et al., 2020; Patelli and Mandrioli, 2020; Rana et al., 2021; Wamba-Taguimdje et al., 2020). It has been argued that blockchain as a cutting-edge technology finds relevant applications in tracing products along all supply chains (from 'farm to fork' Zhao et al., 2019), improving the managerial and decision-making process due to the availability of product information and handling data in a secure and trustworthy way (Kshetri, 2018). Most importantly, blockchain has proved to be a robust technology able to assure food traceability and reliability to authenticate food quality and sustainability (Biswas et al., 2017). This is highly relevant since sustainability and corporate social responsibility stand today as key topics (Gatto, 2020) in the agrifood business. Sustainable production and consumption in the agrifood sector appear as relevant issues for the future of the industry (Corsini et al., 2019; Long et al., 2016; Mangla et al., 2018).

Research (Rana et al., 2021) has argued that blockchain technology substantially contributes to the sustainability of agrifood. However, the adoption, exploration and exploitation of this new emerging technology is a challenging and complex process as it entails massive organisational changes and is accompanied by many challenges related to privacy, scalability and high costs (Rana et al., 2021) as well as the need to develop new skills and capabilities (Fosso Wamba et al., 2020; Smith and Beretta, 2021).

Even though blockchain technologies look disruptive in the current scenario, the empirical pieces of evidence in the agrifood sector are fragmented (Oguntegbe et al., 2022) and are mainly based on qualitative research papers and case studies focussed on single countries (Queiroz and Fosso Wamba, 2019), thereby limiting the generalisability of findings (Kraus et al., 2019). There is also a lack of research that highlights how businesses are applying and getting the full benefits of this cutting-edge technology by innovating and implementing it with patents.

This paper answers the call of the special issue in 'Technologies and digital transformation for sustainability in agribusiness' and brings together the academic debate along with the business perspective by analysing how blockchain technologies are being deliberated by academics and how they are being implemented in patented inventions. More precisely, this paper aims to investigate the link between blockchain, agrifood and sustainability by focussing on both professional and scientific sources. The study aims to lead to a joint academic–practitioner review by considering both academic literature (gathered from the Scopus database) and data from professional documents based especially on patents as well as business cases, newspaper articles, press releases and specialised blogs. Such a new perspective narrows the gap between professional and academic views (Massaro et al., 2021; Secinaro et al., 2022b).

The study employs a content-based analysis (Krippendorff, 2013). This methodology is particularly relevant for analysing both patents and papers/publications. When applied to the assessment of patents, it enables us to better understand the technology, its development and its future pathways. When applied to papers and publications, it allows the generation of new knowledge, participation in critical reflections, detection of future research directions and detailing of further and future research questions (Massaro et al., 2016; Massaro, 2021b). Investigating different and alternative data sources derived from publications, patents and press articles allows researchers to grasp more information and compare and elaborate on more relevant research outcomes and implications.

The paper is structured as follows. The next section describes the background of the study by detailing the current state of the art of digital transformation in the agrifood sector, especially in the adoption of blockchain technologies. The research questions of the article are then presented. Section three highlights the methodology used. Section four provides the findings and a detailed discussion of the results obtained. The conclusion section ends the paper.

2 Theoretical background

2.1 Agrifood sector and digital transformation: Challenges and opportunities

Digital transformation consists of the adoption of advanced digital technologies in business processes and operations (Gong and Ribiere, 2021), triggering major disruptions in business models (Bagnoli et al., 2019; Toniolo et al., 2019; Urbinati et al., 2019), value creation (Ferreira et al., 2019; Westerman et al., 2014) and innovation processes for products and services (Smith and Beretta, 2021), organisational forms and practices (Guenzi and Habel, 2020; Klein et al., 2020; Nambisan et al., 2019), entrepreneurial modes (Nambisan et al., 2019) and business performance outcomes (Millán et al., 2021).

Due to its potential, digital transformation can provide many opportunities for the agrifood sector, making this field very interesting for investigation and study in the literature. For example, by applying advanced digital technologies, the agrifood supply chain can benefit from new market opportunities and new operational and business models to manage food products' sustainability, quality, and safety (Klerkx et al., 2019; Scuderi et al., 2020; Trivelli et al., 2019). Different advanced technologies, such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, augmented and virtual reality and intelligent platforms are finding their application in the agrifood sector in the provision of 'digitised' value-added services (Abeyratne and Monfared, 2016; Scuderi et al., 2020). The studies up to the current date offer extensive evidence of the opportunities that digital transformation can bring for agrifood businesses by through its many contributions, such as empowering the sectors' traceability, safety and security, engendering consumer trust, transparency and accountability and providing fraud prevention (Fosso Wamba et al., 2020; Patelli and Mandrioli, 2020; Rana et al., 2021).

In Europe, the European Commission (2017) identified one of its goals as ultimately linking farmers and rural areas to the digital economy to establish a more intelligent, modern and sustainable future for food and agriculture. Despite those goals, more sceptical approaches have emerged. For example, Rijswijk et al. (2021, p. 80) clearly stated: 'Current digital technologies may have several undesirable, unseen and unknown impacts, e.g., emergent effects that only become clear once these technologies are brought into practice'. Similarly, Herrero (2021, p. 51) underlined, 'Stand-alone technical solutions are in many instances unlikely to result in exclusively positive effects, and they are unlikely to be implemented quickly because of push-backs from players wanting to maintain the status quo'. Some of the problems highlighted by those sceptical authors are related to the social dominance (Sidanius et al., 2004) of those technologies, in which a few big companies can own the majority of the farm data (Herrero et al., 2021). Therefore, despite its potentiality, dubious authors highlight the problems connected with the application of digital technologies in the agrifood industry.

2.2 Blockchain technology in the agrifood sector

Among all the digital technologies, blockchain has been recognised as a possible solution to some of the highlighted problems. Blockchain might contribute to solving some of the open issues, such as data ownership, barriers to small farmers and the digital divide (de Bernardi and Azucar, 2020; FAO, 2021), due to its reliance on a decentralised platform that allows direct peer-to-peer transactions (Ruzza et al., 2020), the elimination of intermediaries (Dal Mas et al., 2020a), distributed and immutable data storage (Tapscott and Tapscott, 2016), validation of information and records by cryptography, transparency and the trusted exchange of data (Schmitz and Leoni, 2019; Secinaro et al., 2022a).

Firms that adopt blockchain technologies can grasp their various benefits. For example, blockchain improves transparency towards the final customer and the complexity of supply chain management (Lu et al., 2019), by using smart contracts (Dal Mas et al., 2020a; Kim and Laskowski, 2017; Tian, 2017). In this way, it is possible to track all of the supply chain: the farmer (e.g., farming conditions and invoices), the processing facility (e.g., production data and certificates), the distributor (e.g., estimated delivery time, storage conditions and transactions), the retailer (e.g., expiry date and time spent on the shelf) and the final customer.

Blockchain technologies also allow the reduction of data duplication and transaction costs for data exchange and storage (Andreassen et al., 2018), an increase in information authenticity, speed food recall, improve safety, security and efficiency (Kshetri, 2018), and improve decision-making processes (Feng et al., 2020). In addition, combining blockchain with other advanced technologies, such as the IoT, can further contribute to an increase in the efficiency of supply chain management and an improvement in the traceability system of the sector (Duan et al., 2020).

Another example of blockchain-based application is increased customer awareness of food safety given a series of food risks in the last years, such as the case of mad cow disease (Losasso et al., 2012; Schlenker and Villas-Boas, 2009). The recent COVID-19 pandemic (WHO, 2020) has fostered the growth of online purchases, increasing the need for customers to know details about the product, the traceability systems to track the origin of products from farm to fork and the related and reliable certificates (Feng et al., 2020; Jensen et al., 2019). blockchain-based applications may represent an answer to satisfying such needs as they provide secure, immutable, cryptographic records of data transactions across all stages of supply chains (Duan et al., 2020), thus assuring food product reliability, traceability and safety.

Accordingly, blockchain technology has been implemented to trace various food products, such as wine, milk and coffee as well as plant production (Xu et al., 2020). Several corporations are currently investing in this direction. For example, Nestlé has established a collaboration with OpenSC, an innovative blockchain platform, to enable its consumers to track their food right back to the farm, providing full transparency of the entire supply chain (Nestlè, 2019).

To sum up, several advantages of blockchain arise, including: 1) improvement in transparency and traceability of the supply chain, 2) reduction in data duplication and transaction costs, 3) increased security, 4) raised customer awareness and 5) fraud prevention.

2.3 Blockchain technology and sustainability in the agrifood sector

Blockchain-based applications have also been proved to lead to sustainable business models (Dal Mas et al., 2020b, 2020a; Massaro et al., 2020) as they are able to foster and empower both environmental and social sustainability. At the same time, the agrifood business is requested to align with the increasing demands for corporate social responsibility and sustainability (Agovino et al., 2018; Dias et al., 2019).

The use and implementation of new technologies significantly contribute to the environmental and social sustainability of the agrifood sector. For example, new technological solutions enable the conservation of essential resources, such as water, and promote environmental sustainability (Lima et al., 2021; Perry et al., 2009). Micro-entrepreneurship, particularly among women, individuals working on micro rural farms and other disadvantaged groups, can be boosted by the production of renewable energy and appropriate energy policies (Aldieri et al., 2021; Futemma et al., 2020; Gatto and Drago, 2021; Shkabatur et al., 2021). Innovative Industry 4.0 technologies have also been used to assure food availability and accessibility during emergencies characterised by social isolation and mobility restrictions, such as the COVID-19 pandemic, thereby supporting social sustainability (Cattivelli and Rusciano, 2020; Drago et al., 2021).

Several authors have underlined how blockchain-based applications can contribute to a more sustainable agrifood business. For example, Kamble et al. (2020) stressed how blockchain can bring a paradigm shift in the way transactions are carried out in agribusiness by lowering the excessive number of middlemen, delayed payments and long transaction lead times. The positive impacts and opportunities brought by such technologies should foster policymakers to regulate the system and facilitate its access.

The use of blockchain technology can also help to ensure the long-term viability of environmentally-friendly supply chains. For example, blockchain-empowered systems allow precise tracking of substandard products that can eventually be reworked and recalled with less resource consumption and a reduction in greenhouse gas emissions. Moreover, compared to centralised traditional energy systems, a peer-to-peer network-based Blockchain energy system can limit the need to transmit electricity over long distances, leading to savings and less wasted energy (Saberi et al., 2019). Blockchain-based applications in supply chains can also limit carbon footprint by supporting the reduction of carbon emissions in the journey of products by offering tools to apply low-carbon product design, production and transportation (De Sousa Jabbour et al., 2019).

According to Saberi et al. (2019), a blockchain-based supply chain in agriculture can protect human rights and fair labour standards. For example, a comprehensive record of product history guarantees customers that the goods they are purchasing are sourced and made from ethically-sound sources. Smart contracts may be particularly well-suited to autonomously tracking and controlling long-term agreements and regulatory policies as well as enforcing or governing suitable corrections. As happens in other fields, for example, healthcare and pharma (Dal Mas et al., 2020b, Spanò et al., 2021), blockchain allows detection of unethical suppliers and counterfeit products since all the information can only be inserted and recorded by authorised parties, preventing serious social harm (Saberi et al., 2019). According to Quayson et al. (2021), the use of blockchain technology can also provide small farmers in developing countries with the opportunity to alleviate some of their social concerns, like fraud, exploitation, corruption, deceit, child labour and financial exclusion, which are usually perpetrated by influential actors. The authors underlined the need to conduct rigorous research on vulnerable small business owners' social sustainability implications to provide policymakers with sound recommendations. In all, blockchain-based applications provide a valuable practical response to the request for a more sustainable agrifood sector.

2.4 Developing the research question

Blockchain is still a technology in its infancy, and more research is required to understand its real potential (Neethirajan and Kemp, 2021). While corporations are investing heavily in blockchain technologies and solutions, they are also exercising caution due to a prevalent belief that the benefits may be overblown (Iansiti and Lakhani, 2017). Most of the research conducted is based on case studies, and a broader approach is required. As with any new technology, its value strongly depends on people's beliefs in its development (Borup et al., 2006). Understanding the on-going debate among people from different fields and with various backgrounds (such as academics, practitioners and journalists) could help to evaluate the expectation of the technology's value.

Although blockchain technology originated with a seminal article released by Haber and Stornetta in 1991, it only became commonly known in 2008 with the development of the Bitcoin Whitepaper. However, the practical translation of scientific articles takes time, and an expanding body of literature highlights a research–practice divide that hinders the applicability of academic research due to a communication chasm between the two communities (Makin, 2021; Neal et al., 2015). Concerning blockchain, there is an increasing desire for a more holistic strategy (Tandon et al., 2020) that may be capable of bridging the research–practice divide (Böckel et al., 2021). Assessing results from practitioners, journalistic and research sources may assist research stakeholders in gaining a better understanding of the value of blockchain in the agrifood sector, especially from a perspective that encompasses the need to pursue sustainability goals. Starting from these premises, this study will from this point forward answer the following research question:

RQ: *How is blockchain studied, communicated to a broader audience and applied in patented solutions to develop a more sustainable agrifood industry?*

3 Methodology

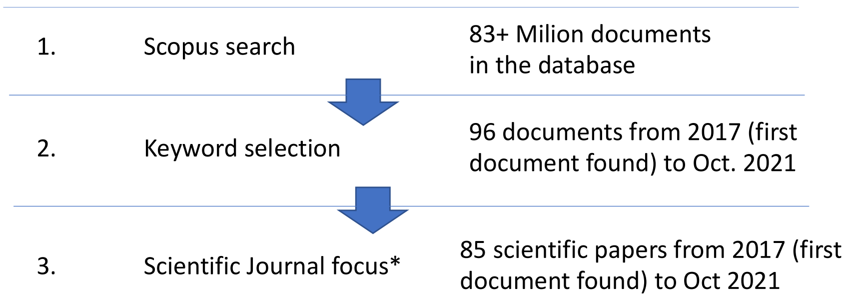
A content analysis methodology is used to address our research question. Content analysis is a broad umbrella word that refers to the systematic examination of the text to extract significant portions of information. Its origins may be traced back to the 17th century (Krippendorff, 2013). In this research, we consider three different sources to map the state-of-the-art of the debate. First, the mapping of the scientific research developed in the field is based on published articles ranked in one of the major scientific databases. Second, patents are utilised to show applied innovation by inventors and firms. While research publications provide valuable insights into scientific breakthroughs, listed patents offer information on technical inventions and technological growth patterns (Kumari et al., 2019, p. 2). Finally, practitioner sources, including the financial press, news headlines and blogs, render an up-to-date state-of-the-art of the most 'trendy' topics in the business scenario, especially when considering niche resources like sector-specific magazines or journals (Dal Mas, 2019; Massaro et al., 2018).

The rapid growth of text sources and the improved power of computers to support human analysis have resulted in the development of many branches and approaches capable of supporting the content extraction of relevant information from vast amounts of data sources. Due to the enormous amount of data that needed to be evaluated to construct the research, multiple methodologies were used, including manual coding and topic modelling, as described in the data analysis subsection.

3.1 Data collection

Data were gathered from three different sources. Regarding academic sources, we decided to investigate the Scopus database, one of the most comprehensive sources for scholarly papers. Following similar studies (Massaro, 2021), we used the keywords 'blockchain' OR 'smart contract' OR 'distributed ledger' AND 'agrifood' OR 'agri-food' OR 'agribusiness' OR 'agri-business' OR 'food' OR 'agriculture' AND 'sustainability' OR 'sustainable' in the title, abstract or keywords. As a qualitative criterion, we opted to limit our research to scientific publications in peer-reviewed journals, eliminating conference proceedings, books and book chapters since articles published in peer-reviewed journals provide greater quality assurance (Massaro et al., 2016). An initial batch of 85 publications was returned from this investigation, labelled under different subject topics. Figure 1 depicts the steps followed, while the footnote reports the exact query string used[i].

Figure 1. Data Collection and Data Analysis for Academic Papers



Source: Authors' elaboration

Patents were chosen using the exact keyword search. As a database source, the European Patent Office (EPO) database was enquired. According to preliminary research, the EPO authority is still evaluating several blockchain applications, which still appear as pending (Massaro, 2021). Therefore, to make the study more comprehensive, all patent applications were included rather than only those that were granted[ii]. The research led to 81 patents.

Finally, we used the Nexis Uni database to collect practitioner documents, which included news stories containing public information on firms (Kim et al., 2015). This specific database has been used in previous studies to access news, business and legal sources (Cook et al., 2018; Massaro et al., 2021). We gathered data using the exact word string as for the Scopus database, merging the concepts of 'blockchain', 'agribusiness' and ‘sustainability’. Unlike academic datasets, Nexis Uni provides neither abstracts nor keywords. As a result of the vast amount of material retrieved, we decided to confine the investigation to the abovementioned terms that were within five words of each other to limit sources with controlled relevance to the study[iii]. Finally, the overall selection was manually checked by first reading the sentences extracted and selected by Nexis Uni, and if some doubts were raised regarding the relevance of the text, reading the overall drafting. No irrelevant articles extracted by the keyword search were found, and all the extracted texts were admitted for further analysis. This method yielded 90 outcomes.

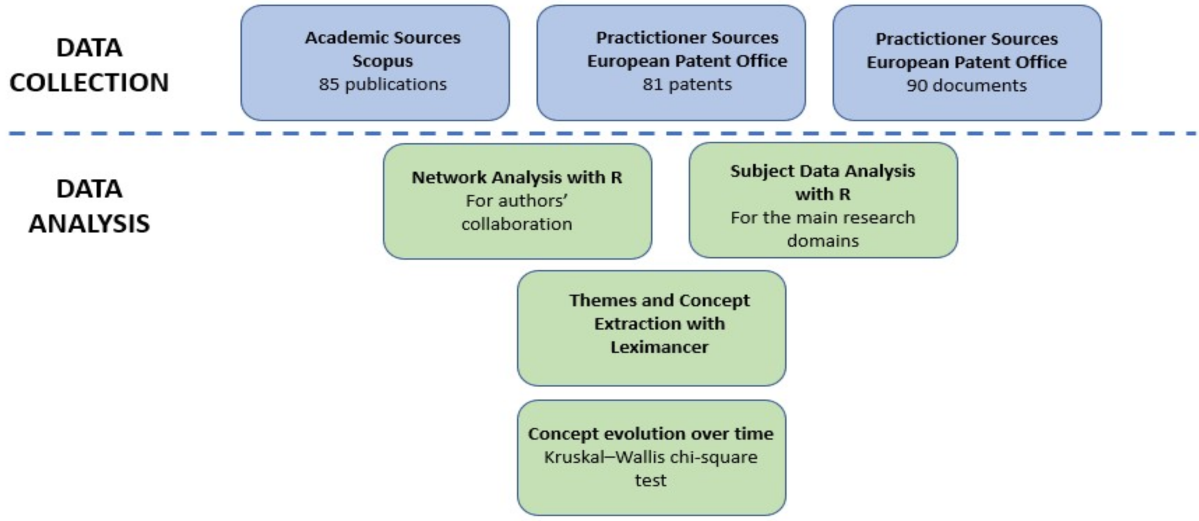
3.2 Data analysis

The first step in the data analysis was a descriptive analysis of scientific papers, patents and professional sources. The data gathered from the various sources was organised and examined in an excel spreadsheet. The goal of this step was to determine the evolution over time of the topic of interest and significant contributors. Using the programme R (version 4.04) and the RStudio IDE, a network analysis was conducted to better understand crucial collaborations among authors (RStudio Team, 2015). Subject area analysis was employed to identify and assess the main research domains within the three sources.

The second step of the analysis focussed on the extraction of topics and themes from the paper and patent abstracts and practitioner sources. The abstract texts construct was adopted (Delgosha et al., 2021) for the finest feasible refining of the most important points included in the various documents. Leximancer was used to automatically classify concepts (Smith and Humphreys, 2006) as it allows the examination of qualitative data, thereby avoiding the subjective and labour-intensive parts of human data coding. Leximancer also offers an automatic text mining approach that determines the concepts contained in the text using internal dictionaries and then delivers a word count for each concept (Massaro et al., 2018). The author analysed the automatic initial concept proposal, and comparable concepts were manually grouped using Leximancer characteristics. Finally, Leximancer used word co-occurrences to arrange concepts into themes (Biroscak et al., 2017). The closeness of two concepts suggests that they are frequently encountered in similar situations. Themes are represented as colourful rings that surround concept clusters provided by Leximancer's conceptual map. The arrows indicate the most likely connection among topics. Additionally, Leximancer can create file tags for specific sources to determine those concepts and theme clusters close to a particular tag on the concept map. Leximancer's overall methodology enables the analyst to determine the global context and deduce the meaning of the topics presented in the text under consideration (Smith and Humphreys, 2006).

The final step of data analysis allows for measuring topic evolution over time as well as significant discrepancies between the three data sources that were used: scientific publications, patents and press articles using word count. The Kruskal–Wallis test was used as a non-parametric test for comparing variations between two or more classes and evaluating categorical variable variances (Tufféry, 2011). The null hypothesis is that there is no significant variation in the number of topics counted between groups. The null hypothesis can be rejected when the p-value of the Kruskal–Wallis chi-square test is less than 0.05, implying that the word count per topic is significantly different among groups. In earlier comparable experiments, a similar approach was devised (Chang et al., 2019; Massaro et al., 2018). Figure 2 reports the data collection and analysis processes.

Figure 2. Data Collection and Data Analysis



Source: Authors' elaboration

4 Findings

4.1 Documents per source and subject area

The documents retrieved from the three data sources reveal that a blockchain-based application in the agrifood sector is a relatively recent topic. Indeed, the first documents appeared in 2012 in the category of patents, while no research papers and newspapers were found up to 2017. We discovered that the topic only started getting traction in 2018 when research papers, patents and newspapers started to flourish and deal with this theme. Research papers published in Scopus were primarily found in recent years (65 articles out of 85 were published in 2020 and 2021). The same trend was seen for patents and newspapers, with almost 50% of them retrieved in 2020 and 2021.

The majority of papers available on the topic come from engineering and environmental sciences (33 and 30, respectively) and the majority of patents from physics (51). Therefore, we can claim that the topic is explored more in the hard sciences. Interestingly, while only a few papers come from business management and accounting (27 in total) and only 13 patents focus on human necessities, the majority of newspapers come from corporate press releases (20 documents). Therefore, while papers and patents are based on technical aspects related to engineering and physical issues, leaving the social and human impact of the technology less investigated, the topic is getting the attention of a bigger audience through newspapers. Table 1 provides detailed information on papers, patent and newspapers by subject.

Table 1. Papers, patents and newspapers by subject

PAPERS	N	PATENTS	N	NEWSPAPERS	N
Engineering	33*	B - Performing Operations; Transporting	3	Newswires & Press Releases	20
Environmental Science	30*	G - Physics	51	Industry Trade Press	19
Business, Management and Accounting	27*	A - Human Necessities	13	Blogs	14
Energy	25*	H - Electricity	13	Newspapers	14
Social Sciences	23*	C - Chemistry; Metallurgy	1	Magazines & Journals	7
Computer Science	17*			Web-based Publications	7
Agricultural and Biological Sciences	15*			Others	9
Others	36*				
TOTAL	**206***	**TOTAL**	**81**	**TOTAL**	**90**

Source: Authors' elaboration.
*Please note that scientific journals hosting the papers ranked in Scopus may be labelled under different subject topics. Therefore, the number of documents seems higher than the actual articles retrieved.

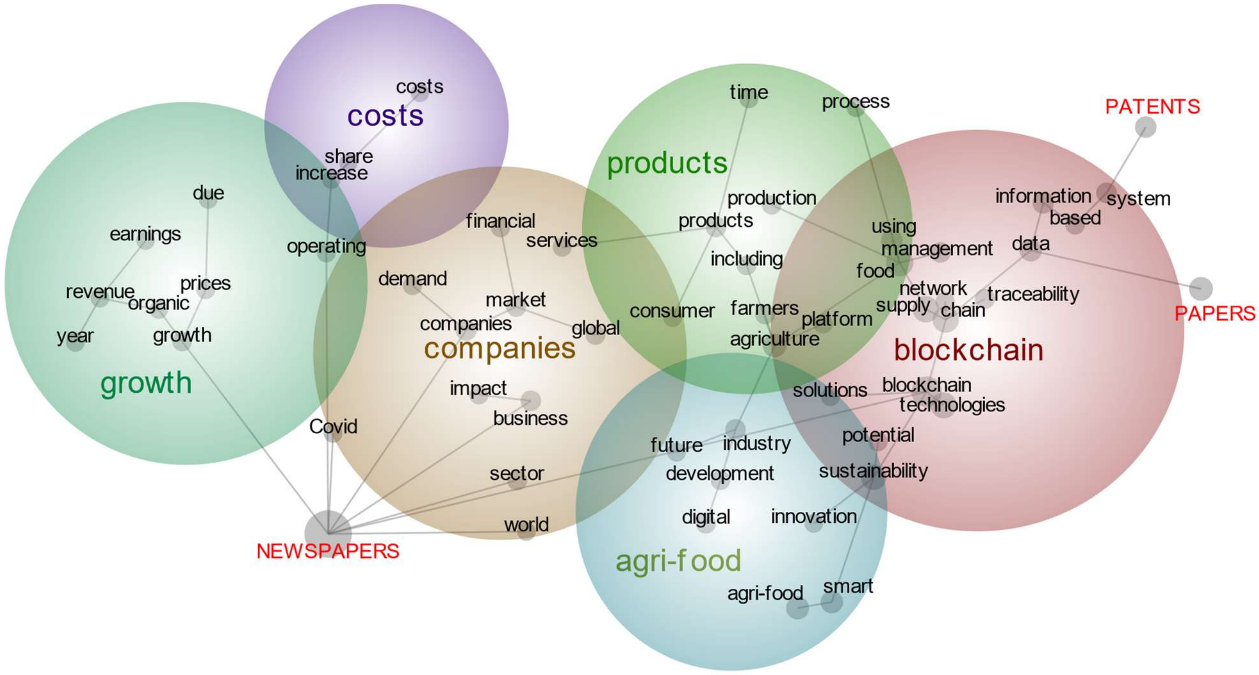
4.2 Topics

The topic analysis revealed the existence of six main themes:

1. The features and impacts of the blockchain system;
2. The features and impacts on the agrifood industry;
3. The impact on products and production processes;
4. Business implications of blockchain;
5. Cost-benefit analysis; and
6. Growth.

Figure 3 depicts the main topics and themes. In the following subsections, each subject is interpreted based on the concept map and a detailed reading of related papers and patents. The picture also depicts the sources and shows whether some topics were discussed more in some sources than in others (e.g., topics discussed more by newspapers than in patents). These findings will be further discussed in the following sub-section.

Figure 3. Topic and thematic analysis



Source: Authors' elaboration.

4.2.1 The features and impacts of the blockchain system

This theme includes all those contributions that specifically focus on the features and impacts of the blockchain system in the agrifood sector. For example, Song et al. (2021) focussed on specific aspects related to the use of blockchain in the supply chain and proposed 'a double-chain structure including the consensus method, the transaction mechanisms, the sustainability assessment method, and the performance optimization strategy' (p. 1429). A similar approach was mentioned by Qian et al. (2020), who discussed the global food trade and proposed a hybrid data storage method combining on-chain and off-chain, with smart contracts used for packaging 'exportation data, exporter inspection data, shipment data, importer inspection data, importation data, and tracing queries' (p. 1). Solutions are then applied to different subsectors in the agrifood field. For example, Griffin et al. (2021) explored the application of blockchain in cotton production and stated: 'Real-world examples of applying distributed ledger technology to current farm data problems in cotton include (1) yield monitor data quality assurance, (2) sustainability metrics and resource tracking of cotton lint quality data from ginner back to subfield locations, and (3) increasing supply chain coordination by providing more information to warehouse managers' (p. 1).

Traceability and sustainability represent key elements that are also discussed in patented solutions. For example, Accenture Global Solutions Ltd (2019, p. 1) patented a 'permission distributed ledger for the promotion of sustainable agriculture'. The topic is less covered by newspapers with but a few exceptions. For example, Gobena (2021) focussed on some drawbacks of blockchain and stated that an 'obstacle is that consensus has to be achieved along the supply chain regarding data points and formats. Importantly, Blockchain will not eliminate the risk of certain types of false statements being entered into the system in the first place' (p. 2).

4.2.2 The features and impacts on the agrifood industry

The second theme focusses on the specific aspect of the agrifood industry and its need for innovation, namely the features and impacts that the blockchain can have on an agrifood business that is also pursuing sustainability goals. For example, Klerkx and Rose (2020) stated that agriculture 4.0 can support vertical farming and food systems, digital agriculture, bioeconomy, circular agriculture and aquaponics but more attention should be paid to fostering sustainable agricultural and, therefore, the concept of responsible innovation. Responsible innovation is a topic that is also covered by the newspapers. For example, Godsil (2021) in a public speech at the 2021 Blockchain Ireland Conference discussed the need to provide gender balance in all the sectors in which this innovation is applied, and agrifood is no exception. Similarly, several patents highlighted the innovation that blockchain can bring and the need to use it more responsibly. For example, the company Data One Technologies developed a patent focussed on the role of innovation in supporting food waste management that connects operators of the value chain from producers to the bin. Blockchain has also been recognised as an important tool in climate action in agriculture, fostering registration of carbon foot emissions, the development of trust among actors that use more sustainable solutions in their work and providing the basis for carbon labelling and certification (FAO, 2021).

4.2.3 The impact on products and production processes

The third theme focusses on the impact of blockchain on agrifood production and products. Several authors have reflected on the possibility of merging blockchain with other agriculture 4.0 technologies to improve animal health and sustainable production. For example, Neethirajan and Kemp (2021, p. 1) stated: 'Sensors enabled blockchain technology affords secure and guaranteed traceability of animal products from farm to table, a key advantage in monitoring disease outbreaks and preventing related economic losses and food-related health pandemics'. Blockchain technology has also been recognised as well received by consumers. In an interview developed by Violino et al. (2019), the authors collected data from a sample of 1,120 interviewees who declared they would be willing to pay an extra 17.8% on product prices for reliable traceability systems. Interestingly, 45% of the preferences were given to 'scratch and win' systems based on a blockchain. Several inventions also considered the impact of blockchain on production and products. For example, a solution developed by the company Ict Korea Inc. (2021) uses blockchain to certify fresh products and create trust between sellers and buyers. Similarly, the Businesswire Network commented on the announcement of BlockApps and the company Bayer 'to track and trace the full lifecycle of agricultural products starting at the seed source' (Finegan, 2020, p. 1). According to the writers, this will allow farmers to access premium services and products due to the system's reliability.

4.2.4 Business implications of blockchain

The fourth topic strongly refers to the business implications of blockchain. This topic was primarily discussed in newspapers. For example, the Newswire Association wrote a comment on blockchain opportunities, stating that 'Blockchain combined with agricultural technologies such as precision farming could help improve productivity significantly, lift millions of smallholder farmers out of poverty and bolster the world's food supply', thus fostering the achievement of social sustainability. The importance of blockchain also led the auditing company KPMG to provide new services based on the blockchain. According to Stefan (2019), 'A Blockchain solution, such as KPMG Origins, could provide a platform which will enable end-users to capture the sustainability credentials of the product directly from the grower to customer' (p. 1). Since the first move by KPMG, several other companies have been developing blockchain-based solutions to reach sustainability goals. Academic sources have focussed on the role of blockchain for specific types of companies, such as start-ups. For example, Spadoni et al. (2019) discussed how blockchain can support new ventures that could develop disruptive business models, access new forms of crowdfunding, create a unique competitive environment based on sustainability principles or employ sustainability elements.

4.2.5 Cost–benefit analysis

The fifth theme discussed refers to the costs–benefits related to the application of blockchain in the agrifood business employing sustainability principles. For example, Spenser (2019) stated: 'The agriculture industry is also using Blockchain to maximize its potential in transport, logistics, and transactional costs. It is achieving this by improving its inventory tracking and shipping processes and reducing associated transaction costs by avoiding the need for third-party involvement from banks' (p. 1). Similarly, Quayson et al. (2021) underlined that 'Blockchain can solve the inefficiencies, complexities, and other social issues of smallholder farmers in the supply chain' (p. 68).

The topic of costs is also considered in papers focussed on defining blockchain architecture for more sustainable agriculture. For example, Song et al. (2021) performed several simulations 'to evaluate the latency, throughput, costs and efficiency of the proposed structure' (p. 1429). Among patents, an invention by the Beijing Technology and Business University (2019), highlighted that 'According to the invention, the problems of serious centralized structure, low data security, the existence of information islands, high tracing cost, low efficiency and the like of the existing tracing system are solved, the data security and reliability of the full supply chain link are ensured, and the tracing information is accurate and credible' (p. 1).

4.2.6 Growth

The sixth theme discussed refers to growth, and it was analysed using different perspectives. First, growth is connected with the increasing demand for dairy products and the need for traceability. According to an article written by RightVision Media (2018) 'Eminent technology companies are striking collaborations with global logistics firms, food producers and retailers to develop effective applications of blockchain in agriculture and food sector to ensure improved data management, reduced transaction costs, augmented logistics, and robust food safety and traceability protocols' (p. 1). The topic of a growing urban population was addressed by Davies and Garret (2018), who stated that blockchain can be used 'for greater transparency, food safety, and identification' (p. 1). Leduc et al. (2021) focussed on the potentiality of blockchain to support the development of a marketplace that could help farmers to increase earnings and support growth, thus fostering the achievement of socially sustainable solutions aimed at the reduction of poverty and the development of entrepreneurial models in the agrifood business.

Table 2 summarises the main findings related to the identified themes and topics, focussing on our three primary research keys (blockchain, sustainability and the agrifood business).

Table 2. Findings

Theme	Main findings related to the research keys
The features and impacts of the blockchain-system	• Blockchain's features in terms of traceability, safety, quality, transparency and scalability have a positive impact on fostering sustainability in the agrifood business. • Blockchain has an impact, especially on supply chains. • Practical applications vary, as described in all the sources (especially papers and patents).
The features and impacts on the agrifood industry	• Blockchain, along with other Industry 4.0 technologies, has an impact on the agrifood business. Such an impact encompasses several aspects of innovation, including responsible innovation in several subfields like food waste, climate action, carbon labelling and certification. • Practical applications vary, as described in all the sources.

The impact on products and production processes	• Blockchain, along with other Industry 4.0 technologies, has an impact on sustainable agrifood products and processes, including animal health and sustainable production. • Customers appreciate the use of blockchain to create and improve sustainable agrifood products and practices. • Practical applications vary, as described in all the sources.
Business implications of blockchain	• Blockchain has an impact on how agrifood companies run their business in a more sustainable way or achieve sustainable aims. • The impacts also involve new services aimed at sustainability promoted by consultancy companies and the creation of start-ups employing new sustainable business models. • Practical applications vary, as described in all the sources (especially newspapers).
Cost–benefit analysis	• The application of blockchain solutions in agrifood has an impact on costs. • Cost reduction can lead to social and environmental benefits for agrifood companies. • Practical applications vary, as described in all the sources.
Growth	• The application of blockchain solutions in agrifood has an impact on growth (in terms of business opportunities) but also stands as a solution to the growth of the population and its need for food. • Blockchain in agrifood can foster the achievement of socially sustainable solutions aimed at the reduction of poverty. • Practical applications vary, as described in all the sources.

Source: Authors' elaboration.

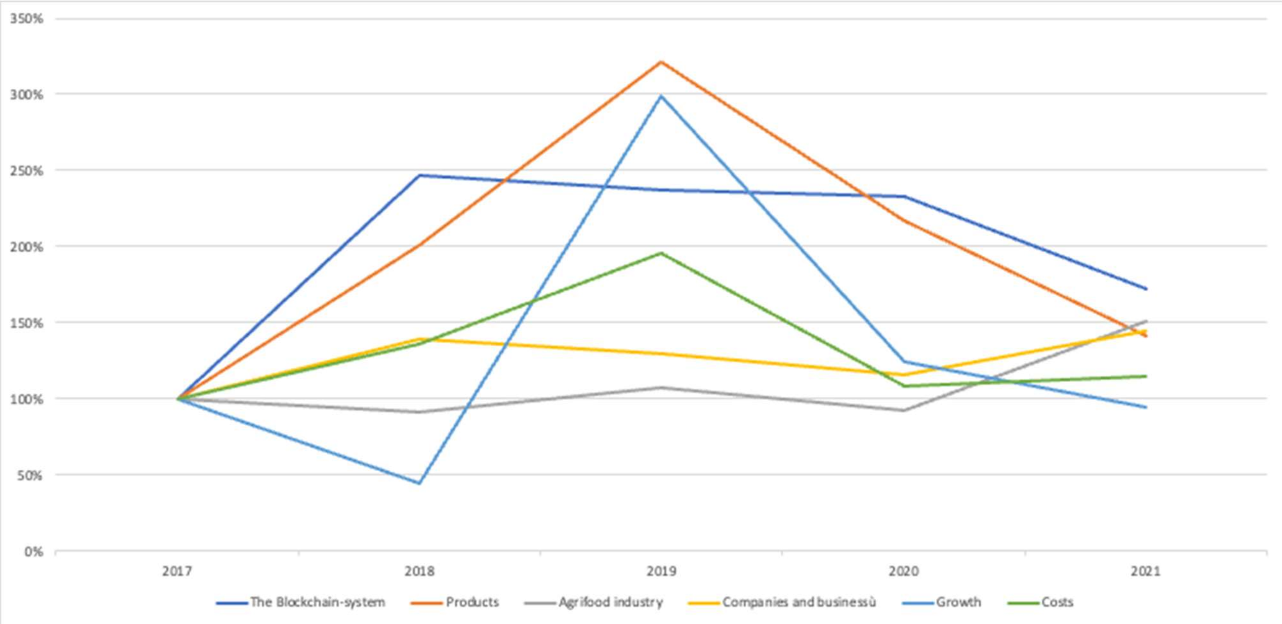
4.3 Theme evolution

Focussing on theme evolution, results show that while some themes are getting attention, others are decreasing in terms of their appearance in the observed sources. For example, the topic of blockchain and its specific characteristics is losing attraction as is its impact on production and products, perhaps due to the maturing research field. Theme evolution must be analysed by considering the evolution of the technology. According to Angelis and Ribeiro da Silva (2019), blockchain is evolving in four main stages. The first two stages were focussed on the development of its characteristics, such as cryptocurrency (Blockchain 1.0) and smart contracts and tokens (Blockchain 2.0). As the technology matures and its features become more well-known, research is moving to better understand its application in different business contexts (Blockchain 3.0), especially when combined with other technologies (Blockchain 4.0).

Results confirm this trend since the topic of the impact of the technology on companies and its effect on the overall industry is gaining traction with an increasing number of documents mentioning it. The issues of cost and growth appear more stable. Indeed, after an initial spike in 2019, they then returned to their original importance as it was in 2017. As discussed by Kerkx and Rose (2020), blockchain will require huge investments to transform the way we produce, distribute and consume food. However, blockchain is a systemic technology, and there is the risk of a social dominance paradox (Massaro, 2021) in which rich countries contribute to the development of the technology that, however, remains limited to only developed countries, thereby increasing the technology divide. As discussed by Kerks and Rose (2020), 'when there is no space for diversity and some systems become dominant and hegemonic, this may generate inequalities and injustices which are non-desirable from a human welfare point of view, an animal ethics viewpoint, or an ecosystem integrity and sustainability standpoint' (p. 3). Therefore, results show that while there is an increasing understanding of the technology, there is also a call for a better understanding of its impacts and side effects.

Figure 4 depicts the main results of the analysis, with 2017 set as the base year with values equal to 100%. Other years are measured compared to 2017. Thus, a number of 150% in 2019 means that the topic appears 50% more compared to 2017.

Figure 4 Themes and their evolution over time



Source: Authors' elaboration.

A word count analysis was used to compare topics coming from different sources (patents, newspapers and papers), and a Kruskal–Wallis analysis and Pairwise Wilcox test were used to investigate differences and compare the three sources. Focussing on the blockchain theme, results show that sustainability is a topic mainly discussed by papers with an average mean rank of 164.73 against an average of 48.875 for patents and 118.296 for newspapers. Regarding the impact of technology on companies, results show that newspapers represent the source that if more focussed on this theme. For example, the global impact of the technology with the three topics of sector, global and impact shows an average mean ranking higher than 140.531. Academics and papers represent the second source that describes the problem with a minimum mean rank for the three topics of 97.158. In contrast, the operating impact of blockchain is well-discussed by newspapers and patents but with less engagement by academics. Finally, considering the overall impact of blockchain on farmers, industry digitalisation is more discussed by newspapers followed by papers.

Results are summarised in Table 3. These findings build on the previous comment on topic trends, showing that there is a call for academics to bring some topics, such as the inclusion–exclusion problem, to a broader audience and embrace more stakeholders in the discussion.

Table 3 Themes and topics. Kruskal–Wallis and Pairwise Wilcox test

Theme	Topic	Kruskal–Wallis test		Mean rank			Pairwise Wilcox test pvalues		
		Chi-squared	PValue	Paper	Patent	Newspaper	Newspaper vs Paper	Newspaper vs Patent	Paper vs Patent
blockchain									
	blockchain	25.339	<0.001	112.243	142.64	88.827	0.023	<0.001	0.003
	technologies	62.042	<0.001	154.539	70.419	109.772	<0.001	<0.001	<0.001
	sustainability	119.131	<0.001	164.73	48.875	118.296	<0.001	<0.001	<0.001
	based	33.925	<0.001	108.368	144.662	90.765	0.066	<0.001	<0.001
	solutions	40.4	<0.001	105.967	89.515	139.315	0.001	<0.001	0.035
companies									
	sector	75.378	<0.001	97.158	82.926	153.111	<0.001	<0.001	0.077
	global	54.6	<0.001	105.697	81.647	146.173	<0.001	<0.001	0.006
	impact	47.583	<0.001	107.368	86.5	140.531	0.001	<0.001	0.002
growth									
	operating	45.81	<0.001	93.5	104.882	138.111	<0.001	<0.001	0.026
industry									
	industry	84.307	<0.001	102.362	73.324	156.29	<0.001	<0.001	<0.001
	digital	37.534	<0.001	110.743	85.257	138.407	0.022	<0.001	0.003
	future	42.416	<0.001	112.592	83.037	138.537	0.052	<0.001	<0.001
products									
	farmers	48.126	<0.001	109.329	83.279	141.395	0.005	<0.001	0.001

Source: Authors' elaboration.
Note: The table shows topics that are statistically significant with an average standard deviation on the mean ranking higher than 25% to focus on topics with higher differences. Themes and topics that are not statistically significant or with a small difference are not reported in the table.

5 Discussion

Our findings allowed us to derive some meaningful implications for practice, research and policies.

Implication #1. Going beyond the hype: A call to investigate technology acceptance to promote blockchain solutions for a more sustainable agrifood sector

Our theme evolution and Kruskal–Wallis and Pairwise Wilcox test analysis revealed that the majority of documents, especially papers and patents, belong to the scientific domains, such as engineering and environmental sciences. Few contributions were provided by the social sciences. Although the identified themes report several practical blockchain applications in the agrifood sector aimed at sustainability goals, the focus on actual managerial implications is still low and mainly comes from newspaper sources. On the other hand, we found that there are extremely few contributions coming from the social sciences that argue that blockchain can be used as a technology to deal with different social issues, inefficiencies and complexities of supply chain actors, such as farmers (Quayson et al., 2021).

Although this aspect may not be well specified, the blockchain applications described in the selected sources require the collaboration of more stakeholders to foster and enjoy the benefit of such a technology in promoting a more sustainable agrifood sector (Duan et al., 2020). Therefore, it seems necessary to create and promote collaborative networks among different actors in food supply chains, starting with farmers, then producers and technology providers, up to customers who seem to appreciate the sustainable benefits brought by the blockchain in this field. However, as argued by Barbosa (2021, p. 8), 'social components such as trust in and satisfaction with agrifood supply chain partners are necessary' for establishing efficient and performant collaborative networks.

Therefore, a deep understanding of the issues related to technology acceptance and perceptiveness by society and the different players in food supply chains emerges as relevant research areas for future research. According to the 'diffusion of innovation theory' (Roger, 1983, p. 5), the acceptance and adoption of technological innovation by organisations and society depends on the 'process by which an innovation is communicated through certain channels over time among the members of a social system', as well as how different actors evaluate the perceived benefits (Lin, 2014) and perceived usefulness (Davis, 1989) of a specific technology. Thus, the level and extent of social interrelations, social communication channels and approaches, and the level of empathy with innovative technology can meaningfully influence attitudes towards adoption.

Therefore, a call emerges for scholars to investigate the issues related to technology acceptance. Such a topic, derived from our analysis, is essential for understanding the technology's level of adoption, comprehending problems related to it and defining new approaches for increasing the acceptance and adoption rate at different tiers of agrifood supply chains. The understanding of fundamental variables related to perceived benefits (Lin, 2014), perceived usefulness (Davis, 1989), the level of trust (Kshetri, 2018), transparency (Kim and Laskowski, 2017) and confidence in the transactions (Lu et al., 2019) among different actors in supply chains are yet open research areas to address concerning blockchain adoption in agrifood to pursue sustainable benefits. More research is needed to empirically understand the role and implications of blockchain technologies to solve different social and environmental issues and to assess the contribution to the United Nation's Sustainable Development Goals (SDGs).

Implication #2. Measuring blockchain value creation and appropriation for a more sustainable agrifood sector

The data analysed demonstrates that research and business debate does not focus very much on an understanding of the business implications and the impact of blockchain technologies on sustainable business models in the agrifood sector. The dialogue is mainly concentrated on underlining the benefits and advantages of technology, while the transformative consequences are yet unexplored, even if some experiences are reported (like the new consulting services provided by consultancy firms to agrifood businesses open to the adoption of new technological solutions).

In addition, the different opportunities and benefits that food supply chain actors could grasp with the use of blockchain technologies are mainly found in newspaper sources, and few contributions are provided by academics. Although the literature on blockchain has evidenced its impact and threats to traditional business models (Dal Mas et al., 2020) as well as the impact this technology may have on value propositions (Morkunas et al., 2019), few papers have focussed on how firms could create and acquire value from it in a broader ecosystem approach.

Academic sources discuss the opportunities of blockchain technology to create sustainable business models in the agrifood sector (Tiscini et al., 2020) and the role of blockchain technologies in supporting the development of disruptive business models by new and innovative start-ups that pay attention to sustainability issues (Spadoni, 2019). However, a comprehensive examination of how and in what ways different supply chain actors are appropriating value from the application of blockchain technology is still lacking. Therefore, there is a need for further research that focusses on understanding and identifying the value creation and appropriation process for different players in the agrifood supply chain. Empirical research is also necessary to determine the type of value that blockchain technology can create (social, financial, sustainable; Moore, 2000) and who is gathering this value, with an eye open to sustainability concerns and the adoption of SDGs.

Implication #3. Sustainability is an academic topic that requires more technical solutions to employ blockchain in the agrifood business

Sustainability represents a key topic in the agrifood business. Even though sustainable production and consumption in this sector are even more relevant for the future of the industry (Long et al., 2016; Mangla et al., 2018), digital transformation in such a field is still in its infancy, and it is related to a complex process. The introduction of new digital solutions means considerable organisational changes, the adoption and consequent usage of digital technologies with the right resources and capabilities in the management of such technologies, and the need to foster the creation of networks, especially among smaller farmers and agricultural firms. Even though technical solutions are important to support the agrifood sector, sustainability is a topic primarily discussed by papers rather than in patents. The patent development that goes in this direction seems too limited in terms of research and inventions, especially in blockchain-based applications that provide a valuable practical response to the request for a more sustainable agrifood sector. In contrast, academic works have already widely investigated how blockchain has proved to be able to foster the development of new sustainable business models (Dal Mas et al., 2020a, 2020b; Massaro et al., 2020).

Based on a scant patent development in support of sustainable food systems and adequate technical solutions, and given that the new technologies have the potential to maximise an efficient usage of resources for achieving sustainability goals in agrifood (Benyam et al., 2021), innovations and patents are needed to support all the stakeholders in the agrifood sector that could use sustainable solutions. For example, there is a need to create digital platforms for connecting farmers, suppliers and buyers. In this way, customers can push sustainable practices by leveraging blockchain, which has been recognised as a valuable tool in agriculture for fostering registration of carbon footprint emissions and developing trust among actors whose work is based on sustainable solutions. Accordingly, future patents should focus on providing technological solutions based on consumer and firm needs that go in the direction of promoting environmental sustainability in the agrifood sector. If we look at the existing patents, some of them already go in this direction. For example, the one named 'Distributed ledger-based identity and origins of supply chain application enabling financial inclusion and sustainability' is based on methods, systems and apparatus, including computer programmes encoded on a computer storage medium, employing a permissioned distributed ledger for the promotion of sustainable agriculture. However, they are scant, and further development is needed.

6 Conclusions

In concluding this article, it is essential to recall the initial premises of this study that were based on the argument that digital transformation could provide relevant opportunities to agrifood supply chain actors and could help unravel different challenges. Blockchain technologies are playing a crucial role in speeding up the digital transformation process of the agrifood supply chains given their traceability, safety, quality and transparency scalability (Patelli and Mandrioli, 2020) and are also fostering the development of new sustainable business models (Dal Mas et al., 2020a, 2020b; Massaro et al., 2020). Yet to better understand the usefulness and applicability of blockchain technology, it is necessary to know how and where businesses are using it, how they are grasping the benefits coming from it, the main barriers related to the level of applicability and the theoretical benefits and empirical evidence. Our analysis of both academic literature and data from professional documents based especially on patents as well as business cases, newspaper articles, press releases and specialised blogs provides relevant pieces of evidence related to expectations, the gap between research and practice, open research areas, problems and challenges. The following subsections highlight the research contribution, future research opportunities, practical implications and limitations.

6.1 Research contribution and future research avenues

Recent literature has focussed on underlining the relevance of blockchain technologies (Fosso Wamba et al., 2020). However, up to now, there have been no contributions that consider the joint perspectives of researchers along with business reports and patent inventions to understand companies and investors and academic perspectives. Starting from this premise, this study analysed a joint academic–practitioners review by investigating the link between blockchain, agrifood and sustainability, focussing on both professional and scientific sources. This integrated approach is relevant for closing the research–practice gap by highlighting how both perspectives are evolving.

The paper provides several novel contributions. To the best of our knowledge, there is no previous research that has analysed in an integrated way scientific papers along with business reports, practical cases and patent inventions in the field of blockchain in the agrifood sector. Therefore, our contribution enriches previous studies (Fosso Wamba et al., 2020; Queiroz et al., 2021), offering an up-to-date picture of the current scenario. The joint academic–practitioners analysis enhances the previous literature by providing insights on a broader perspective regarding the opportunities and potentialities of blockchain technologies for digital transformation and sustainability of the agrifood sector.

Research findings also show that despite opportunities, there are many challenges that firms face in their journey towards the adoption of advanced technologies, such as blockchain. These challenges concern the needed competencies, technical skills, financial means, functional and operational complexities, resistance to adoption and lack of strategy alignment.

Therefore, new research avenues can be delineated. First, there is an open call for future research studies that apply the technology acceptance model (TAM; Davis, 1989), institutional theory (Meyer and Rowan, 1977; Meyer and Scott, 1983) and innovation diffusion theory (Rogers, 2003) to investigate the issues related to technology acceptance, such as the perceived usefulness and ease of use and the required digital capabilities. In addition, it is essential to define new approaches to increase the acceptance and adoption rate at different tiers of agrifood supply chains.

We also highlighted that there is a need for further research that focusses on understanding and identifying the value creation and appropriation process for different players in the agrifood supply chain. We found that future patents should focus on providing technological solutions based on consumer and firm needs that go in the direction of promoting environmental sustainability since such patents look now to be very scant.

Finally, we observed that academics should focus on providing sound research based on known theories and rigorous methodologies to support decision makers in promoting policies under a sustainability lens.

6.2 Practice and policy implications

Our research has practical relevance for agricultural businesses and managers. First, our investigation underlined how blockchain technology could support the agrifood sector as well as the benefits that stakeholders may reap from a sustainability perspective. We also highlighted the role of the needed collaboration between research and development and technology providers in boosting innovation while also enhancing sustainability within the agrifood business. The current debate calls for increased practical collaboration among academics, technology providers and practitioners in the field in sharing practical experiences and case studies. Knowledge sharing appears relevant for bridging the gap and facilitating the dialogue among various parties and stakeholders to encourage more collaborative methods that result in more profitable and sustainable farming practices, thus taking advantage of the multiple benefits that blockchain-based solutions may bring. Dedicated tools and facilitators should be used in this context, and policymakers should support such a dialogue given its potential impact on environmental as well as social sustainability. From such a perspective, strategies for policymakers to foster and support blockchain investments may be represented by dedicated funding opportunities or subsidised contribution calls for projects, along with the creation of networks among smaller farmers and agricultural firms. Such projects and networks may support the various actors in understanding the potential of blockchain technologies for the agrifood business itself and as a catalyst to promote innovation.

6.3 Limitations

Like all research, our study has some limitations that could lead to future research opportunities in addition to the ones identified in the discussion section. The first constraint is related to the keywords chosen and the topic at hand. Even though we looked at prior research and the areas receiving the most attention from the scientific community today, the number of documents is rising fast. As a result of the rapid development and practical implementation, our actual results may be skewed. Nonetheless, this will open the door to new exploratory study excursions to better understand how blockchain can shape the future, leading to a more sustainable agrifood sector.

One more limitation arises from the number of patent solutions identified to date, as well as the time required to file fresh discoveries and applications. Again, we should not rule out the possibility that pioneering entrepreneurs would explore innovative solutions for future sustainable agriculture. While patents represent a primary source for practitioners, newspapers articles, reports from entrepreneurial associations, press releases from companies, blogs, public speeches and whitepapers are quicker in reporting, sharing and debating new ideas and new practical technology applications and their outcomes, as they do not go through a peer-review procedure like academic papers and patents. Still, the breaking news concerning innovative applications, famous cases and the public engagement of multinational companies may quickly change the scenario and divert interests in different directions.

Finally, even though we employed a rigorous research protocol, the objectivity of the analysis may be biased. Our investigation may have led us to overlook significant scientific contributions to the debate. Different search keys may lead to new fascinating research avenues.

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[i] Scopus query string: (TITLE-ABS-KEY (blockchain OR "smart contract" OR "distributed ledger") AND TITLE-ABS-KEY (agrifood OR agri-food OR agribusiness OR agri-business OR food OR agriculture) AND TITLE-ABS-KEY (sustainability OR sustainable)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017))

[ii] Statpat query string: SELECT a.appln_id, a.ipr_type, a.nb_applicants, a.nb_inventors, a.nb_citing_docdb_fam, a.earliest_publn_year, a.granted, tlt.appln_title_lg, tlt.appln_title, abst.appln_abstract
FROM tls201_appln AS a LEFT JOIN tls202_appln_title AS tlt LEFT JOIN tls203_appln_abstr AS abst WHERE a.appln_filing_year between 2000 and 2020 -- filtra nel periodo 2000-2020 AND ((CONTAINS (abst.appln_abstract, 'blockchain') OR CONTAINS(abst.appln_abstract, 'smart AND contract') OR CONTAINS(abst.appln_abstract, 'distributed AND ledger')) AND (CONTAINS (abst.appln_abstract, 'agriculture') OR CONTAINS (abst.appln_abstract, 'agribusiness') OR CONTAINS (abst.appln_abstract, 'food'))) ORDER BY a.appln_i

[iii] Nexis uni query string: (blockchain OR 'smart contracts' OR 'distributed ledger') near/20 (agribusiness or agrifood or agri-business or agri-food) AND sustainability