



Drivers, barriers and supply chain variables influencing the adoption of the blockchain to support traceability along fashion supply chains

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Abstract

The critical role of blockchain technology in ensuring a proper level of traceability and visibility along supply chains is increasingly being explored in the literature. This critical examination must focus on the factors that either encourage or hinder (i.e. the drivers or barriers) the implementation of this technology in extended supply chains. On the assumption that the blockchain will need to be adopted at the supply chain level, the enabling factors and the contingent variables of different supply chains must be identified and analysed. The appropriate identification of supply chain partners is becoming a critical factor of success since the globalization of supply chains makes their management and control increasingly difficult. This is particularly true of the fashion industry. Five blockchain providers and seven focal companies working in the fashion industry were interviewed to compare their different viewpoints on this topic. The results highlight which drivers, barriers, and supply chain variables impact the implementation of the blockchain and specific research propositions are formulated.

Keywords Traceability · Blockchain · Fashion

1 Introduction

Supply chains today are incredibly complex, comprising multi-echelon and geographically dispersed companies. Globalization, different international regulations, and varied cultural and human behaviors worldwide are all challenges to managing companies through their supply chains. These evolutionary phenomena have made it arduous to acquire relevant and trustworthy information within supply chains and have dramatically increased the potential for inefficient transactions, fraud, pilferage, or simply a deterioration in supply chain performance (Hastig and Sodhi 2020).

The urgent need for traceability of both product and process in supply chains has been documented in several industries, including the agri-food sector (Sun and Wang 2019; Yadav et al. 2020; Mukherjee et al. 2021), pharmaceutical

and medical products (Chen et al. 2019) and luxury products (Choi 2019). The lack of transparency and visibility in all processes of the supply chain prevents customers from verifying the origin of the raw materials and the processes that the product underwent before reaching the store shelves, with a high risk of fraud and counterfeiting of products. The costs involved in verifying supply chains' intermediaries, in assessing their reliability and transparency in the production processes further complicates managing traceability in supply chains (Ahluwalia et al. 2020; Choi 2020). Strategic and competitive reputational issues arise from these risks and the lack of supply chain transparency.

In response to these concerns, the technological advancements of the digital era are providing companies with many opportunities that can be exploited in the supply chain (Xiong et al. 2021). The term digital supply chain refers to data exchanges occurring between actors involved in a supply chain and also to how the supply chain process may be managed through a wide variety of innovative technologies (Büyüközkan and Göçer 2018) such as the Internet of Things (IoT), Big Data Analytics, cloud computing and the blockchain itself. Blockchain technology is particularly relevant (Casey and Wong 2017; Tapscott and Tapscott 2017; Samson 2020) in overcoming the difficulties mentioned above due to its centralized database in which all the information of

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the supply chain partners is recorded immutably. The literature on the use of blockchain technology in supply chains is quite recent (e.g. Chang et al. 2019) but has experienced significant growth in recent years thanks to the evidence that emerged on the potential of this technology applied to supply chains of different sectors such as food supply chains (Katsikouli et al. 2021; Bechtsis et al. 2021; Sharma et al. 2021; Mukherjee et al. 2021), humanitarian supply chains (Baharmand et al. 2021) or pharmaceutical chains (Hosseini Bamakan et al. 2021; Hastig and Sodhi 2020). Existing papers are focusing on illustrating the potential value of the blockchain and its interoperability with existing technology, such as IoT, and in particular, for the fashion industry, this technology has enormous potential in improving the information flows of supply chains (Agrawal et al. 2021; Wang et al. 2020; Bullón Pérez et al. 2020; Agrawal et al. 2021; Choi and Luo 2019). The fashion industry is characterized by a multitude of international suppliers collaborating in the creation of collections, and nowadays the development of complete traceability is certainly a relevant issue for all companies in the sector. The blockchain is characterized by the possibility of ensuring traceable information and represents a technology that in the future will be massively used by fashion companies, even if currently there are few cases of application of this technology in the fashion industry (Ahmed and MacCarthy 2021). The fashion sector, however, still presents little empirical evidence as many companies are still studying and evaluating blockchain technology and have not yet moved on to the next phase of implementing the technology. Further studies on the adoption of blockchain technology in the fashion industry are encouraged to evaluate the factors that may contribute to (or hinder) the implementation of the blockchain system in extended fashion supply chains (Caldarelli et al. 2021). At present, there are still few blockchain applications, so any new studies that delve into the feasibility of this tool are very useful in helping to understand the contexts in which the blockchain can achieve positive results for fashion companies and their supply chains (Chang et al. 2019; Queiroz and Wamba 2019).

Bearing in mind these gaps, this paper aims to investigate the adoption of the blockchain to enhance traceability along supply chains. In particular, the drivers and barriers that favor or hinder the introduction of blockchain technology among supply chain actors will be investigated for the fashion industry. The first research question (RQ1) will be: *Why do fashion companies adopt, or not adopt, blockchain technology as a system to improve traceability along supply chains in the fashion industry? What are the drivers and barriers to the implementation of blockchain in fashion supply chains?*

Traceability cannot be implemented at the level of a single node in the supply chain, but it affects entire fashion supply chains (Ahmed and MacCarthy 2021). For this

reason, the implementation of blockchain technology should embrace the perspective of the whole supply chain by further investigating the variables that may enable or influence the adoption of blockchain technology at the supply chain level in the fashion sector. For this reason, the second research question (RQ2) is, therefore: *How do supply chain variables impact the adoption of blockchain technology as a system for improving traceability along fashion supply chains?*

These questions are tackled through the analysis of 12 case studies of the fashion industry, which describe fashion companies that are considering the use of blockchain technology to track their supply chain processes. The sample includes both providers (five) and focal companies (seven) to compare their different viewpoints on the topic.

The paper is organized as follows. Section 2 reviews previous studies focusing on blockchains and the relationship between the blockchain and traceability practices within extended supply chains. Section 3 is dedicated to the research aims, and Sect. 4 presents the methodology. Sections 5 and 6 provide a comprehensive analysis of results, while Sect. 7 highlights the concluding remarks.

2 Literature review

2.1 The revolution of using blockchain technology for supply chains

The blockchain concept was proposed by the developer Satoshi Nakamoto and since 2009, has been fully validated through the bitcoin system implementation (Nakamoto 2008). A blockchain refers to an open, shared, and distributed ledger that enables information disclosure and responsibility attribution and is suitable for dealing with valuable information (Pazaitis et al. 2017).

As stated by Fu et al. (2018), *'The blockchain entries could represent transactions, contracts, assets, identities, or practically anything else that can be digitally expressed using smart devices. New versions of blockchain technology implementation offer support for the implementation of smart contracts encoded in ledger blocks, which implement different business rules that need to be verified and agreed upon by all peer nodes from the network. When a transaction arrives, each node updates its state based on the results obtained after running the smart contract. Such replication process offers a great potential for control decentralization'*.

Based on a structure composed of nodes, blockchain technology can support digital integration in complex supply chains. The blockchain can address the limitations of traditional supply chains thanks to the features (Kouhizadeh et al. 2021) described below.

First, a distributed ledger of transactions is replicated to every node of the blockchain network. As already

mentioned, the distributed ledger is open to all nodes, which may have restrictions depending on their permission level. Transactions create new blocks that are chained to the previous blocks, and everyone who has read permission can verify the validity of the transactions: for instance, a seller can notify a buyer about a transaction, and the existence of this transaction will be verified directly from the ledger. In this way, all the actors in a digital supply chain can be verified (Pazaitis et al. 2017; Raval 2016).

Moreover, the blockchain offers the possibility of developing smart contracts for automating business transactions and document exchanges between parties within the supply chain. Smart contracts can be developed on blockchains and used to automate supply chain transactions at a very detailed level (Savelyev 2017). For instance, smart contracts can enable automated transactions of pre-determined agreements between parties. The blockchain can make the transactions transparent and reliable, thus generating safe financial transactions.

Finally, public-key cryptography is used to encrypt and decrypt a transaction. This feature ensures a high level of security while sustaining the whole architecture within the digital supply chain. As a result, the blockchain can enable the quick, reliable, and efficient execution of transactions and document exchanges securely and at a low cost (Pazaitis et al. 2017).

From the operational point of view, the adoption of a blockchain system can simplify supply chain processes by reducing, for instance, disputes over invoices. The results of an IBM study indicate that, worldwide, invoices for over 100 million dollars are annually subject to dispute (IBM 2019). According to the IBM estimations, the blockchain could avoid this kind of dispute in 90–95% of cases. Purchase orders and purchase agreements, which are formalized among supply chain partners, can be registered in digital formats in a blockchain and made available only to the intended parties through their private keys. This drastically reduces the need for emails or other means of communication. With the blockchain, messages and documents are transferred between supply chain members via blockchain nodes, with confidential data stored and made accessible with a private key. If records are correctly uploaded on a blockchain platform, it becomes a single source of truth, and supply chain partners can access relevant information in real-time.

2.2 Blockchain and supply chain traceability

The identification of all transactions and information exchanged within a supply chain, as well as that of all suppliers collaborating in the chain, is becoming a weapon of success: by giving evidence (and therefore enabling tracing) regarding the origins, supply chains are assuming a key role

for consumers, who are increasingly interested in knowing the details of products purchased (Morkunas et al. 2019). Authors have debated concerning the interoperability of blockchains with IoT devices (such as the RFID), verifying the benefits of an interconnection between blockchains and IoT identification to track products and processes. The first evidence in this sense comes from food supply chains. For example, we cite the collaboration between the multinational Nestlé and Walmart that have implemented successfully the blockchain developed by IBM (Zelbst et al. 2019). More in general in the food sector the blockchain has demonstrated its important role in ensuring product safety traceability (Rogerio and Parry 2020). The logistics sector also experimented the potential of blockchain technology; distribution companies such as Maersk, UPS, and FedEx have indeed successfully implemented this technology (Kshetri 2018). The implementation of blockchain technology has also proved useful in the pharmaceutical sector, in particular for products that require to be stored and distributed at a controlled temperature (Bamakan et al. 2021). Significant results were also achieved in the humanitarian sector, in which blockchain technology was used for enhancing swift trust, collaboration, and resilience within a humanitarian supply chain setting (Dubey et al. 2020; Baharmand et al. 2021).

Real cases of blockchain adoption made it possible to verify and validate the identities of individuals, resources, and products in extended supply chains. Nevertheless, the establishment of traceability for a network is still an open challenge for many companies and sectors due to the difficulty of structuring traceability practices across company boundaries to identify suppliers located internationally (Moretto et al. 2018). In structuring traceability systems, companies must define tools and mechanisms to transmit information, focusing not only on their internal processes but also on complete inter-organizational traceability that can align different supply chain actors and ensure that data is exchanged in a standardized way. In most cases, traceability practices along the supply chain have been supported by tags, labels, barcodes, microchips, or radio-frequency identification (RFID), applied to each product (or to each batch), but nowadays, digital tracking technologies are opening new horizons and new possibilities. Blockchains widely enable the tracking of products and service flow among enterprises thanks to the possibility of the access control and activity logging that occurs in all nodes of the supply chain (Chang et al. 2019). Based on this structure composed of nodes, the blockchain represents a weapon that can protect every company involved from fraud and misleading information. Each partner in a supply chain, and every action it performs, are identified and tracked since the blockchain's architecture ensures the truthfulness of the data stored in it. Not only that, but the blockchain also allows consumers to be protected

from commercial fraud by allowing quick identification of original pieces and thus fighting the so-called grey market (i.e. the parallel sales market outside the official circuits of the brand). In this way, the blockchain avoids, or at least reduces, the phenomenon of counterfeits by allowing consumers to verify information (Kshetri 2018).

Blockchain technology also allows strengthening communication actions and the advertising campaigns of companies that aim to tell the consumer the story of their products. The blockchain makes it possible to check the history of the product along the entire supply chain and its use is strongly supported by the greater consumer demand for tracked products. According to a recent PricewaterhouseCoopers (PwC) report (2019), customers are willing to pay 5 to 10% more than the list price to buy traced products.

However, although many contributions detail the potential of the blockchain to support traceability systems in some specific contexts (specifically in the food, pharmaceutical, humanitarian, and logistics sectors), empirical evidence in the fashion industry is still fragmentary. Many fashion companies are currently verifying the benefits of this technology for their business and they have not yet moved on to the next operational phase which involves the real implementation of the blockchain technology (Caldarelli et al. 2021). What emerges from the literature review is the potential of this technology in various sectors, and, in the face of the positive results, the fashion industry is working to understand the advantages and limitations of the specific fashion business (Ahmed and MacCarthy 2021). The first results from the evaluation of blockchain technology in the context of fashion help to underline how this technology can lead to better control of the fashion supply chains, characterized by high levels of internationalization of production and distribution (Agrawal et al. 2021; Ahmed and MacCarthy 2021; Bullón Pérez et al. 2020). The studies identify how the blockchain theme for the fashion sector is closely linked to the goal of improving traceability in all the procurement, production, and distribution of fashion products. The goal of improving traceability in the fashion supply chains is of primary importance for companies in this sector, not only to know the movements of physical products, the real-time stocks in points of sale and distribution warehouses, the progress of the subcontractors' activities but also to verify the sustainability of the entire supply chain, composed of many actors that, with different roles and tasks, cooperate in the creation of collections (Choi and Luo 2019; Wang et al. 2020).

The fashion context has yet to be guided towards identifying the benefits and difficulties related to the use of blockchain technology in the fashion sector. Further evidence in the fashion industry is encouraged to analyze the factors that favor (or hinder) the implementation of blockchain technology in extended and complex fashion supply chains (Caldarelli et al. 2021).

3 Research aims

Blockchain technology is not yet widespread among companies, and research is still open to evaluating the new possibilities that blockchains can offer to various industrial sectors (Pólvora et al. 2020). Further research contributions are encouraged to identify the factors that could contribute to, or that may hinder, the implementation of the blockchain within supply chains (Chang et al. 2019; Queiroz and Wamba 2019), in particular in the fashion industry (Choi et al. 2019; Caldarelli et al. 2021; Ahmed and MacCarthy 2021; Agrawal et al. 2021).

The overall goal of this research is to address the potential for using blockchain technology in fashion supply chains by considering the specific company variables (i.e. the drivers and the barriers) that would affect its implementation. In particular, the current literature does not clarify which are the factors that a company considers to be facilitators, or which to be obstacles, in their adoption of blockchain technology (Chang et al. 2019; Pólvora et al. 2020; Queiroz and Wamba 2019). Fashion companies today, are at the stage of evaluating the relevance of blockchain technology for their business: their initial step will focus on the identification of the main drivers and barriers in the adoption of blockchain technology. Current blockchain literature mainly takes a technological perspective and a more managerial point of view that would understand the drivers and barriers in the adoption of blockchain technology is still missing. Recognizing this research gap, the first research question is formulated as follows.

RQ1: Why do fashion companies adopt, or not adopt, blockchain technology as a system to improve traceability along supply chains in the fashion industry? What are the drivers and barriers to the implementation of blockchain in fashion supply chains?

The literature also makes little contribution to addressing the supply chain variables that would support the implementation of the blockchain in the specific fashion context. Further studies are needed to support an understanding of how to operate in making the implementation of blockchain technology effective and successful among fashion supply chain partners (Wang et al. 2019). There is a need to study in-depth the main variables that enable proper and successful implementation of blockchain technology within fashion supply chains (SCs). Industries differ in terms of their different SC relationships, setting the path for a contingency foundation to blockchain implementation choices within supply chains (Caniato et al. 2009; Pólvora et al. 2020). Using the contingency approach emphasizes that SCs can have different structures and that these may be related to several contingencies, such as environment, technology, organizational goals, or the characteristics of

the members of the SC, such as skills, knowledge, and size (Caniato et al. 2009). In line with the approach suggested by the contingency theory, the study of blockchain technology in the fashion context will have to take into account the characteristics of the fashion supply chain itself. Recognizing this research gap, the second research question was formulated for an in-depth investigation of specific fashion supply chain variables (i.e. contingent variables and enablers) impacting the implementation of the blockchain technology.

RQ2: How do supply chain variables impact the adoption of blockchain technology as a system for improving traceability along supply chains of the fashion industry?

4 Research methodology

Given the exploratory nature of the topic under investigation, we decided to adopt a multiple case study methodology to anchor our results in the real world. The case study methodology is appropriate when research is exploratory and the phenomenon under investigation is still poorly studied as it offers the opportunity to achieve in-depth results through direct experience (Voss et al. 2002). Multiple case studies are conducted to achieve a depth of information and to increase the external validity of the results (Voss et al. 2002). Although research studies are available regarding the implementation of the blockchain in the financial context, a perspective that considers the implementation of the blockchain in manufacturing supply chains, and more specifically in the fashion industry, is still lacking.

4.1 Sample selection

The goal of the study is to investigate how company variables (drivers and barriers) and supply chain variables (enablers and contingent variables) impact the adoption of blockchain technology to improve traceability in the fashion supply chain. The literature suggests that the adoption of blockchain technology might differ strongly in different industries (van Hoek 2019) and that the nature of the industry is one of the most impactful variables for supply chains (Treiblmaier 2018).

For this reason, the sample used in this paper is homogeneous in terms of industry, and the fashion industry was selected as this industry is consistently working on the improvement of product traceability at the supply chain level (Choi 2019). The reasons for this attention are several. First, the phenomenon of counterfeiting heavily afflicts this industry. In addition, companies are increasingly interested in verifying their supply chain partners for purposes

of social and environmental sustainability (Moretto et al. 2018; Mukherjee et al. 2021). Furthermore, this industry is already investigating the possible contribution of blockchain technology for achieving these goals. The blockchain is, therefore, becoming a tool for protecting companies in this context (Choi and Luo 2019; Fu et al. 2018). To mention a few examples, companies such as Levi's, Tommy Hilfiger, and LVMH are already evaluating or implementing blockchain technologies. For these reasons, the fashion supply chain is an interesting context in which to study the potential of blockchain technology (Agrawal et al. 2018).

Simultaneously, the sample is heterogeneous in terms of the types of actors included, as both focal companies and the providers of blockchain technology were included. The former were all interested in the adoption of the blockchain system within their supply chain. In particular, focal companies were included to get the perspective of supply chain decision-makers. Within the fashion supply chain, the important changes and investments will be driven by the focal company, which will push the rest of the chain in the same direction. For this research, seven focal companies were interviewed to discuss the roles and the responsibilities involved in the blockchain project in their company. This part of the sample was homogeneous in terms of size, as it is generally only large companies that are evaluating blockchain projects and have the financial resources to afford this kind of project. Furthermore, these companies are strong enough to influence the rest of the supply chain. Only brand owners were included in the sample. All the companies in the sample were either implementing or evaluating the implementation of blockchain technology to meet their traceability goals; the reason why we decided to include companies that are both implementing and evaluating the technology is that the former is potentially more aware of the enablers and contingent variables whereas the latter of drivers and barriers. The companies are considered anyhow comparable as implementing companies are mainly in the early stage in the project whereas evaluating companies have been working on these proposals for a certain amount of time, so data and perception are comparable. This choice of the sample will make it possible to achieve a full understanding of the drivers and barriers and also the supply chain variables that influence the adoption of blockchain technology in the fashion industry.

In addition to representatives from the fashion industry, blockchain providers are included in the sample to introduce the perspective of actors who are in the position to talk with several companies, and who have a breadth of perspective on the main drivers, barriers, enablers, and contingent variables addressed by their customers. The providers were asked to present their understanding of the viewpoints of their fashion customers. For the providers to be eligible for the research, they needed to work explicitly with fashion

companies. This part of the sample is heterogeneous in terms of company size, as both large companies and small startups are emerging to support fashion companies in their adoption of blockchain technology. Five blockchain providers were interviewed for the study, and they spoke from the position of the technology expert and also from the perspective of sales and commercial managers who are in contact with customers in the fashion industry.

A total of 12 case studies were thus included in the research (Tables 1 and 2): five technology providers who support companies in blockchain implementation and seven focal companies that are evaluating blockchain implementation in their respective supply chains. The number of case studies is considered sufficient to reach saturation (Yin 2003).

4.2 Data collection

To collect the data, semi-structured interviews were conducted, and for this purpose, a semi-structured interview protocol was developed. A research protocol increases research reliability and validates the research by guiding data collection. Furthermore, a protocol provides essential information on how to carry out case studies by standardizing the procedures used to collect the data (Yin 2003). Due to the exploratory purpose of this study, open questions were asked and the protocol developed did not follow a rigid pattern but allowed the conversation to be natural so that the characteristics of the framework would be shaped by the answers given in the interviews. The protocol was revised in the course of the interviews to incorporate the insights gathered.

Two separate interview protocols were designed, one for the focal companies and one for the providers. The former was composed of (1) an introduction to the company (e.g., company name, role of the person interviewed, number of employees, turnover, description of the supply chain in terms of sourcing, making and delivery and the global scope of the SC for the focal company); (2) a description of the traceability system already in place with the focal company (e.g. reasons for adoption of a traceability system, technologies adopted, impact on processes, main drawbacks, etc.); (3) an evaluation of the main drivers and barriers to the adoption of

blockchain technology; (4) the characteristics of the supply chain and how these variables influence the implementation of the blockchain. The interview protocol for the providers included (1) an introduction to the company (name and role of the person interviewed, number of employees, turnover, description of the services offered to companies); (2) a description of the blockchain technology that they are selling to their customers; (3) an analysis of the main reasons for fashion customers implementing blockchain technology, including an investigation of drivers and barriers; (4) an analysis of how the individual supply chain features impact companies' adoption of blockchain technology.

The data collection stage involved multiple investigators and interviewers and all the interviews were recorded and transcribed (Eisenhardt 1989). Trick questions were included to verify the information and to identify any bias. The whole data collection process was conducted in 2019. Data collected through direct interviews were then combined with secondary data, such as white papers, company websites, documents provided by the company, case studies presented in conferences or specific workshops, etc.

After the interview, each case was analyzed on its own. The data collected through the direct interviews were then categorized onto a spreadsheet. It was then analyzed and triangulated with secondary data, such as the companies' documents, newspapers, and reports on both the focal companies and the providers. In empirical studies, a combination of different sources makes it possible to understand all facets of the complex phenomenon studied (Harris 2001).

4.3 Data analysis

The data analysis involved three stages: a within-case analysis, a cross-case analysis, and a theory-building stage. For this data analysis, the research team met many times after the initial site visits to develop a strategy for synthesizing the data. In cases where some data were missing or unclear, the respondents were contacted again by phone for clarification.

To maintain the narrative of the findings, a within-case analysis was conducted to identify each company's peculiarities (its drivers and barriers), while the main supply chain variables (enablers and contingent variables) for each case were highlighted. Several quotations from informants have been included in the within-case analysis, as reported along with the description of the results in the paper. In particular, open coding was adopted for the within-case analysis, and labels and codes were identified based on transcripts of the interviews. The within-case analysis involved following several steps: reading the transcripts of the interviews twice to take notes and grasp the general meaning of the interview. Through this process, the most frequent words used in each case were identified, and these were used to create the coding labels. Finally, data interpretation was performed

Table 1 Sample composition—Providers

Company	Location	Revenue
<i>Provider 1</i>	Italy	39 Million \$
<i>Provider 2</i>	Italy	Around 100.000€
<i>Provider 3</i>	Italy	46 Billion \$
<i>Provider 4</i>	Italy	4 Million €
<i>Provider 5</i>	Italy	2 Million €

Table 2 Sample composition – Focal companies

Company	Location	Revenue	Number of employees	Degree of globalization
<i>Focal Company (FC) 1</i>	Italy	54 Billion €	150.000	Stores in more than 150 countries Global supply network
<i>Focal Company (FC) 2</i>	Italy	60 Million €	260	Global customers Mainly local suppliers
<i>Focal Company (FC) 3</i>	Italy	150 Million €	1400	Global customers Local and global suppliers are equally important
<i>Focal Company (FC) 4</i>	Italy	3 Billion €	6.500	Stores in more than 150 countries Global supply network
<i>Focal Company (FC) 5</i>	Italy	1 Billion €	3.800	Stores in more than 150 countries Global supply network
<i>Focal Company (FC) 6</i>	Italy	1,5 Billion €	4.000	Stores in more than 100 countries Global supply network
<i>Focal Company (FC) 7</i>	Italy	1,5 Billion €	6500	Stores in more than 150 countries Global supply network

where each case was taken individually and its variables were described and interpreted. This included examining the final results to conclude the within-case analysis.

These coding labels were then used to perform the cross-case analysis (Annex A). The cross-case analysis was initially jointly performed for the focal companies and providers to combine their different points of view and to raise differences during the discussion. The purpose of the cross-case analysis was to identify both commonalities and differences among the cases. The cross-case comparisons helped to extract the common patterns. The cross-case analysis was performed independently by two researchers and then the results were compared to find similarities and differences and to increase the descriptive validity. In the case of any misalignment, a revision of results was performed to arrive at a common classification for each case.

Finally, the theory-building stage was completed, where interpretation and abstraction were performed. This involved iterating data and theory to design a new framework for characterizing the design of decentralized two-sided platforms that are built upon blockchain technology. Results of this step are provided in the Table reported in the Result section.

5 Drivers and barriers for blockchain technology

5.1 Drivers for blockchain technology

The analysis of the within-cases allowed us first of all to identify two main groups of drivers for the blockchain technology: the internal and the external. In terms of the internal drivers, companies presented decisions taken within the

company to improve internal performance metrics such as efficiency and effectiveness. In terms of external drivers, companies presented the incentives or requests obtained from external actors, which could be either the supply chain or the customers. This distinction was made particularly clear by the providers, who illustrated the different requests received from some of their customers, as indicated in a quote from Provider 2: *‘For us, it is particularly important to understand why a customer is approaching the blockchain. Some of them are mainly interested in the possibility to exploit traceability at a lower cost or through the automation of some steps, so mainly with an internal perspective. Some others are, actually, more focused on the external perspectives: either for specific requests of the customers or retailers or for the willingness to onboard on the project the overall supply chain. But this is an important distinction, guiding potentially different approaches’.*

Based on these insights, the cross-case analysis considered three different variables, i.e. the internal drivers, the external drivers (the supply chain), and the external drivers (the customers), as reported in Annex A. We noticed that almost all of the companies have listed some elements in all three groups of drivers. Internal drivers are mentioned strongly by providers whereas focal companies are stressing more the importance of external drivers, especially supply chain ones. This difference could depend on the fact that providers are also considering the perspective of companies that at the end decided to not move forward in the adoption of the blockchain technology; focal companies, on the contrary, strongly understand the importance to generate value along the supply chain or for accomplishing the request of customers.

Having compared the different cases, their commonalities and differences were considered and are combined in Table 3.

Table 3 Drivers towards blockchain technology

Internal drivers (company)	External drivers (supply chain)	External drivers (customers)
<p>EFFICIENCY ORIENTED</p> <ul style="list-style-type: none"> - business efficiency (e.g., through breaking down data silos, reduction of insurance and bureaucracy costs, reduction of logistics risks) - process automation - reduction of the costs of compliance <p>EFFECTIVENESS ORIENTED</p> <ul style="list-style-type: none"> - improving internal decision making - reduction of counterfeit products - data safety 	<p>VISIBILITY ALONG THE CHAIN</p> <ul style="list-style-type: none"> - trust: sharing of data among different actors of the supply chain (with reduction of opportunistic behaviors in the supply chain) - accountability of what is reported by different actors in the chain <p>TECHNOLOGICAL REASONS</p> <ul style="list-style-type: none"> - shared communication layers: blockchain is agnostic in terms of formatting of data - decentralization and disintermediation in the network <p>EXTENSION OF BEST PRACTICES</p> <ul style="list-style-type: none"> - adoption by main competitors - sharing of ethical principles along the supply chain 	<p>ACCOUNTABILITY TOWARDS END CONSUMERS</p> <ul style="list-style-type: none"> - providing customers with data to understand whether the price is representative of the value of the product - providing customers with reliable data about the product and the company - desire to assure the authenticity and the ownership of products to end consumers <p>EXPLOITATION OF CRITICAL SUCCESS FACTORS</p> <ul style="list-style-type: none"> - confirm to customers the history of products (such as the origin of raw materials and production activities) - marketing desire: present the company as innovative and willing to share data with customers and stronger communication with customers for reasons of brand awareness <p>ACCOUNTABILITY TOWARDS RETAILERS</p> <ul style="list-style-type: none"> - allowing retailers to decide to source from reliable suppliers

The first group concerns **internal drivers**, meaning the reasons that push the individual company to implement blockchain technology. In particular, companies presented either efficiency- or effectiveness-oriented reasons for their adoption of the blockchain. These companies highlighted strongly the benefits expected in terms of reduction of costs to be achieved through greater business efficiency (in terms of the reduction of insurance costs or bureaucracy costs), generally to be achieved through an extensive process of automation. Several companies also emphasized as important the need to reduce the cost of compliance. This was expressed by the manager of Provider 2, who reported: *‘In Castel Goffredo there is a district where 60% of European socks are produced. One of the most interesting topics that came up with them is the management of compliance. Each of these companies, of which many are subcontractors for other brands like Zara, have a series of certificates that [they] must produce. But they come to need 15 different certificates for each company, so every 2/3 days they have an audit, which involves dedicating people and wasting time. This is a big problem for them because the certifications are different, but they also have many common points. Maybe they have to produce one for a brand and a similar one for another brand. Thanks to a blockchain and a smart contract, they could reduce these kinds of costs’*. The cost of compliance was probably the most frequently cited driver for the blockchain, and also in the literature. This driver was cited by all the providers, illustrating that this is the main point emphasized by the providers in terms of what matters to their customers. This point, especially in the fashion industry, could represent an important element especially for smaller companies, with several customers and request to accomplish.

Although this driver was strongly presented in the case studies, and especially by the providers, it is interesting that several other drivers were also emphasized. In terms of the internal drivers, several case studies spoke of the importance of using blockchain technology to increase effectiveness, in particular, due to improvements in the decision-making process, as information is always required immediately and must be easily available. This was supported by an additional driver linked to data integrity and data safety, as companies need to be sure of the validity of the data that they use for decision-making. This driver is, anyhow, not specific to the industry, but presented also in literature as one of the main advantages of the blockchain technology independently from the area of application.

However, the most recurrent driver, specific to fashion products, is the possibility of reducing counterfeit products. This was highlighted by almost all the focal companies, all of whom are potentially strongly impacted by this issue. Provider 2 gave an example of this when they reported that one of their customers had suffered damage due to counterfeit

products that equaled 10% of their total revenue. FC3 reported: *'We are part of a blockchain project sponsored by the government. The main reason why the government pushed this project was a willingness to protect Made in Italy'*. This is a relevant driver for the industry, that was also mentioned for example for food products in other domains.

The second group of drivers pertains to external drivers and includes the **supply chain drivers**, where other supply chain actors play an important role. This is a perspective just partially investigated in existing literature, for example considering the logistics industry. The first group of supply chain drivers concerns the willingness to increase visibility along the overall chain, thanks to the trust demonstrated in the sharing of data among different actors. This was expressed by Provider 1: *'I think generally, a blockchain is solving a problem of trust. It is solving a problem in which multiple different actors, within a specific kind of system, whether it is a supply chain system, or whether it is a government, like a political system, or different kind of social system, where different actors have incentives to anticipate in the system and some of the actors have incentives to cheat, not be transparent, maybe gain more out of the system. Blockchain essentially enforces trust onto a system so individual actors can't take advantage or manipulate the system for their advantage'*. What the blockchain does is create controlled data shared by multiple companies. Every company has its information system, making incorrect data modifications impossible. The blockchain makes possible a process in which multiple organizations interact with each other and, at the same time, it ensures that only correct data are exchanged through this interaction. Data are stored on the blockchain in a way that means they are non-falsifiable and cannot be tampered with. The reason for the blockchain increasing trust is not that data are automatically true, but that accountability for what is reported is clear. A good example of this is reported by Provider 3: *'I can also write false information because the blockchain does not validate the data per se, so if I write the temperature that a sensor detects while I have a warehouse full of sushi and the temperature is at 40 degrees but I write 0, the blockchain records 0. However, the fact remains that I digitally sign cryptographically what I am writing and I also take responsibility for what I am writing. So if a garment is made of merino wool and I declare that it is made of merino wool, this remains written, and therefore, there is this kind of advantage'*.

Some of the other companies also reported drivers that are consistent with the features of the blockchain itself: the blockchain is agnostic, or interoperable in terms of data, and so it makes it possible to achieve benefits such as having common communication layers among all levels of the chain and obtaining disintermediation of the network. These drivers are valid for the fashion industry but aligned with

the main drivers of the technology itself, as presented in literature streams about blockchain technology.

Another group of supply chain drivers concerns the use of the blockchain as an extension of best practices along the chain. Several companies stated that they are studying this new technology as their main competitors are doing the same: this point was highlighted by several focal companies, whereas it was quite neglected by the providers. If this should become the standard, the late joiners might experience some damage either because they are late or simply because they are perceived as not being innovative. The difference existing between focal companies and providers is interesting to highlight and is making this variable particularly critical for the industry under investigation, where innovation represents definitively a critical success factor. Very interesting is what was mentioned by companies such as FC3, who said they want to use the blockchain to stress more ethical behaviors along the entire chain.

Companies also expressed their willingness to adopt the blockchain because of the **requests of their customers**. This created the third group of drivers. The customers of the fashion industry can be divided into end consumers and retailers. This difference is a peculiarity of this industry, where retailers and end consumers might play a relevant, but different role. In terms of the end consumers, the companies want to become increasingly transparent concerning them. In particular, some consumers are especially interested in buying from open companies, and so the companies are willing to demonstrate the validity of what they offer in terms of the quality of the product, its authenticity, the features of the products, etc. This topic emerges as particularly critical in this industry, due to the strong scandals that happened in the past. On the one hand, the application of the blockchain to the production portion of the supply chain will make it possible to verify exactly which actors collaborate in the production of a product, with evident benefits in terms of product authenticity and also the protection of social and environmental sustainability (for instance by ensuring the origin of raw materials purchased at the international level). It enables the suppliers to be controlled in a more precise way as regards the stringent laws in the environmental field and concerning guarantees that must be provided about child labor and more generally, about the safety and contracts of their workers.

On the other hand, the blockchain will make it possible to follow the products during all their distribution steps all across the world. This will guarantee the authenticity of the products available in shops, and it will also work as a certification for consumers. Focal companies, in particular, are reinforcing the importance of using technology to support the story and the validity of the history of their products. This perspective is comparable to what is presented also in the literature about food products.

In terms of the retailers, they may push companies towards a more transparent approach and so the focal companies will need to respond to these requests. This is mainly achieved through accountability towards the end consumer. A good example was reported by Provider 1: *'I think that money is the main driver for the economic sustainability. And so, it might not be the customers like you and me, but it might be the customer like the big department stores. Maybe these department stores don't want to work more with you. Creating more transparency, people can make better decisions on where they source'*.

Thirdly, several companies presented the coherence of this approach by providing typical critical success factors (CSFs) of fashion companies, especially the high-end ones, such as telling the story, increasing brand awareness, and presenting the company as innovative and open towards its consumers. Proof of the products' authenticity will add further security to the claims made by the brands: it will assure the consumers that information on the final product and certifications are verified by the company and its suppliers. This helps in the prevention of false claims and includes the field of sustainability where the risk of 'greenwashing' is always present (concerning both environmental aspects and social sustainability). This is a point strongly stressed especially by focal companies, willing to find new levers to differentiate proper sustainability and just minimal levers.

These results are summarized in the following research proposition:

RPI: The implementation of blockchain technology to improve traceability along the fashion supply chain is driven by three main groups of factors: to increase internal efficiency and effectiveness at the process level, to be aligned with the requests emerging at the fashion supply chain level, and to increase the level of trust communicated to end consumers and fashion retailers.

5.2 Barriers to blockchain technology

Bridging the digital and physical worlds by making the products' path accessible to the customers through a blockchain system is not easy in any situation, and this is why some of the barriers are discussed here.

The within-case analysis enabled two main groups of barriers to be identified: those that were strongly linked to the technology and those that were more oriented to cultural approaches and to the readiness of the industry to accept this new way of working. The former was mainly described by the providers, who saw the technology as the critical element, whereas the focal companies were more focused on industry-specific elements. This result could depend on the sample composition: focal companies are already implementing in the late stage of evaluation of the technology, thereby being quite sure of the willingness to introduce this technology. On the contrary, technology providers have the perspective of both adopters and not adopters and in this case, technological barriers appear more relevant and complicated to overcome.

The cross-case analysis was performed considering these different approaches and it is summarized in Table 4.

The first group of barriers is **technology-specific**. First, was the theme of the investments needed to support the development of a blockchain system as the blockchain is still perceived as an expensive technology. This was particularly regarded as an issue due to the risk that it would increase the costs of the final product. For example, FC5 said, *'The reason why blockchain is deeply discussed within my company is that the cost is still particularly high, especially in comparison to other traceability systems. If we need to transfer this cost in the prices of the products, marketing, and salespeople are not aligned and not willing to accept this additional point whether they are not able to see the value for the customers'*. Moreover, the blockchain is seen as a complex technology, difficult to understand and motivate, for example, FC3 mentioned, *'For me, it, was not easy to understand how the technology works and so to trust the technology. Now I got it but the problem is still not completely solved as now it is a matter of understanding which are the data to properly share.'* This barrier is not industry-specific but connected to the technology itself. In this vein, solutions identified in other industries could also become a lever to overcome this technology in the fashion domain too.

The second group of barriers is called **industry-specific** as they relate to specific features of the fashion industry, such as the generally low level of digitalization in the supply chain (thereby requiring a big jump, especially for small companies), which is also related to a generally low technological culture in the industry. Moreover, at present, there is no

Table 4 Barriers to blockchain technology

Technology specific	Industry-specific
<ul style="list-style-type: none"> - difficult to understand how the technology works - the high cost of the technology 	<ul style="list-style-type: none"> - low level of digitalization in the supply chain - missing a shared technological standard in the industry - missing a technological culture in the industry - collaboration among different SC partners

technological standard, and several companies are worried about this. For example, FC1 reported, *'Today, the biggest problem is not so much to use the blockchain, but to use it in the same way because if everyone makes his [own] blockchain fragment there is also a big race for who will be the winner-take-all'*. Finally, to use the blockchain it is necessary to have strong collaboration among the supply chain partners, but the overall level of collaboration in the fashion industry is often poor, and this could reduce the feasibility of adopting blockchain technology. This is something presented as particularly critical by focal companies, especially those in the evaluating phase. To overcome this barrier is relevant to expand the adoption of blockchain technology in this domain.

These results are summarized in the following research proposition:

RP2: The implementation of blockchain technology to improve traceability along the fashion supply chain is halted by two main groups of factors: a low understanding of the newly emerging technology in the fashion industry and the perception that the fashion industry is not yet ready from either a technological or a cultural point of view.

6 Supply chain variables and the impact on blockchain technology

Exploratory case studies were used to understand if and how the characteristics of the supply chain might impact the blockchain.

What the cases suggest is that two different groups of supply chain variables could influence the adoption of

blockchain technology. First, there are the enablers, considered to be elements existing within the supply chain that could support and exploit the adoption of blockchain technology. Second, there are contingent variables, described as the contextual factors of the supply chain, which could impact the potential benefits achievable through blockchain technology as well as the possibility of implementing it. These two groups of variables were used to perform the cross-case analysis reported in Annex A and summarized in Table 5. In analyzing the data reported in Annex A, we could notice that there is quite a good consensus about the enablers identified in different cases; these enablers are pretty in line with the main barriers previously identified, addressing that these variables could reduce the risks and the uncertainty generated by the technology. On the other hand, reading data of the cross-case analysis, some differences among the case could be highlighted in terms of contingent variables. Providers are focusing more on fixed parameters, such as the supply chain complexity and the features of the industry, whereas focal companies are strongly presenting the relationships existing. This dichotomy again provides evidence of which are the elements influencing the adoption since the beginning and which are the most relevant points presented during the implementation, with a more practical and business perspective.

6.1 Supply chain contingent variables for blockchain technology

The case studies highlight several contingent variables that could influence the adoption as well as the success of blockchain technology. Cases are quite aligned in the identification of variables to consider but have different perspectives

Table 5 Supply chain enablers and contingent variables of blockchain technology

Contingent variables	Enablers
SUPPLY CHAIN COMPLEXITY - the size of the companies (easier to use with big suppliers, more relevant with small ones) - number of nodes involved (the higher the number of nodes the higher the safety of the system) - globalization of the supply chains (the more the supply chain is global the greater the need to bring information to the consumers) - level of vertical integration (less relevant when production activities are owned)	- proper supply chain traceability system already in place (with the appropriate units of analysis, single product or container) - need to integrate blockchain with other technologies, such as IoT - willingness to collaborate with other actors in the chain
TYPE OF RELATIONSHIP - duration of the relationships with suppliers (best used with stable suppliers) - supplier commitment towards the company (adoptable with committed suppliers)	
INDUSTRY - level of regulation (less valuable when the regulations are already super strong and are monitoring everything, but proper regulations might be an enabler factor) - positioning (adaptable with high-end products)	

about the possible positive or negative influence of the variables. This is something very specific for the industry under investigation and not investigated in current literature. The most frequently mentioned, and also most controversial element, pertained to **supply chain complexity**. This result highlights the complexity of the supply chain as an important element fostering or reducing the effectiveness of the adoption of the new technology. Discussion on this point varies widely as some companies address the supply chain complexity as being the greatest difficulty to introducing blockchain technology, with related costs and risk of failure (e.g., FC5). In contrast, other companies say that it is because of the high level of supply chain complexity that it is so important to exploit the traceability of the supply chain, and in this way, the potential value of blockchain technology is too.

In this group, four main elements could be identified, which are consistent with the literature about supply chain complexity. First, the size of the company matters, but the impact of this factor is controversial from the companies' points of view. On the one hand, the blockchain may offer its strongest contribution when small suppliers are involved, as their inclusion is critical to providing reliable and trustworthy data. On the other hand, these companies are also those where the industry-specific above are stronger, and so the possibility of involving them is more challenging.

The second element concerns the number of nodes involved: some companies indicated that the higher the number of nodes involved the higher the safety of the blockchain system. This is confirmed by the fact that it is easier to verify the validity of data provided when the number of actors involved is low, as it is easy to use alternative methods. At the same time, other companies pointed out that when the number of nodes to be involved is high, the complexity in implementing the technology and therefore the related costs increase, thereby reducing the feasibility of the project.

Thirdly, the globalization of the supply chain was considered and discussed. Here again, contrasting opinions were given as some companies said that the more global the supply chain, the more difficult but also necessary it became to provide reliable information to the consumers. This is something very peculiar for this industry and with the sample analyzed, considering that all the focal companies considering present a high level of upstream and downstream globalization, as illustrated in Table 2. Again, in terms of the number of nodes involved, the more global the supply chain, the higher the costs of the technology.

Finally, the level of vertical integration was mentioned. In keeping with the opinions reported regarding the number of nodes involved, the contribution of the blockchain is higher if the level of vertical integration is low, as within a single company other methods, such as the more traditional centralized database, are sufficient.

According to these insights, the following research proposition was formulated:

RP3: Supply chain complexity influences the implementation of blockchain technology to increase traceability as the higher the supply chain complexity (in terms of size of the companies involved, number of nodes, globalization of the fashion supply chain, and level of vertical integration) the higher is the relevance of traceability along the fashion supply chain, but also the higher is the difficulty in implementing the blockchain technology.

The second contingent variable relates to the **type of relationship** existing between the supply chain partners. Blockchain technology is most effective with suppliers who have been adopted for a long period, whereas in the case of a spot relationship, the cost and time required to integrate a new supplier into the blockchain would be greater than the value to be obtained. This is a definitive and critical point for the fashion industry, as most of their products last for not more than one season. Suppliers will likely be extensively revised for each collection, thereby reducing the number of actors that can be meaningfully involved in the blockchain. At the same time, suppliers must be committed to the relationship. The combination of these two elements was illustrated by FC4: *'There are big companies with fixed and stable suppliers and therefore they can contractually manage this integration. When you have so many suppliers, even small ones that go in rotation, [it] is much more difficult. We are perhaps big names, but we have volumes that are not comparable to someone else. And so the difficulty lies in keeping the supplier bound and performing what you ask him. We have productions in Asia where we are very small and we have to get in line with the others. In sneakers, if you talk about Adidas, Puma, or Nike, we are 0. The volume, in that case, is king.'*

According to these insights, the following research proposition was formulated:

RP4: Blockchain technology is easier to implement in the fashion supply chain with long-lasting relationships, where there is a high level of collaboration and trust.

Finally, some contingent factors are specific to the **industry**. From this perspective, two main contingent variables were highlighted by the interviews: the level of regulation and the product positioning. Regulations can play a role in driving the adoption of the blockchain, but at the same time, they can render the technology useless. For example, Provider 2 gave the example of the pharma industry, which is already strongly regulated in terms of traceability and so it is less valuable for it to use blockchain technology as the achievable benefits would be little different. In this case, the

fashion industry can have a good potentiality, considering still a limited level of regulation about the topic, but a growing relevance and perceived urgency.

For the latter, product positioning, the cost of the investment and the level of data to be shared are the same, independent of the type of product considered. To mitigate the barriers related to the cost of the technology while exploiting the drivers related to customers, there is greater potential when the technology is adopted for high-end products. This is a typical relevant variable for the industry, in discriminating among several strategic decisions.

According to these insights, the following research proposition was formulated:

RP5: Blockchain technology is easier to implement in a regulated industry, such as the fashion one, where there is a strong need for traceability, which is not yet achieved, and for high-end products.

6.2 Supply chain enablers for blockchain technology

In terms of the enablers, the cases highlighted that some elements can make strengthen or ease the impact of both drivers and barriers on the implementation of blockchain technology. In particular, the case studies highlighted how essential it is for fashion companies to evaluate the application of blockchains first of all, in guaranteeing the **traceability of their products**. Knowing where products come from and what paths they have taken before arriving in the stores is useful both for brands, to check their supply chain, and for the customers who get additional information on the product purchased. The major goal for the application of the blockchain in the field of fashion, therefore, becomes to trace and retrace every single passage of a product, from the raw materials until the final store. The blockchain is not only a tool that facilitates traceability, but it also enables the sharing of data. Most of the companies agreed that a proper supply chain traceability system should be in place, whether the companies wanted to exploit the benefits of blockchain technology. This was a point of agreement between the providers and the focal companies and differed from the initial expectations that the use of the blockchain was to foster traceability along the supply chain. This result is not always completely aligned with the insights of the literature, where the relevance of blockchain to foster visibility is often presented. It is interesting to consider what FC7 reported: ‘We already have in place a traceability system that was developed several years ago. This is fundamental, as without a proper system it is irrelevant. Our driver is to increase visibility along the supply chain.’

The second element highlighted concerns the **possibilities offered by other technologies on the market**. In

particular, correct verification requires a critical revision of the other technologies available on the market that allow information sharing (for example, QR code, NFC, and the RFID system) to understand if they can meet the goals of brand transparency. A relevant question that companies will have to ask themselves is whether smart labels, such as NFC tags or custom plug-ins for e-commerce, could convey sufficient information to consumers for their business purposes. Also, if the existing technologies are insufficient and the blockchain might provide a real contribution, it is necessary to understand how to integrate the blockchain with other existing technologies to include existing data in ensuring reliable information.

The third and last enabler is the **collaboration** among all supply chain partners. Blockchain development inevitably requires that content and data will be collected from multiple sources and suppliers and that information will be constantly updated. This means involving each participant along the supply chain in a long-term collaboration project, which must be grounded on mutual trust. The development of a blockchain project must foresee, at least initially, the creation of support for companies in the network that will co-participate in the transparency project promoted by the brand, without forgetting that the hostilities or reticence of suppliers who may not want to collaborate with the other suppliers will also have to be managed.

According to these insights, the following research proposition was formulated:

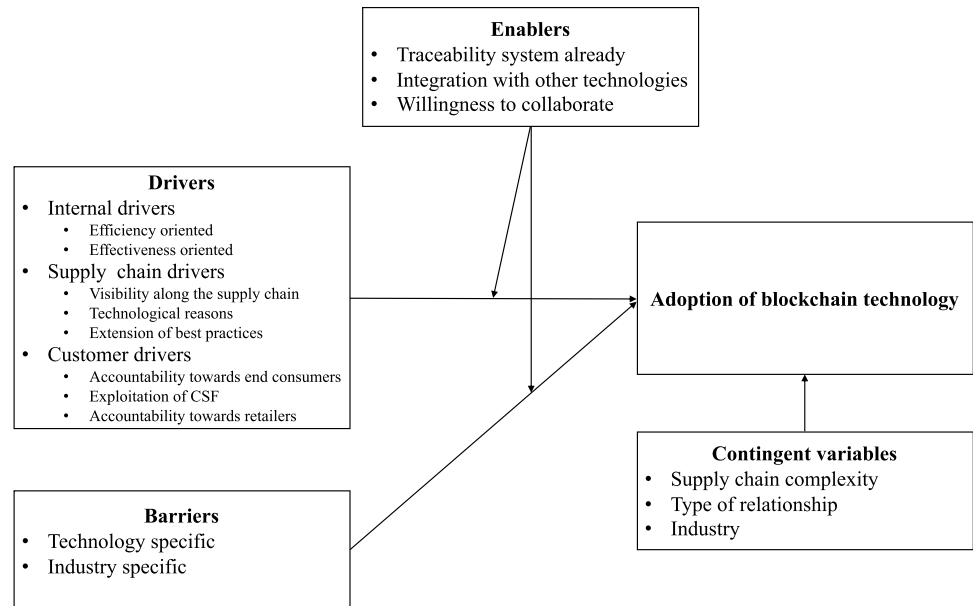
RP6: The impact of drivers to foster the implementation of blockchain technology and of the barriers to interfere with the implementation of blockchain technology along the fashion supply chain depend on an already existing traceability system, on the possibility of integration with other technologies, and collaboration between supply chain partners.

6.3 Detailed research framework

Results of the paper are summarized in a research framework as depicted in Fig. 1.

Shreds of evidence of the case studies and the summary of the detailed research framework provided above are also necessary to offer some guidance about steps and phases that companies should perform to introduce blockchain technology in the fashion supply chain.

The driver of traceability along the supply chain, which is pushing companies towards blockchain projects, reveals how strong is the need of companies to develop common databases to collect accurate supply chain information about traceability and sustainability. This first need to be fulfilled becomes the first question to which companies must answer in the process of defining the technology that

Fig. 1 – Detailed Research Framework

supports such information sharing: “Does a company need a database to collect and share data with Supply Chain partners?”. If companies respond negatively to this question, blockchain technology cannot and must not be taken into consideration. A negative answer can be justified, for example, by companies that are not very advanced concerning the issue of traceability and sustainability and that manage the SCs still in “watertight compartments” among the different SC partners.

On the contrary, if the response is positive, the company will have to understand how much this point is relevant for other actors of the supply chain and wonder about how many partners will have to participate in information-sharing activities. In particular, if the technology is not relevant for external partners and the exchange of information will be limited between a dyad of partners, a blockchain will be a superstructure, which, would entail considerable costs and a considerable development commitment. In this case, a centralized database, managed directly by the focal company and accessible to the partners, could be a more streamlined solution.

After identifying the number of participants in the data-sharing project, the type of relationship to be established and the kind of relationship willing to maintain should also be analyzed. Considering that in a blockchain the partners will have to exchange sensitive data, it is necessary to understand the level of trust to be established. If the relationship with the identified partners is not of full confidence the blockchain project must be discarded; alternatively, multiply the copies of the centralized databases

in such a way that partners can access but not have full control over all data. Blockchain technology contemplates that a partner can change data for all connected partners, but if this is not supported by trust, the blockchain project cannot continue.

Subsequently, the operative aspects at the production level must be analyzed. Which transactions will have to be connected and which production process must be linked in the eventual blockchain? In other words, which production process must be traceable and traceable must be defined precisely to comply with the traceability drivers that have encouraged the evaluation of a blockchain project. If the need for traceability were not so strong, the blockchain project would not make sense. Probably for these companies, the traceability of the supply chain is not so strong as to justify investments in new technology, but other less expensive processes are sufficient. Instead, if the traceability of the production processes along the entire supply chain will be a very strong need of the company then the blockchain will be the ideal solution.

7 Conclusion

‘Blockchain’ is one of the keywords for the future. When it was born, more than ten years ago, it was linked only to the bitcoin economy. Today, the decentralized database where transactions between users are recorded is not only linked to banks’ transactions, but it is playing a significant role within supply chains. International competition and the

advent of innovative technologies are just some of the critical challenges that the fashion industry faces today. These challenges require new ways of operating and accordingly, require changes in the supply chain processes.

Although explored in other industries, literature is still quite preliminary at presenting what fashion companies specifically can do to implement blockchain technologies. For this reason, this paper aims to understand the main drivers, barriers, enablers, and contingent variables that explain the adoption of blockchain technology in the fashion industry. To tackle this goal, the research was based on multiple case studies, conducted through interviews with five blockchain providers and seven fashion focal companies. Through analysis of the case studies, the main groups of drivers (i.e. internal drivers, supply chain drivers, and customer drivers), barriers (i.e. technology and industry-specific), enablers, and contingent variables (i.e. supply chain complexity, industry, and type of relationships with suppliers) were identified.

Although exploratory, from an academic point of view this work contributes to the schematization of the discussion on the blockchain, identifying drivers and barriers for the fashion context and illustrating how the main features of the industry may influence technology adoption. This industry has some peculiarities and a great relevance, to justify a focus in the existing literature and in trying to understand which principles valid in other industries could be replicated to fashion one. Moreover, current literature is just partially considering how supply chain variables could influence the adoption of blockchain technology to increase the visibility along the supply chain; this paper, with a specific focus on the fashion industry, tries to address which might be these areas of influence, contributing to the literature. Moreover, the results hint at additional areas for investigation. Technology appears to offer a potentially valuable tool in the field of sustainability where previously, companies developed to control and audit systems based on internal protocols. These were developed ad hoc by each brand or, in more advanced cases, supported by certifications of environmental

and social sustainability. The blockchain will unquestionably make it possible to see, in real-time, which actors in the supply chain process the final products, and more generally, it will make it possible to provide guarantees on the sub-working activities through which these products have passed. In the fashion sector, it is common practice for suppliers to make use of sub-suppliers for production processes that require highly specialized skills. The blockchain is increasingly available for all sectors that need to certify the quality and origin of their products and raw materials. The potential of this technology lies in its ability to obtain greater consumer confidence and to guarantee products in terms of sustainability and all that happens along the fashion supply chain. This will allow brands to provide verified information on the materials, processes and, people behind their products. This topic is particularly relevant especially for fashion companies and further research could be necessary too.

From the managerial point of view, this perspective is a hot issue. This guide can be a useful tool for directing discussion on the feasibility of a blockchain project. This research offers valuable and original contributions to practitioners who are thinking about the drivers and barriers to new blockchain projects, while the research also identifies concrete questions that managers can use to check whether blockchain technology meets the needs of their particular production context.

However, the paper does have some limitations, which open opportunities for further investigation. First, the paper does consider both providers and focal companies but there is no proper discussion of the differences between the two groups of actors. Additional research might also include the viewpoint of the suppliers and compare the perspectives reported by different actors in the chain. Second, the paper illustrates the main drivers and barriers towards the adoption of the blockchain. The benefits and the costs to the companies are not discussed: further study might involve an action research project to assess the impacts in terms of performance.

Annex A: Drivers, Barriers, Enablers, and Contingent variables

Case	Internal drivers (company)	External drivers (supply chain)	External drivers (customers)	Barriers	Enablers	Contingent variables
<i>Provider 1</i>	<ul style="list-style-type: none"> - business efficiency through breaking down data silos - reduction of the costs of compliance - improving internal decision making 	<ul style="list-style-type: none"> - trust: reduction of opportunistic behaviors in the supply chain - reduction of information asymmetries at different stages of the supply chain → - reduction of bounded rationality → - authenticity and consistency of data 	<ul style="list-style-type: none"> - providing customers with data to understand whether the price is representative of the value of the products - allowing retailers to decide to source from reliable suppliers 	<ul style="list-style-type: none"> - low level of digitalization in the supply chain 	<ul style="list-style-type: none"> - proper supply chain traceability system already in place (with appropriate units of analysis, a single product or container) 	<ul style="list-style-type: none"> - supply chain complexity (globalization, number of actors involved, size of companies)
<i>Provider 2</i>	<ul style="list-style-type: none"> - data safety - reduction of counterfeit products - reduction in the cost of compliance 	<ul style="list-style-type: none"> - increase in efficiency at the supply chain level - shared communication layers: blockchain is agnostic in terms of the format of data - adoption by main competitors - decentralization and disintermediation in the network 	<ul style="list-style-type: none"> - stronger communication with customers for reasons of brand awareness 	<ul style="list-style-type: none"> - definition of the governance and the central authority - difficulty to understand which data are appropriate to share through the blockchain, to avoid the risk of data overflow 		<ul style="list-style-type: none"> - level of regulation (less valuable when the regulation is already super strong and is monitoring everything)
<i>Provider 3</i>	<ul style="list-style-type: none"> - process automation (e.g., through smart contracts) - business efficiency and reduction of internal costs 	<ul style="list-style-type: none"> - trust: sharing of data among different actors of the supply chain - accountability for what is reported by different actors in the chain - shared communication layers: blockchain is agnostic in terms of the format of data 	<ul style="list-style-type: none"> - desire to assure the authenticity and the ownership of products to end consumers - providing customers with data to understand whether the price is representative of the value of the product - marketing desire: present the company as innovative and willing to share data with customers 	<ul style="list-style-type: none"> - missing a technological culture - difficult to understand how the technology works 	<ul style="list-style-type: none"> - proper supply chain traceability system already in place 	<ul style="list-style-type: none"> - number of nodes involved (the higher the number of nodes the higher the safety of the system) - market globalization
<i>Provider 4</i>	<ul style="list-style-type: none"> - reduction of counterfeit products 	<ul style="list-style-type: none"> - trust of data provided by other supply chain actors - accountability for what different actors are responsible for doing 	<ul style="list-style-type: none"> - desire to assure traceability of the supply chain to assure sustainable and ethical behaviors 	<ul style="list-style-type: none"> - the cost of blockchain is going to impact the cost to customers 	<ul style="list-style-type: none"> - willingness to collaborate with other actors in the chain 	<ul style="list-style-type: none"> - level of regulation (proper regulations might be an enabling factor)

Case	Internal drivers (company)	External drivers (supply chain)	External drivers (customers)	Barriers	Enablers	Contingent variables
<i>Provider 5</i>		<ul style="list-style-type: none"> - trust of data provided by other supply chain actors - accountability for what different actors are responsible for doing 	<ul style="list-style-type: none"> - desire to assure the authenticity and the ownership of products to end consumers - marketing desire: present the company as innovative and willing to share data with customers 	<ul style="list-style-type: none"> - the high cost of the technology 	<ul style="list-style-type: none"> - need to integrate blockchain with other technologies, such as IoT - willingness to collaborate with other actors in the chain 	<ul style="list-style-type: none"> - global supply chains (the more the supply chain is global the greater the need to bring information to the consumers) - SC complexity - duration of relationships with suppliers (best used with stable suppliers) - positioning: the method is better suited to luxury products as a product cannot cost 5\$, and it is also necessary to share all the data
<i>FC 1</i>	<ul style="list-style-type: none"> - business efficiency and reduction of internal costs (e.g., reduction of insurance costs, of bureaucracy costs) 	<ul style="list-style-type: none"> - trust of data provided by other supply chain actors - accountability for what is reported by different actors in the chain 	<ul style="list-style-type: none"> - the desire of new consumers to have more open companies - providing customers with reliable data about the product and the company - providing customers with data to understand whether the price is representative of the value of the product 	<ul style="list-style-type: none"> - missing a technological standard 	<ul style="list-style-type: none"> - willingness to collaborate with other actors in the chain 	
<i>FC 2</i>	<ul style="list-style-type: none"> - Simplify the internal processes of data traceability 	<ul style="list-style-type: none"> - trust of data provided by other supply chain actors - accountability for what is reported by different actors in the chain 	<ul style="list-style-type: none"> - providing end customers with reliable data about the product and the company 		<ul style="list-style-type: none"> - proper supply chain traceability system already in place - willingness to collaborate with other actors in the supply chain 	<ul style="list-style-type: none"> - global supply chains (to insert data of global markets such as North Korea, China, or Bangladesh)
<i>FC 3</i>	<ul style="list-style-type: none"> - reduction of counterfeit products - process automation and business efficiency and reduction of internal costs (e.g., reduction of insurance costs, of bureaucracy costs) - reduction of logistics risks - reduction of the cost of compliance 	<ul style="list-style-type: none"> - accountability for what is reported by different actors in the chain - sharing of ethical principles along the supply chain 	<ul style="list-style-type: none"> - providing end customers with reliable data about the product and the company 	<ul style="list-style-type: none"> - difficult to understand which data are appropriate to share through the blockchain, to avoid the risk of data overflow - the high cost of the technology - missing a shared technological standard in the industry 		<ul style="list-style-type: none"> - supply chain complexity (difficult to implement when there is high SC complexity)

Case	Internal drivers (company)	External drivers (supply chain)	External drivers (customers)	Barriers	Enablers	Contingent variables
<i>FC 4</i>	<ul style="list-style-type: none"> - reduction of counterfeit products - reduction of the cost of compliance - process automation and business efficiency and reduction of internal costs 	<ul style="list-style-type: none"> - accountability for what is reported by different actors in the chain 	<ul style="list-style-type: none"> - providing customers with data to understand whether the price is representative of the value of the product - confirm to customers the history of products (such as the origin of raw materials and production activities) 	<ul style="list-style-type: none"> - missing a shared technological standard in the industry 	<ul style="list-style-type: none"> - proper supply chain traceability system already in place - willingness to collaborate with other actors of the supply chain 	<ul style="list-style-type: none"> - duration of the relationships with suppliers (best used with stable suppliers) - supplier commitment towards the company
<i>FC 5</i>	<ul style="list-style-type: none"> - reduction of counterfeit products 	<ul style="list-style-type: none"> - trust of data provided by other supply chain actors - sharing of ethical principles along the supply chain (verify the origin of raw materials and production activities; - verify the sustainability (both social and environmental) of the upstream supply chain) - the main competitors are evaluating the BC (great debate in the fashion sector) 	<ul style="list-style-type: none"> - confirm to customers the history of products (such as the origin of raw materials and production activities) 	<ul style="list-style-type: none"> - the high cost of the technology - a collaboration among different SC partners (identify the partners who are willing to collaborate in this project) 	<ul style="list-style-type: none"> - proper supply chain traceability system already in place - need to integrate blockchain with other technologies, such as IoT 	<ul style="list-style-type: none"> - level of vertical integration (less relevant when production activities are owned) - duration of the relationships with suppliers - global supply chains (more relevant but more challenging for global supply chains)
<i>FC 6</i>	<ul style="list-style-type: none"> - data safety - reduction of counterfeit products 	<ul style="list-style-type: none"> - trust of data provided by other supply chain actors - sharing of ethical principles along the supply chain (verify the origin of raw materials and production activities; - verify the sustainability (both social and environmental) of the upstream supply chain) - the main competitors are evaluating the BC (great debate in the fashion sector) 	<ul style="list-style-type: none"> - storytelling about the product for the consumer 	<ul style="list-style-type: none"> - a collaboration among different SC partners 	<ul style="list-style-type: none"> - proper supply chain traceability system already in place 	<ul style="list-style-type: none"> - supply chain complexity (globalization, number of actors involved, size of companies)
<i>FC 7</i>		<ul style="list-style-type: none"> - trust of data provided by other supply chain actors at the international level - the main competitors are evaluating the BC (great debate in the fashion sector) 	<ul style="list-style-type: none"> - map the finished product lots that are shipped around the world 	<ul style="list-style-type: none"> - low level of digitalization in the supply chain 	<ul style="list-style-type: none"> - proper supply chain traceability system already in place 	<ul style="list-style-type: none"> - supply chain complexity (globalization, number of actors involved, size of companies)

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Declarations

Conflicts of interest The authors have no competing interests to declare that are relevant to the content of this article.

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