frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 11 February 2025
DOI 10.3389/fsufs.2025.1401735

OPEN ACCESS

EDITED BY
Pier Paolo Miglietta,
Università del Salento, Italy

REVIEWED BY
Nugun P. Jellason,
Teesside University, United Kingdom
Lan van Wassenaer,
Wageningen University and Research, Netherlands
Tomy Perdana,
Padjadjaran University, Indonesia

*CORRESPONDENCE
Antonella Samoggia
✉ antonella.samoggia@unibo.it

RECEIVED 15 March 2024
ACCEPTED 27 January 2025
PUBLISHED 11 February 2025

CITATION
Samoggia A, Fantini A and Ghelfi R (2025) The promised potential of blockchain technology for transparency and fairness in agri-food chains: insights from the coffee sector. *Front. Sustain. Food Syst.* 9:1401735. doi: 10.3389/fsufs.2025.1401735

The promised potential of blockchain technology for transparency and fairness in agri-food chains: insights from the coffee sector

Antonella Samoggia*, Andrea Fantini and Rino Ghelfi

Department of Agriculture and Food Sciences, University of Bologna, Bologna, Italy

In recent years, blockchain technology has emerged as a tool with the potential to enhance transparency, fairness and sustainability within agrifood supply chains. This research contributes to the ongoing discourse on the implications of adopting blockchain, by addressing the issue of the potential of blockchain technology to contribute to fairness within the coffee chains. Starting from a theoretical framework that conceptualizes agrifood fairness and its relationship with blockchain, the research proceeds with an exploration of adopted blockchains' fairness relevant information in 47 coffee products commercialized by 25 coffee roaster companies. The objective is to assess how specific characteristics associated with both roaster companies and products influence the quantity and quality of fairness relevant information disclosed through blockchain. Data elaboration includes linear multivariate regressions processing information related to coffee roaster companies and products, and assessing the types of fairness information conveyed through the blockchain. By establishing correlations between these characteristics and specific types of fairness, this study reveals that some companies' characteristics—such as company size and strength of commitment—and some coffee products' characteristics—such as product storytelling, existence of certifications and presence of blockchain information on the coffee packaging—influence the amount of fairness relevant information displayed on the blockchain platforms available to end users. This suggests that blockchain technology can aid in increasing transparency in supply chains and conveying fairness relevant information to end users. Its effectiveness is particularly significant in companies adopting sustainability oriented measures and appropriate company policies. In these contexts, blockchain can serve to increase visibility of ongoing fairness oriented processes.

KEYWORDS

blockchain, fairness, coffee, agrifood, governance, business model blockchain, agri-food, business model

Introduction

Coffee, one of the most important products in global food chains, is experiencing an extensive reach, with a notable daily consumption of approximately three billion cups. The escalating global demand for this beverage has fueled a production increase of over 60 percent since the 1990s (Borrella et al., 2015; International Coffee Organization, 2021; International Trade Centre, 2021). This surge not only highlights the popularity of coffee but also solidifies its pivotal role in the international market.

However, beneath the surface of this dynamicity lies a landscape full of challenges. The environmental footprint of coffee cultivation raises concerns. Furthermore, the sector is characterized by the issue of an unequal distribution of value. As past studies highlighted, there are structural asymmetries across the coffee supply chain, with large players influencing the supply chain, especially over chain bargaining processes, government regulations, industry practices, and the formulation of industrial standards. Their concentrated power tends to marginalize smaller stakeholders, creating a system where value and decision-making are mainly controlled by a few dominant entities in a way that is typical of the global value chains (Miatton and Amado, 2021; Gereffi, 2018; Ponte, 2019) (Figures 1, 2). This economic disparity becomes a breeding ground for social and economic dynamics such as rural poverty and economic vulnerability in coffee-growing regions. Moreover, the coffee industry faces the possibility of heightened price volatility, a phenomenon that complicates the economic stability of small-scale producers (International Trade Centre, 2021; Samoggia and Fantini, 2023).

To address these challenges and promote greater environmental, social, and economic sustainability in the coffee sector, various regulatory tools have been introduced in recent decades. For instance, the European Union's food labeling regulations ensure that consumers receive essential information to make informed purchasing decisions. Additionally, market-based mechanisms such as certifications and voluntary standards have been implemented to encourage coffee operators to adhere to recognized sustainability criteria, aiming to redistribute power and value more equitably along the supply chain. However, as studies indicate, the effectiveness of these tools has been limited (Quiñones-Ruiz et al., 2015; Giuliani et al., 2017). Their impact has fallen short of fully addressing the persistent inequalities and lack of transparency in the sector, highlighting the urgent need for innovative solutions that can overcome these limitations and bring about meaningful change.

In recent years, one of the most promising tools for enhancing transparency and promoting equity and sustainability in agrifood supply chains is blockchain technology (Tripoli and Schmidhuber, 2020; Pergamo, 2020). Thanks to its capacity of guaranteeing an unaltered and decentralized flow of information throughout the supply chain, from farm to consumers, blockchain is often recognized for its potential in reshaping existing business models, fostering innovative practices, and enhancing transparency and traceability across various sectors (Tripoli and Schmidhuber, 2020; Bager and Lambin, 2020; Miatton and Amado, 2021; Dal Mas et al., 2023). This potential is reflected in a growing attention in the scientific literature related to the adoption of this technology by many companies in the coffee sector (Azzi et al., 2019; Pournader et al., 2020; Singh et al., 2022; Alamsyah et al., 2023). Yet, the practical effectiveness of this technology in making supply chains more transparent and fairer has to be fully demonstrated (Bager et al., 2022; Singh et al., 2022).

Considering these factors, this study aims to address this research gap by exploring the capability of blockchain technology in conveying fairness relevant information within the coffee chain. By analyzing the use of blockchain by coffee roaster companies around the world, this investigation seeks to ascertain the degree to which blockchain platforms provide transparency and disseminate fairness relevant information regarding the management practices of coffee roasters with upstream stakeholders, so to share it with the other chain stakeholders, from farmers to consumers. Specifically, the study poses the following research questions: Do blockchain platforms provide fairness relevant information to end-users? Are there specific characteristics of companies and products within coffee blockchain systems that advance transparency and fairness?

These questions, the conceptual model developed, and the resulting research hypotheses aim to contribute novel insights both conceptually and methodologically to the study of blockchain technology. Additionally, they seek to explore potential practical implications, fostering a deeper understanding of this tool and enhancing its effective use and application in real-world contexts.

The paper is structured into sections, beginning with an initial section defining the theoretical framework and exploring the growing role of blockchain in promoting fairness along the coffee supply chain. This is followed by a section detailing the methodology and presenting results, a discussion section, and concluding with key insights and recommendations.

Theoretical framework

Fairness and socio-ecological systems

This study draws on the theoretical concept of fairness. Although fairness and social sustainability are implicitly mentioned

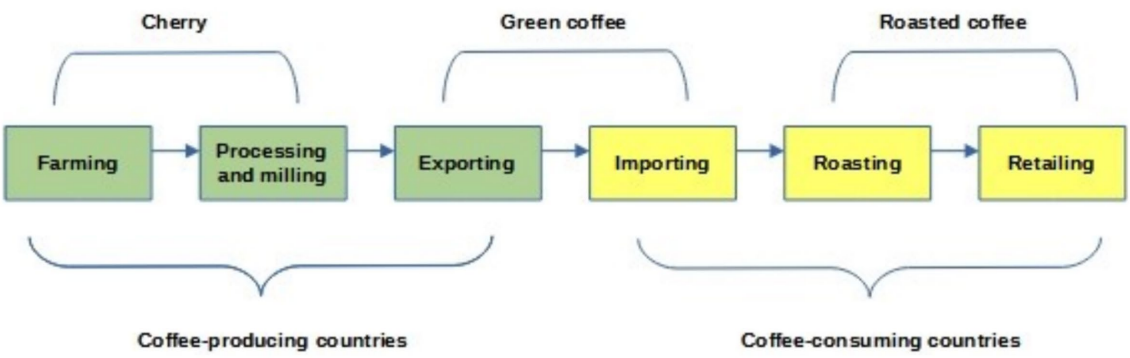

FIGURE 1
Global coffee supply chain.

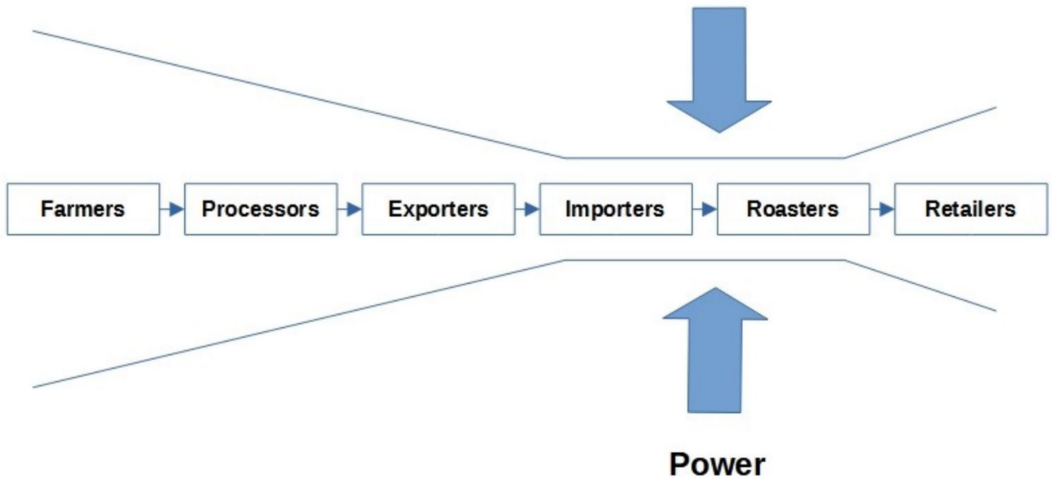

FIGURE 2
Concentration of power in global coffee supply chain (inspired by Gereffi, 2018 and Ponte, 2019).

in many of Sustainable Development Goals of the 2030 Agenda by United Nations, achieving a universally accepted definition of fairness requires clarifications at the conceptual level. Past literature has generally categorized fairness into three primary dimensions: distributive, procedural, and interactional fairness (Samoggia and Beyhan, 2022). Distributive fairness deals with the tangible outcomes of exchanges and how they are allocated among various actors within the agro-food chain, focusing on equitable outcome distribution (Adams, 1965). Procedural fairness examines the processes through which outcomes are achieved, including negotiation procedures and actors' perceptions of the fairness of these processes (Thibaut and Walker, 1978). Interactional fairness measures the extent to which individuals within the chain are treated with courtesy, dignity, transparency, and respect throughout the execution of procedures (interpersonal fairness) as well as they are informed about the processes (informational fairness) (Bies and Moag, 1986; Samoggia and Beyhan, 2022; Samoggia et al., 2023). The interplay of these three dimensions can guarantee fairness—and social and economic sustainability—in agrifood chains, ensuring that the benefits and burdens are equitably distributed among all stakeholders.

Concurrently, past studies conceptualized the interdependence of social, economic, and environmental sustainability, prompting exploration into socio-ecological systems (Holling, 2001; Giampietro et al., 2009; Preiser et al., 2018; Berkes, 2017). This interplay impacts vulnerable actors within supply chains, amplifying the effect of environmental degradation on marginalized groups or weak actors in supply chains (Hochedez, 2022; Rubio and Amaya, 2021; Fantini, 2023a, 2023b; Murray et al., 2023). In this context, environmental fairness emerges as a key concept, emphasizing the role of environmental practices in mitigating or exacerbating inequalities. Building on these foundations and in alignment with other studies, this research adopts a comprehensive framework centered on distributive, procedural, and interactional fairness augmented by environmental fairness, setting the stage for a complete examination of fairness dynamics within the agro-food chain (Figure 3).

Connecting blockchain, fairness and marketing communication

A blockchain is essentially a decentralized, distributed, and public digital ledger that records transactions across multiple computers. This feature gives blockchains significant potential to improve traceability and overall performance by offering enhanced security and transparency. A blockchain serves various purposes, including the efficient recording of each asset's movement through the supply chain nodes. This unified approach parallels the physical product's journey (Azzi et al., 2019; Litke et al., 2019; Rejeb et al., 2020).

However, the integration of blockchain into agrifood systems presents both opportunities and challenges that demand comprehensive exploration. While blockchain proponents emphasize its potential to foster trust, transparency, and efficiency by eliminating intermediaries and ensuring payment execution via smart contracts, skeptics caution against exacerbating power imbalances, disproportionately burdening small producers, who are generally less familiar with this technology, and posing challenges in data verification (Tripoli and Schmidhuber, 2020; De Vries, 2020; Miatton and Amado, 2021; Rejeb et al., 2020; Klaus, 2017; Yiannas, 2018; Azzi et al., 2019; Allena, 2020; Pournader et al., 2020; Rejeb et al., 2020; Saurabh and Dey, 2021; Singh et al., 2022; Alamsyah et al., 2023). Other authors suggest that blockchain can sometimes serve mostly for marketing purposes than for ensuring genuine transparency (Bager and Lambin, 2020; Bager et al., 2022).

This complex scenario necessitates further attention and exploration to unlock blockchain's full potential and ensure equitable benefits across supply chain stakeholders. In this context, this study adopts a theoretical model (Figure 4) that elucidates the interconnectedness between blockchain transparency, fairness, and marketing, offering insights into how these realms mutually influence and shape each other within the coffee supply chain. This model is an original and exploratory framework designed to address a specific research gap through a heuristic and deductive approach. It builds on recent literature addressing global coffee chains, business and corporate strategies, fairness in agri-food systems, and the potential

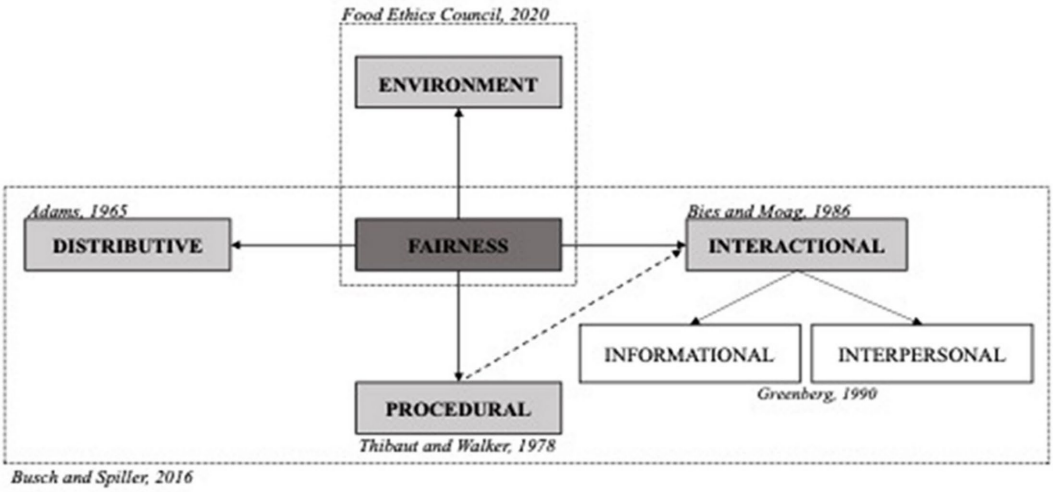

FIGURE 3
Fairness in agro-food chain. Source: Del Prete and Samoggia (2023).

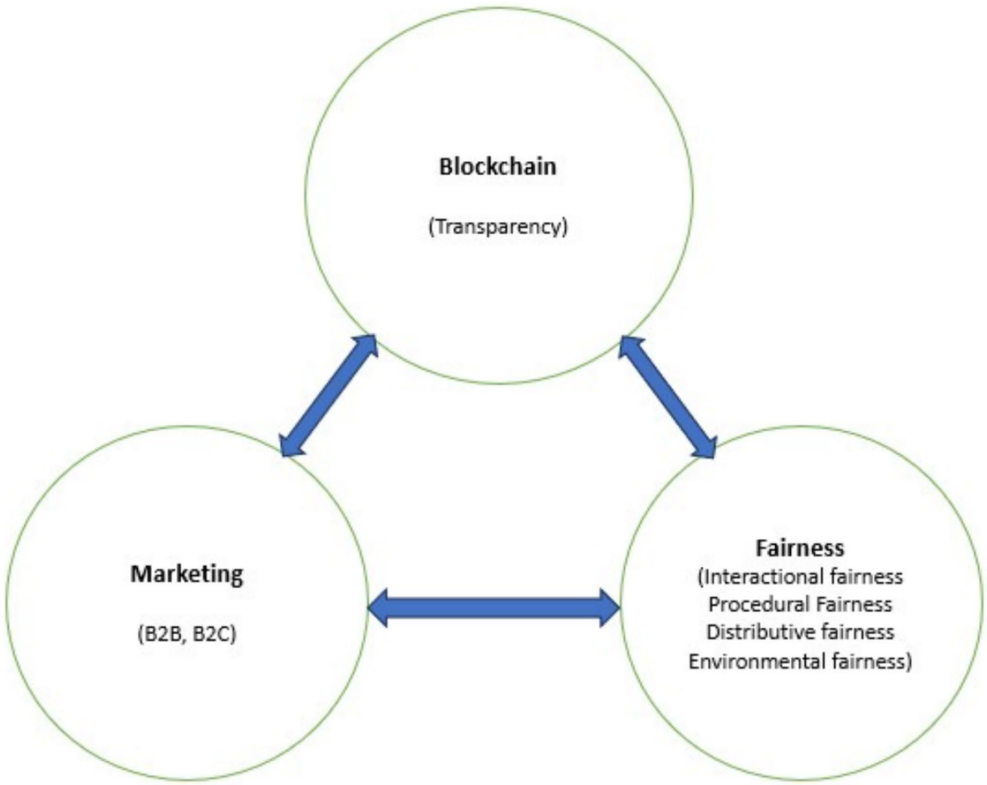

FIGURE 4
Theoretical framework for fairness role of blockchain in coffee supply chains.

of blockchain technology (Ponte, 2019; Samoggia and Beyhan, 2022; Bager et al., 2022; Samoggia et al., 2023; Miatton and Amado, 2021; Azzi et al., 2019; Rejeb et al., 2020; Singh et al., 2022).

The model highlights how blockchain technology can serve dual purposes: it can facilitate marketing and communication efforts, depending on the chosen business model (B2B or B2C), and prioritize transparency and fairness within supply chains. Moreover, it elucidates how the objectives of fairness and marketing communication can mutually influence each other, shaping the utilization of blockchain and impacting both the quantity and quality of information it provides. Greater transparency can foster increased fairness within supply chains (Bies and Moag, 1986; Samoggia and Beyhan, 2022; Samoggia et al., 2023), making it crucial to ascertain the true level of transparency conveyed through the blockchain and the factors influencing it (Rothenberger, 2015; Nai et al., 2020). At the same time, demonstrating greater transparency and a higher level of fairness

within a company's supply chain can serve as a significant competitive advantage. This positions the company as socially and environmentally responsible in the eyes of consumers, enhancing its market appeal. The potential connection among transparency, fairness and B2C marketing activities should also be understood within this context. Additionally, there is a B2B communication aspect. By leveraging the information disclosed through blockchain technology, companies can facilitate improved communication and operational efficiency across the supply chain, fostering stronger partnerships and streamlined processes.

Within this dynamic interplay between corporate strategies and initiatives aimed at enhancing transparency and various types of fairness along the coffee supply chain, specific attributes of coffee roaster companies and their products are likely to play a significant role in influencing the nature and scope of the data disclosed through blockchain technology. For instance, companies deeply committed to social and environmental sustainability may disclose more information compared to those with less commitment in these areas. Similarly, products emphasizing fairness may feature more extensive disclosures on the blockchain than others. Therefore, investigating these connections can yield valuable insights.

Expanding on this model and its underlying assumptions, the following research hypotheses are formulated. The first two hypotheses pertain to the relationship between specific characteristics of companies and coffee products. They are as follows:

> *HP1*. Roaster companies' characteristics influence the amount of fairness relevant information displayed in the blockchain.
>
> *HP2*. Coffee products' characteristics influence the amount of fairness relevant information displayed in the blockchain.

In line with the assumptions of the theoretical framework, it becomes equally compelling to delve deeper into this interaction, analyzing how individual characteristics may lead to specific types of fairness disclosure. Consequently, two additional hypotheses are formulated:

> *HP3*. Roaster companies' characteristics lead to specific types of fairness relevant information disclosure (procedural, interactional, distributive and environmental).
>
> *HP4*. Coffee products characteristics' lead to specific types of fairness relevant information disclosure (procedural, interactional, distributive and environmental).

Methodology

The methodology used includes two stages: data collection and data elaboration.

Data collection

The research involved a detailed review of the websites of roaster companies worldwide, of coffee products, and of blockchain platforms. The coffee roaster companies were identified among the most well known roaster companies at global level, and consequently their coffee products. The blockchain platforms consulted are the following: ThankMyFarmer, Bext360, TrackGood, Ifinca, Fairchain, FoodChain, IBM Food Trust, Xilene, Azure Blockchain Service. This stage of the research was carried out between October and December 2023.

Once the coffee roasters, products, and blockchain platforms were identified, the research initiated the data collection process of coffee blockchain information. It consisted of two steps. First, the information available on the blockchain platforms was categorized into 18 key common aspects, covering logistical, environmental, economic, and procedural factors. The completeness index of information was determined by calculating the percentage of entries in the individual blockchains out of the total 18 defined aspects. Subsequently, each fairness aspect was linked to a specific type of fairness (Table 1) based on the theoretical definitions outlined earlier and on the definitions found in past literature on the various fairness categories (Bies and Moag, 1986; Samoggia and Beyhan, 2022; Samoggia et al., 2023). The research adopts a heuristic and exploratory approach. It is specifically designed to identify and define a set of descriptive elements based on the analysis of existing blockchain platforms and the information they provide. For example, the attribute "farmers information" is linked to procedural and interactional fairness, as it expresses the ability of this attribute to provide insights into the interactive dynamics (informational and relational) among farmers, as well as their role in establishing equitable practices and prices. Similarly, the attribute "health certification" is associated with Interactional and environmental fairness, as it provides information on interactional dynamics, offering supply chain actors' insights into the health conditions of operations and the environmental impact thereof. Conversely, "payments to farmers" is evidently linked to distributive fairness. This is attributed to its role in providing precise quantitative information on the distribution of value within the coffee supply chain. This approach allowed for the assessment of the overall completeness of information provided across the 18 fairness aspects, and the completeness of information related to each type of fairness.

Second, data collection focused on gathering information about the characteristics of the coffee roaster companies and products featured on the blockchain platforms. Roaster companies' characteristics include company financial and economic quantitative (e.g., total volume of production and company size) and qualitative data (e.g., participation in sustainability programs, market type, geographical location of the company headquarters etc.). Financial and economic quantitative data were gathered from ORBIS financial statements database (Bureau van Dijk—2024), and qualitative data by consulting roaster companies' websites and official company reports, such as annual, sustainability or corporate responsibility reports. Products' characteristics, collected through extensive consultation of blockchain platforms and companies' websites, include features such as "product storytelling," "price" or "existence of certifications."

Tables 2, 3 provide the list of the information and data collected, along with the rationale behind their selection. Each information was operationalized in a string or numeric value (% or binary value). In addition to clarity, this method of data collection offers the significant advantage of replicability.

Data elaboration

Data and information used in data elaboration

The subsequent stage aimed at defining the variables for data elaboration. The dependent variable was a percentage expressing the

TABLE 1 Blockchain information aspects and link to a specific type of fairness.

Information provided (blockchain)	Procedural fairness (PF)	Interactional fairness (IF)	Distributive fairness (DF)	Environmental fairness (EF)
Region of origin	×			
Farmers information	×	×		
Health certification		×		×
Phytosanitary certification				×
Harvesting information	×	×		×
Coffee and drying information	×			×
Transport documentation	×			
Traceability documentation	×	×		
Lab analysis				×
Payments to farmers and other actors (distribution of value along the chain)			×	
Presence of certifications	×	×	×	×
Process/transport dates	×			
Roasting location	×			
Import country	×			
Export country	×			
Country of distribution	×			
Visible and accessible transactions	×		×	
Accessible smart contract	×		×	

magnitude of fairness relevant information displayed in the blockchain. This value was derived from a compilation of the frequency of information occurring in the examined blockchains, for a total of 18 attributes (Table 1). This set of information was classified according to the theoretical framework (Figures 1, 2), referencing various types of fairness. Each blockchain displayed different fairness relevant information. The cumulative value of these individual pieces of each product fairness relevant information was the dependent variable (index of fairness relevant information completeness) expressed in percentages. Roaster companies' and products' characteristics were identified as independent variables. Some characteristics have a descriptive role and given their limited variability, they were excluded from further model elaboration processing. Regarding roaster companies, these characteristics were: "headquarters," "international operations," "business perspective," "employee advocacy," "collaboration with NGOs" and "diversification of product portfolio." Regarding coffee products, these characteristics were: "coffee quality," "bean variety," "flavor profile."

Data elaboration steps

The data elaboration included three different steps. First, the initial step focused on processing data of the coffee roaster companies. The risk of collinearity was excluded through careful selection and VIF (variance inflation factor) check, establishing a set of independent variables. Some variables ("corporate social responsibility initiatives" and "current transparency initiatives") were excluded due to the presence of collinearity. The variables kept after this selection, defined as explanatory variables were: "trend of production value in the last 6 years," "company Size," "extent of global presence" (market type), "existence of transparency programs," "strength of commitment" (fair trade practices). Subsequently, a linear multivariate regression was conducted, with the magnitude of fairness relevant information completeness in the blockchain as the dependent variable and considering $p < 0.05$ as the threshold for significance.

Second, the same methodology was applied to product data, seeking to identify which product characteristics might influence the amount of fairness relevant information completeness present in the blockchain. In this case, the potentially explicative variables were: "price," "coffee quality," "presence of blockchain information on the packaging," "existence of certification," "product storytelling." To facilitate a better assessment of response variations based on these characteristics, a dichotomous approach was adopted. The dichotomization cut-off was established by indicating the presence of a specific characteristic or by analyzing frequencies and averages of the factors.

Finally, aligning with the established theoretical framework, the research evaluated the level of fairness potentially conveyed by the information in the blockchain, by linking individual information aspects to specific types of fairness (procedural, interactional, distributive, and environmental fairness), and calculating frequencies and percentages. This allowed to identify which type of fairness is most valued in the information accessible to the end user.

The final step involved conducting linear multivariate regressions for each type of fairness to either confirm or reject hypothesis 3 and 4. Data elaboration was performed using IBM SPSS Statistics 28.

TABLE 2 List of roaster companies characteristics and definition of variables, rationale and source of information.

Characteristic	Variable (for each roasting company)	Value	Rationale	Source of information
Headquarters	Geographical area	0 = North America; 1 = Europe; 2 = Asia	This variable may help determine whether cultural or economic differences among various regions can influence the adoption of blockchain technology	Website, blockchain platform
Financial performance	Trend of production value in the last 6 years	% of variation (from 2016 to 2022)	Financially stable companies may have the resources to invest in blockchain technology	ORBIS financial statements database
Company size	Company size based on total production volume	0 = Small and medium; 1 = Large (based on EU recommendation 2003/361: less than 250 employees = Small and medium enterprises; more than 250 employees = Large enterprises)	Larger companies may have more resources to invest in blockchain technology	ORBIS financial statements database
International operations	Extent of global presence (market type)	0 = Regional; 1 = Global	Companies with international operations may face additional complexities in supply chains, influencing interest in blockchain for transparency	ORBIS financial statements database, website
Business perspective	Business model	0 = B2B; 1 = B2C (business-to-business; business-to-consumer)	Different business models may prioritize distinct information for the end user of the blockchain	Company's website
Employee advocacy	Internal programs promoting employee well-being	0 = No; 1 = Yes	Companies with strong internal advocacy for fairness may be more inclined to extend these values to their supply chains through blockchain	Company's website, blockchain platform
Corporate social responsibility (CSR) initiatives	Presence and extent of CSR programs	0 = No; 1 = Yes	Companies with a strong commitment to social responsibility may be more inclined to adopt blockchain for fairness	Company's website, blockchain platform
Current transparency initiatives	Existence of company transparency programs	0 = No; 1 = Yes	Companies already engaged in transparent practices may be more inclined to adopt blockchain for further transparency	Company's website, blockchain platform
Commitment to fair trade	Strength of commitment: involved in fair trade practices	0 = No; 1 = Yes	Companies with a strong commitment to fair trade may see blockchain as a tool to enhance their existing efforts	Company's website, blockchain platform
Collaboration with NGOs	Partnerships with non-governmental organizations (NGOs)	0 = No; 1 = Yes	Collaboration with NGOs may reflect a commitment to ethical practices, impacting interest in blockchain adoption	Company's website, blockchain platform
Distribution channels	Presence in various distribution channels (e.g., supermarkets, specialty stores, cafes)	0 = No; 1 = Yes	The diversity of distribution channels may impact the perceived need for transparency and fairness	Company's website, blockchain platform
Diversification of product portfolio	Range of coffee products offered	0 = No; 1 = Yes	Companies with a diverse product portfolio may have different considerations for transparency across different product lines	Company's website

Results

Coffee roaster companies and products applying blockchain technology

The research identified 47 products and 25 roaster companies that implement blockchain technology (Table 4). The selected roaster companies are small to medium-sized and large businesses, and reflect the coffee market's diversity. These companies operate in various continents (North America 5, Europe 19, Asia 1), ensuring a broad covering of various global contexts. No roaster companies from other continents were present at the time of analysis.

Furthermore, the results show that most coffee roasters identified have a business to consumer perspective (B2B = 2, B2C = 23), have

TABLE 3 List of products characteristics and definition of variables, rationale and source of information.

Characteristic	Variable (for each product)	Value	Rationale	Source of information
Price	€/kg	0 = Less or equal to 30 €/kg (average coffee price); 1 = More than 30 €/kg	A higher price may indicate a product of superior quality, suggesting increased assurances of fairness	Website
Coffee quality	Specialty coffee	0 = No; 1 = Yes	Labeling coffee as "specialty" may signify heightened focus on the quality and thoroughness of information to be incorporated into the blockchain	Website, blockchain platform
Bean variety	Arabica vs. Robusta, heirloom varieties	0 = Arabica 100%; 1 = Blend	Different bean varieties have distinct flavors and characteristics, affecting consumer demand and potentially the desire for transparency	Website, blockchain platform
Flavor profile	Detailed flavor descriptions on packaging	0 = No; 1 = Yes	Companies emphasizing specific flavor profiles may be more concerned with maintaining the integrity of their product through transparent sourcing	Website, blockchain platform
Product storytelling	Inclusion of detailed narratives about the coffee's journey on packaging or marketing materials	0 = No; 1 = Yes	Companies emphasizing the story behind their products may be more inclined to adopt blockchain for storytelling transparency	Website, blockchain platform
Presence of blockchain information on the packaging	Presence of a QR code or links on the packaging	0 = No; 1 = Yes	The inclusion of blockchain information on product packaging may indicate an intention to boost the perceived value of this technology, concurrently serving as a strategy to promote a transparent image for the company	Website, blockchain platform
Existence of certifications	Presence of certification label on the packaging or specific product blockchain	0 = No; 1 = Yes	The presence of certification labels may imply a greater attention to transparency throughout the supply chain	Website, blockchain platform

internal programs promoting employee well-being (employee advocacy: no = 21, yes = 4), are present in various distribution channels (e.g., supermarkets, specialty stores, cafes) (distribution channels: no = 4, yes = 21), and have a diversified range of coffee products offered (diversification of product portfolio: no = 4, yes = 21). Moreover, coffee products are mostly made with Arabica vs. Robusta, as bean varieties (bean variety: Arabica = 44, blend = 3), and provide a detailed flavor descriptions on packaging (flavor profile: no = 44, yes = 3).

Coffee roaster companies' and product characteristics' influence on fairness relevant information in blockchain

The first analysis concerns the companies' characteristics. The study reveals a noteworthy positive significance concerning "strength of commitment" ($p = 0.009$; $B = 0.417$). In contrast, negative significant values are observed for "company size" ($p = <0.022$; $B = -0.480$) (Table 5). This shows that higher levels of "strength of commitment" and "existence of transparency programs" are associated with an increased amount of information displayed on the blockchain. Conversely, larger company sizes and higher trends of production value over the years are linked to a lower amount of information on the blockchain.

This observation may imply that roaster companies that are already established or solidifying their position in the market might be less inclined to share comprehensive fairness relevant information about the supply chain. In this context, blockchains could be perceived more as tools to provide an image of transparency rather than facilitating full transparency. Non-significant values are recorded for the variables related to "existence of transparency programs" and "market type."

Thus, it can be affirmed that hypothesis HP1 is confirmed: some coffee roaster companies' characteristics have an impact on the amount of fairness relevant information disclosed through the blockchain technology.

Regarding the analysis associated to the products characteristics (Table 6), significant and positive values are particularly evident for the variables "presence of blockchain information on the packaging" ($p = 0.012$; $B = 0.386$), "product storytelling" ($p = 0.019$; B = 0.388) and "existence of certifications" ($p = 0.040$; B = 0.272). This could mean that more fairness relevant information is shared where there is a greater interest in showing transparency. In contrast, no significance is observed for the remaining variables: "price," and "coffee quality." Therefore, it can be affirmed that hypothesis HP2 is confirmed: some coffee products' characteristics have an impact on the amount of fairness relevant information disclosed through the blockchain technology.

Fairness values

Concerning the distribution of fairness types, the results highlight two notable aspects warranting deeper investigation. Firstly, there is a discernible imbalance among the fairness types represented in the blockchain information. Out of the 18 selected attributes, procedural fairness stands out as the most frequently represented type (14 attributes refer to this type), while other fairness types, notably distributive fairness and interactional fairness, exhibit lower representation (4 attributes). Table 7 provides a detailed resume of the distribution of various fairness types. Certain blockchain attributes, such as the presence of certifications or farmers information, demonstrate associations with multiple fairness types.

Moreover, Table 7 incorporates the average percent coverage values for each fairness type, revealing another noteworthy aspect marked by significant disparity. Specifically, attributes linked to procedural fairness showcase the highest coverage across the blockchains of various roaster companies. Conversely, other attributes, notably interactional fairness and distributive fairness, have lower average values (40.96 and 34.81, respectively). This implies that the information conveyed by blockchain gives priority to certain aspects over others.

The subsequent step involved conducting additional regressions to examine potential correlations between the roaster companies and products characteristics and the promotion of diverse forms of fairness. The independent variables were the same characteristics employed in the preceding regressions. In each regression, a distinct type of fairness was selected as the dependent variable.

The outcomes of these analyses associated to the roaster companies' characteristics are presented in Table 8. As evident from the table, values vary across different fairness types, with "company size" and "strength of commitment" consistently displaying the most significant impact. Notably, "company size" exhibits negative and significant values for procedural, distributive, and environmental fairness (−0.047, −0.016, and −0.017, respectively). This suggests that, when it comes to company size, large companies tend to assign less value to three out of four fairness types compared to small and medium-sized companies. This aligns with the earlier discussion about the quantity of disclosed information.

Similarly, significant values are observed for "strength of commitment," recording significant values for procedural, distributive, and environmental fairness (0.034, 0.017, and 0.07, respectively). This confirms that a stronger and stated commitment, especially regarding fair practices, is associated with a higher valuation of these fairness types.

"Existence of transparency programs" shows significant values only in the regression with procedural fairness (0.047), while other features do not yield significant values. In the case of interactional fairness, none of the features exhibit significant values. The R and R^2 values are acceptable for all regressions, except of interactional fairness, which presents lower values (0.399 and 0.142, respectively). Therefore, the results confirm hypothesis HP3: some roaster companies' characteristics lead to specific types of fairness relevant information disclosure.

TABLE 4 Selected coffee roaster companies and number of products with blockchain technology.

Roaster company name	Number of products	Geographical area (headquarters)
1850	1	North America
Andytown Roasting	1	North America
Barcaffè	1	Europe
Beyers 1769	2	Europe
Blendstar	1	Europe
Caffè Barbera	3	Europe
Caffè San Domenico	1	Europe
Crazy Mocha	1	North America
Glaede	4	Europe
Grand	2	Europe
Goodlife	1	Europe
Happy Belly	4	Europe
Hema	4	Europe
Lavazza	1	Europe
La Semeuse	1	Europe
Moyee Coffee	4	Europe
Musetti	1	Europe
Nescafé (Nestlè)	2	Europe
Nula	2	Europe
Orang Utan Coffee	1	Europe
Philocoffea	4	Asia
Rainbow Coffee	1	Europe
Segafredo Zanetti	1	Europe
Starbucks	1	North America
Sucafina	2	Europe

TABLE 5 Multiple regression model on coffee roaster companies' characteristics and fairness relevant information in blockchain.

Variable	Standardized β	Sig.	VIF
Company size	−0.480	<0.022**	1.927
Strength of commitment (fair trade practices)	0.417	0.009**	2.398
Existence of transparency programs (sustainability report)	0.419	0.172	2.388
Market type	0.070	0.699	1.662
Trend of production value (last 6 years)	0.005	0.821	1.274

Number of observations = 25. $R^2 = 0.633$; adjusted $R^2 = 0.537$. The R and R^2 values surpassing 0.5 validate the reliability and soundness of the model. The standardized regression coefficient (β), representing the standardized relationship between the dependent and independent variables, ranges from −480 to 0.419. Additionally, all VIF values are below 4, indicating that there is no risk of collinearity. Significance levels: $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *.

TABLE 6 Multiple regression model on coffee products characteristics and fairness relevant information in blockchain.

Variable	Standardized β	Sig.	VIF
Price	−0.210	0.211	1.914
Coffee quality	0.030	0.836	1.595
Product storytelling	0.388	0.019**	1.954
Existence of certifications	0.272	0.040**	1.286
Presence of blockchain information on the packaging	0.386	0.012**	1.676

Number of observations = 46. $R^2 = 0.474$; adjusted $R^2 = 0.410$. The R and R^2 values for product characteristics are slightly lower than those observed for company characteristics. The standardized regression coefficient (β) ranges from −0.210 to 0.657, and all variance inflation factor (VIF) values are below 4, indicating the absence of collinearity. Significance levels: $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *.

TABLE 7 Presence of fairness types in blockchain information: absolute and relative frequency, and average percent coverage.

	Absolute frequency	Relative frequency	Completeness—average value (%)
Procedural fairness	14	77.8	68.22
Interactional fairness	4	22.2	40.96
Distributive fairness	4	22.2	34.81
Environmental fairness	5	27.8	49.64

TABLE 8 Multiple regression model on companies characteristics and fairness types in blockchain.

Companies characteristics	Standardized β	Sig.	VIF
Procedural fairness			
Company size	−0.484	0.047*	1.927
Strength of commitment (fair trade practices)	0.581	0.034*	2.398
Existence of transparency programs (sustainability report)	0.201	0.047*	2.388
Market type	0.116	0.589	1.662
Trend of production value (last 6 years)	−0.025	0.893	1.274
Interactional fairness			
Company size	−0.345	0.205	1.927
Strength of commitment (fair trade practices)	0.383	0.207	2.398
Existence of transparency programs (sustainability report)	0.216	0.468	2.388
Market type	0.195	0.433	1.662
Trend of production value (last 6 years)	−0.035	0.873	1.274
Distributive fairness			
Company size	−0.587	0.016*	1.927
Strength of commitment (fair trade practices)	0.649	0.017*	2.398
Existence of transparency programs (sustainability report)	0.138	0.583	2.388
Market type	0.315	0.143	1.662
Trend of production value (last 6 years)	0.119	0.515	1.274
Environmental fairness			
Company size	−0.587	0.017*	1.927
Strength of commitment (fair trade practices)	0.649	0.007**	2.398
Existence of transparency programs (sustainability report)	0.138	0.583	2.388
Market type	0.315	0.143	1.662
Trend of production value (last 6 years)	0.119	0.515	1.274

Number of observations = 25. Procedural fairness: $R^2 = 0.633$; adjusted $R^2 = 0.537$. Interactional fairness: $R^2 = 0.321$; adjusted $R^2 = 0.142$. Distributive fairness: $R^2 = 0.516$; adjusted $R^2 = 0.388$. Environmental fairness: $R^2 = 0.399$; adjusted $R^2 = 0.326$. Significance levels: $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *.

TABLE 9 Multiple regression model on coffee products characteristics and fairness types in blockchain.

Products characteristics	Standardized β	Sig.	VIF
Procedural fairness			
Price	−0.194	0.185	1.689
Coffee quality	0.151	0.285	1.595
Product storytelling	0.421	0.010**	1.954
Existence of certifications	0.400	0.003**	1.286
Presence of blockchain information on the packaging	0.340	0.023*	1.676
Interactional fairness			
Price	−0.202	0.168	1.689
Coffee quality	0.141	0.318	1.595
Product storytelling	0.309	0.053	1.954
Existence of certifications	0.451	<0.001***	1.286
Presence of blockchain information on the packaging	0.393	0.009**	1.676
Distributive fairness			
Price	−0.153	0.313	1.689
Coffee quality	0.186	0.209	1.595
Product storytelling	0.415	0.014*	1.954
Existence of certifications	0.454	0.001**	1.286
Presence of blockchain information on the packaging	0.285	0.063	1.676
Environmental fairness			
Price	−0.141	0.376	1.927
Coffee quality	0.194	0.211	2.398
Product storytelling	0.462	0.009**	2.388
Existence of certifications	0.460	0.002**	1.662
Presence of blockchain information on the packaging	0.175	0.270	1.274

Number of observations = 25. Procedural fairness: $R^2 = 0.497$; adjusted $R^2 = 0.436$. Interactional fairness $R^2 = 0.497$; adjusted $R^2 = 0.436$. Distributive fairness: $R^2 = 0.457$; adjusted $R^2 = 0.391$. Environmental fairness: $R^2 = 0.399$; adjusted $R^2 = 0.326$. Significance levels: $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *.

The values pertaining to products' characteristics are illustrated in Table 9.

It is evident that the values associated with "presence of storytelling" and "existence of certifications" hold significance across all types of fairness. Notably, the value of "existence of certifications" is highly significant for all fairness types (0.003, <0.001, 0.016, and 0.002), underscoring its substantial impact. "Presence of storytelling" remains significantly influential in all cases, except for interactional fairness, where it still maintains a value proximate to the significance threshold (0.053). Furthermore, "presence of blockchain information on the packaging" exhibits noteworthy significance, particularly in relation to procedural and interactional fairness (0.023 and 0.09, respectively).

This implies that the incorporation of specific claims on packaging or websites has an impact on how fairness information is presented. Furthermore, it affirms that the adoption of blockchain technology, to some extent, functions as a marketing tool, since, through these specific claims, it can convey a transparent and trustworthy image of the companies. The absence of significant values for the remaining two selected characteristics indicates that neither "price" nor "coffee quality" seems to have an impact on the displayed fairness information.

The R and R^2 values are acceptable for all regressions, with a slightly lower value in the case of environmental fairness (0.399 and 0.326, respectively).

In conclusion, the results confirm hypothesis HP4: some coffee products' characteristics lead to specific types of fairness relevant information disclosure.

Discussion

Effectiveness of the study and comparison with previous studies

This study delves into the tangible impact of blockchain through an analysis of information released by various roaster companies on their respective platforms. The central challenge was to thoroughly examine how the adoption of this innovative technology genuinely contributes to fostering transparency and conveying fairness relevant information for both upstream and downstream actors.

The chosen model has proven to be effective. Originating from a well-defined theoretical framework and established through a comprehensive review of recent scientific literature on the subject, the identified variables exhibited significant relevance. The regression analysis provided a robust framework for comprehending specific correlations. For example, the decision to encompass companies across the entire size spectrum—small and medium-sized companies,

as well as large companies—yielded an important finding of the research: a discernible inverse relationship between company size and the information displayed on the blockchain.

Equally impactful were the selections of other characteristics, serving as reliable variables to explore the intricate relationship between certain company and product characteristics, the information accessible to blockchain users, and the level of fairness conveyed through this information.

Certain outcomes of this study reaffirm the pivotal role that blockchains can play in enhancing transparency, aligning with assertions made by various authors in recent years (Klaus, 2017; Yiannas, 2018; Azzi et al., 2019; Allena, 2020; Pournader et al., 2020; Rejeb et al., 2020; Saurabh and Dey, 2021). However, aligning with more critical perspectives, a portion of the results refutes the overemphasis on this tool, demonstrating with empirical data that blockchain is not a panacea. Its successful implementation necessitates a deep understanding of both its potential and limitations (Singh et al., 2022; Bager and Lambin, 2020; Samoggia and Fantini, 2023).

Additionally, the analysis exploring the connection between company and product characteristics and different forms of fairness stands out as an innovative aspect of this research.

Blockchain use: between the promotion of transparency and marketing

One of the key objectives of this study was to assess the effectiveness of blockchains in ensuring transparency and completeness of information within global coffee supply chains. The research initially focused on specific attributes within the examined blockchains and later delved into analyzing the potential relationship between selected characteristics related to products and companies and the actual level of information accessible to end users.

As confirmed by the results, which align with other studies (Bager et al., 2022; Singh et al., 2022), blockchain adoption plays a crucial role in securing relevant information on global coffee supply chains, but it does not always guarantee full transparency and fairness relevant information. Notably, critical issues arise concerning the nature of the information shared via blockchain. While there is a substantial focus on environmental and logistical aspects and relational dynamics among involved actors, there is a noticeable scarcity of information concerning the distribution of value along the supply chain. Few companies provide detailed information in this area, creating opacity around one of the crucial aspects highlighted in the literature—the percentage of value retained at the base of the chain, composed of small farmers and wage workers (Bair and Hough, 2012; Lerner et al., 2021; Baquero-Melo, 2023; Moreira and Lee, 2023).

The observation of a negative correlation between companies' size and the level of shared information suggests that, to some extent, blockchain use may primarily serve a marketing and promotional function. In this sense, small and medium-sized companies may have a greater interest in showcasing full transparency to appeal to consumers concerned with fairness. In contrast, larger, established companies might opt to share less sensitive information to avoid competitive exposure or criticism related to value distribution along the supply chain. While this study cannot definitively determine where genuine corporate commitment ends and instrumental blockchain use begins, it highlights the challenge posed by the absence of crucial information in clarifying the underlying asymmetries within the coffee sector (Bager et al., 2022; Samoggia and Fantini, 2023).

On a positive note, the study reveals a significant correlation between the adoption of Fair practices and the level of information shared, indicating the influential role of declared and certified commitments on transparency. This aligns with findings from other authors (Miatton and Amado, 2021) and highlights the promising potential of blockchain technology in the right context.

Regarding the product characteristics, similar dynamics can be observed. The notable aspect is that the characteristics exerting the most positive impact on the disclosed information level are centered on three key elements: the tangible presence of certifications and the incorporation of storytelling and labels linked to the blockchain. While the first characteristic may imply real commitment, the last two are clearly more related to promotion and marketing. This observation reinforces the dual trend in blockchain use: a genuine commitment to transparency and the strategic use of this technology for promotional purposes, focusing on the promotion of a company's "ethical" and "trustworthty" image.

Blockchain use and promotion of fairness

Another goal of this study was to investigate whether the adoption of blockchain could contribute to promoting greater fairness throughout the supply chain. The data reveals a dual and conflicting trend, confirming the focus on aspects of procedural fairness while neglecting distributive fairness. This echoes a previously highlighted point, indicating a certain level of opacity regarding the actual distribution of value along the supply chain.

The confidence expressed by some authors in the ability of blockchains to enhance trust and equity (Klaus, 2017; Tripoli and Schmidhuber, 2020; Yiannas, 2018; Azzi et al., 2019; Allena, 2020; Pournader et al., 2020; Rejeb et al., 2020; Saurabh and Dey, 2021) is challenged by a reality where information about the distribution of value, like the share allocated to farmers or the presence of smart contracts, is often missing. While blockchain-viewable information aligns with observations on its role in marketing and communication (Rejeb et al., 2020), empowering a consumer-centric paradigm and enhancing supply chain efficiency, essential information for ensuring complete fairness is frequently absent. This raises concerns about the extent to which end-users can genuinely understand the intricate dynamics within supply chains, raising doubts on the inherent ability of blockchains to contribute significantly to real transparency and fairness.

Instead, blockchains appear most effective in promoting fairness where concrete commitments, such as certifications and fair practices, are already in place. Trusting in this technology without conditions carries a dual risk: it may be viewed solely as a marketing tool, neglecting the complex context in which it operates, or it may inadvertently generate counterproductive effects (Bager and Lambin, 2020; Singh et al., 2022; Samoggia and Fantini, 2023; Bager and Lambin, 2020). Access barriers to technology can lead to unequal participation, especially by the weakest actors like small farmers. While digital technologies impact power dynamics within the coffee value chain, the actual involvement of producers in value creation may remain limited, subject to decisions by other stakeholders. This highlights the need for deploying blockchain with an appropriate legal

framework and supportive policies to build an effective strategy for fair coffee value distribution and safeguarding the weakest actors in the supply chain.

Coffee value chain governance

The results and discussion make it evident that the current effectiveness of blockchain technology is crucial but contingent on certain conditions. Identifying these conditions is essential to fully harness the potential of this technology. Previous literature has highlighted the inherent limitations of blockchain, similar to other market tools like certifications, labels, and standards, in addressing the structural inequalities within the coffee industry (Bager and Lambin, 2020; Singh et al., 2022). Thus, there is a necessity to formulate a more comprehensive strategy that actively engages policy actors while prioritizing knowledge and education.

Several authors recommend empowering local and international institutions to establish a legal framework ensuring greater transparency and fairness in supply chains (Quiñones-Ruiz et al., 2015; Vellema et al., 2015; Giuliani et al., 2017). Clearly defined regulations that advocate the redistribution of information and decision-making/negotiating power within supply chains, supported by targeted economic policies fostering associations and cooperatives of small coffee farmers and protecting them in their countries of origin, could represent a basis for an effective strategy aimed and rectifying some of the important asymmetries in the coffee sector.

This strategy could be complemented by focused training campaigns targeting actors facing the most significant accessibility challenges, particularly small farmers. In this context, associations and cooperatives of smallholders could assume the responsibility of delivering comprehensive training on blockchain technology usage, as well as elucidating the intricate dynamics of supply chains.

Managerial implications

This study offers valuable insights into the effective use of blockchain in business management. Firstly, the analysis shows comprehensive coverage of aspects related to procedural and environmental fairness, with a slightly lower representation of interactional fairness. However, distributive fairness is notably less represented. In particular, smaller roaster companies exhibit higher transparency and information completeness, suggesting a distinctive advantage for emerging businesses in the competitive landscape. Achieving transparency across all company sizes would not only enhance confidence in equitable value distribution along the chain but also promote products over less transparent competitors.

A second consideration arises from this perspective. While some instances of information deficiency may be attributed to a reluctance to disclose sensitive data, in other cases, it may result from inadequate training in blockchain usage within roasting companies. Allocating resources to training and providing comprehensive information about supply chain processes and actors through blockchain to end users, including consumers, could prove to be a significant competitive advantage over time. This strategic investment has the potential to yield attractive returns and position companies as transformative entities in the coffee sector.

Insights for further research

Strengths, limitations, and critical issues highlighted in the discussion warrant further exploration of a technology with promising potential. The study involved 25 roaster companies, spanning from small and medium-sized businesses to large corporations. Given the growing adoption of this technology, expanding the sample to include more companies and production chains would be beneficial, allowing the insightful findings of this study to be validated on a larger scale. Future research could delve into the actual transformative impact of blockchain on supply chains, examining the real effects over time in terms of fairness and sustainability among various stakeholders.

Another path for further research could explore the economic, political, and social contexts in which blockchain operates. Specifically, it would be interesting to quantitatively test the effectiveness of blockchain in institutional contexts already committed to addressing inequality and opacity in the coffee and other agrifood supply chains, compared to contexts lacking such institutional action. Past literature highlighted the important role of targeted policies and governmental measures in this regard (Quiñones-Ruiz et al., 2015; Vellema et al., 2015; Giuliani et al., 2017), and additional data could provide valuable insights.

Lastly, future research could focus on supporting small actors in the supply chain with the use and spread of this technology. Understanding variations in the quality and quantity of information entered into the blockchain among small actors with full training from independent sources (e.g., associations or cooperatives) compared to those with limited training or training from roaster companies would be particularly interesting.

Conclusion

The present study shed light on the potential and real impact of one of the most innovative technologies in recent years, namely blockchain. It delved into this by examining the information provided by various roaster companies on their respective platforms, focusing on a key aspect of blockchain—its ability to enhance transparency and fairness within coffee supply chains.

The chosen model, derived from existing literature on blockchain technology and an initial analysis of specific dynamics within global coffee supply chains, proved to be effective. Regressions, based on selected factors, revealed a correlation between certain characteristics of companies and products in the sample and the quantity and quality of information disclosed through blockchain. This allowed for an assessment of the link between blockchain usage and its actual effects. Specifically, it helped determine the extent to which these features could contribute to promoting greater fairness within supply chains. The analysis of both the quantity and quality of disclosed information, along with its connection to specific types of fairness, painted a concrete and detailed picture of blockchain technology's role in ensuring transparency and conveying fairness relevant information within supply chains.

In line with existing literature, this study highlights the promising potential of blockchain technology, yet also acknowledges its limitations. Notably, it suggests that the effectiveness of blockchain, like other technologies, is more pronounced in socio-political contexts where supply chain asymmetries are already being addressed through significant institutional measures and appropriate policies. In these

contexts, blockchain can serve as an excellent enhancer and catalyst for ongoing processes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AS: Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Validation, Writing – review & editing. AF: Data curation, Formal analysis, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. RG: Conceptualization, Funding acquisition, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was funded by the project "Rafforzamento della capacita istituzionale per favorire la competitività e sostenibilità del settore agricolo e lo sviluppo delle aree rurali in Colombia" (Strengthening institutional capacity to foster the competitiveness and sustainability of the agricultural sector and the development of rural areas in Colombia), funded by Agenzia Italiana per la Cooperazione allo Sviluppo (AICS), European Union, Food and Agriculture Organization of the United Nations (FAO)-Cooperation Program DRET II, Contract No. AID 012184/01/0.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Adams, J. S. (1965). Inequity in social exchange. *Adv. Exp. Soc. Psychol.* 2, 267–299. doi: 10.1016/S0065-2601(08)60108-2

Alamsyah, A., Widiyanesti, S., Wulansari, P., Nurhazizah, E., Dewi, A. S., Rahadian, D., et al. (2023). Blockchain traceability model in the coffee industry. *J. Open Innov.: Technol. Mark. Complex.* 9:100008. doi: 10.1016/j.joitmc.2023.100008

Allena, M. (2020). Blockchain technology for environmental compliance: towards a "choral" approach. *Environ. Law* 50, 1055–1103. Available at: https://www.jstor.org/stable/27010194

Azzi, R., Chamoun, R. K., and Sokhn, M. (2019). The power of a blockchain-based supply chain. *Comput. Ind. Eng.* 135, 582–592. doi: 10.1016/j.cie.2019.06.042

Bager, S. L., and Lambin, E. F. (2020). Sustainability strategies by companies in the global coffee sector. *Bus. Strateg. Environ.* 29, 3555–3570. doi: 10.1002/bse.2596

Bager, S. L., Lambin, E. F., and Persson, M. (2022). Blockchain is not a silver bullet for agro-food supply chain sustainability: insights from a coffee case study. *Curr. Res. Environ. Sustain.* 4:100163. doi: 10.1016/j.crsust.2022.100163

Bair, J., and Hough, P. A. (2012). The legacies of partial possession: from agrarian struggle to neoliberal restructuring in Mexico and Colombia. *Int. J. Comp. Sociol.* 53, 345–366. doi: 10.1177/0020715212468354

Baquero-Melo, J. (2023). Labour control regimes in the rural and urban workplaces of global production networks: the coffee case of Colombia. *J. Agrar. Change* 23, 247–265. doi: 10.1111/joac.12499

Bies, R. J., and Moag, J. S. (1986). "Interactional justice: communication criteria of fairness" in Research on negotiation in organizations. eds. R. J. Lewicki, B. H. Sheppard and B. H. Baseman (Greenwich, CT: JAI Press), 43–55.

Borrella, I., Mataix, C., and Carrasco-Gallego, R. (2015). Smallholder farmers in the speciality coffee industry: opportunities, constraints and the businesses that are making it possible. *IDS Bull.* 46, 29–44. doi: 10.1111/1759-5436.12142

Berkes, F. (2017). Environmental Governance for the Anthropocene? Social-Ecological Systems, Resilience, and Collaborative Learning. *Sustainability*. 7, 1232. doi: 10.3390/su9071232

Dal Mas, F., Massaro, M., Ndou, V., and Raguseo, E. (2023). Blockchain technologies for sustainability in the agrifood sector: a literature review of academic research and business perspectives. *Technol. Forecast. Soc. Chang.* 187:122155. doi: 10.1016/j.techfore.2022.122155

De Vries, A. (2020). Bitcoin's energy consumption is underestimated: a market dynamics approach. *Energy Res. Soc. Sci.* 70:101721. doi: 10.1016/j.erss.2020.101721

Del Prete, M., and Samoggia, A. (2023). Does fairness matter? Consumers' perception of fairness in the agro-food chain. *Front. Sustain. Food Syst.* 7:1116319. doi: 10.3389/fsufs.2023.1116319

Fantini, A. (2023a). Urban and peri-urban agriculture as a strategy for creating more sustainable and resilient urban food systems and facing socio-environmental emergencies. *Agroecol. Sustain. Food Syst.* 47, 47–71. doi: 10.1080/21683565.2022.2127044

Fantini, A. (2023b). Right to the city or environmental gentrification? A discussion about risks and potential of urban agriculture. *Urban Geogr.* 44, 1003–1010. doi: 10.1080/02723638.2023.2174351

Gereffi, G. (2018). Global value chains and development: redefining the contours of 21st century capitalism. Cambridge: Cambridge University Press.

Giampietro, M., Mayumi, K., and Ramos-Martin, J. (2009). Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM): theoretical concepts and basic rationale. *Energy* 34, 313–322. doi: 10.1016/j.energy.2008.07.020

Giuliani, E., Ciravegna, L., Vezzulli, A., and Kilian, B. (2017). Decoupling standards from practice: the impact of in-house certifications on coffee farms' environmental and social conduct. *World Dev.* 96, 294–314. doi: 10.1016/j.worlddev.2017.03.013

Hochedez, C. (2022). Food justice: processes, practices and perspectives. *Rev. Agric. Food Environ. Stud.* 103, 305–320. doi: 10.1007/s41130-023-00188-4

Holling, C. S. (2001). Understanding the complexity of economic, ecological, and social systems. *Ecosystems* 4, 390–405. doi: 10.1007/s10021-001-0101-5

International Coffee Organization (2021). Coffee development report: the future of coffee. London: International Coffee Organization.

International Trade Centre (2021). The coffee guide. *4th* Edn. International Trade Centre: Geneva, Switzerland.

Klaus, I. (2017). Don Tapscott and Alex Tapscott: blockchain revolution. *New Glob. Stud.* 11, 47–53. doi: 10.1515/ngs-2017-0002

Lerner, D. G., Pereira, H. M. F., Saes, M. S. M., and Oliveira, G. M. D. (2021). When unfair trade is also at home: the economic sustainability of coffee farms. *Sustainability* 13:1072. doi: 10.3390/su13031072

Litke, A., Anagnostopoulos, D., and Varvarigou, T. (2019). Blockchains for supply chain management: architectural elements and challenges towards a global scale deployment. *Logistics* 3:5. doi: 10.3390/logistics3010005

Miatton, F., and Amado, L. (2021). Fairness, transparency and traceability in the coffee value chain through blockchain innovation. Proceedings of the International

Conference on Technology and Entrepreneurship—ICTE. April 20–21, 2020, San Jose, CA, USA.

Moreira, U., and Lee, K. (2023). Governance and asymmetry in global value chains of the coffee industry: possibility for catch-up by emerging economies. *Seoul J. Econ.* 36:1. https://ssrn.com/abstract=4372460

Murray, D. S., Cole, I., Nunez, N., Parker, E. M., Mikulis, A., Herreid, A. M. (2023). The environmental responsibility framework: A toolbox for recognizing and promoting ecologically-conscious research. *Earth's Future*, 11, e2022EF002964. doi: 10.1029/2022EF002964

Nai, J., Kotha, R., Narayanan, J., and Puranam, P. (2020). Transparency and fairness in organizational decisions: an experimental investigation using the paired ultimatum game. *Strategy Sci.* 5, 55–70. doi: 10.1287/stsc.2019.0100

Pergamo, R. (2020). La blockchain: la tecnologia e l'applicazione al settore agroalimentare. *Pianeta PSR* 93. available at: https://www.pianetapsr.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/2414

Ponte, S. (2019). Business, power and sustainability in a world of global value chains. London: Zed Books Ltd.

Pournader, M., Shi, Y., Seuring, S., and Koh, S. C. L. (2020). Blockchain applications in supply chains, transport and logistics: a systematic review of the literature. *Int. J. Prod. Res.* 58, 2063–2081. doi: 10.1080/00207543.2019.1650976

Preiser, R., Biggs, R., De Vos, A., and Folke, C. (2018). Social-ecological systems as complex adaptive systems: organizing principles for advancing research methods and approaches. *Ecol. Soc.* 23:art46. doi: 10.5751/ES-10558-230446

Quiñones-Ruiz, X. F., Penker, M., Vogl, C. R., and Samper-Gartner, L. F. (2015). Can origin labels re-shape relationships along international supply chains?—the case of Café de Colombia. *Int. J. Commons* 9:416. doi: 10.18352/ijc.529

Rejeb, A., Keogh, J. G., Zailani, S., Treiblmaier, H., and Rejeb, K. (2020). Blockchain technology in the food industry: a review of potentials, challenges and future research directions. *Logistics* 4:27. doi: 10.3390/logistics4040027

Rothenberger, S. (2015). "Fairness through transparency: the influence of price transparency on consumer perceptions of price fairness" in Working Papers CEB 15-008, (Bruxelles: Université Libre de Bruxelles), 1–32.

Rubio, D. I. C., and Amaya, A. O. (2021). Impacto ecológico, social y económico de fincas certificadas en buenas prácticas agrícolas y comercio justo. *Cuad. Desarro. Rural* 17:2020. doi: 10.11144/Javeriana.cdr17.iese

Samoggia, A., Argiriou, A., Mallidis, I., Früh, S., Beyhan, Z., Fantini, A., et al. (2023). An exploration of agro-food chain distributive, procedural and interactional fairness in food products. *Front. Sustain. Food Syst.* 7:1209414. doi: 10.3389/fsufs.2023.1209414

Samoggia, A., and Beyhan, Z. (2022). Fairness-enabling practices in agro-food chain. *Sustainability* 14:6391. doi: 10.3390/su14116391

Samoggia, A., and Fantini, A. (2023). Revealing the governance dynamics of the coffee chain in Colombia: a state-of-the-art review. *Sustainability* 15:13646. doi: 10.3390/su151813646

Saurabh, S., and Dey, K. (2021). Blockchain technology adoption, architecture, and sustainable agri-food supply chains. *J. Clean. Prod.* 284:124731. doi: 10.1016/j.jclepro.2020.124731

Singh, C., Wojewska, A. N., Persson, U. M., and Bager, S. L. (2022). Coffee producers' perspectives of blockchain technology in the context of sustainable global value chains. *Front. Blockchain* 5:955463. doi: 10.3389/fbloc.2022.955463

Thibaut, J., and Walker, L. (1978). A theory of procedure. *Calif. Law Rev.* 66:541. doi: 10.2307/3480099

Tripoli, M., and Schmidhuber, J. (2020). Emerging opportunities for the application of blockchain in the agri-food industry. Rome and Geneva: FAO and ICTSD.

Vellema, W., Buritica Casanova, A., Gonzalez, C., and D'Haese, M. (2015). The effect of specialty coffee certification on household livelihood strategies and specialisation. *Food Policy* 57, 13–25. doi: 10.1016/j.foodpol.2015.07.003

Yiannas, F. (2018). A new era of food transparency powered by blockchain. *Innov. Technol. Gov. Glob.* 12, 46–56. doi: 10.1162/inov_a_00266