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EDITED BY
Ashutosh Dhar Dwivedi,
Copenhagen Business School, Denmark

REVIEWED BY
Sébastien Boillat,
University of Bern, Switzerland
Desiree Daniel,
University of Bern, Switzerland

*CORRESPONDENCE
Christina Singh,
christina.singh@posteo.net
Aleksandra N. Wojewska,
aleksandra.natalia.wojewska@univie.ac.at

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Coffee producers' perspectives of blockchain technology in the context of sustainable global value chains

Christina Singh[1]*, Aleksandra N. Wojewska[2]*, U. Martin Persson[3] and Simon L. Bager[4]

[1]Cowi A/S, Kongens Lyngby, Denmark, [2]Department of Development Studies, Faculty of Social Sciences, University of Vienna, Vienna, Austria, [3]Department of Space, Earth, and Environment, Physical Resource Theory, Chalmers University of Technology, Gothenburg, Sweden, [4]Earth and Life Institute (ELI), Université catholique de Louvain, Georges Lemaître Centre for Earth and Climate Research (TECLIM), Louvain-la-Neuve, Belgium

Transparency and equitability are key for improved sustainability outcomes in global value chains. Blockchain technology has been touted as a tool for achieving these ends. However, due to the limited empirical evidence, claims on transparency and sustainability benefits are largely theoretical. We lack an understanding of the benefits and drawbacks for upstream actors within global value chains and how this affects technology adoption. Addressing this gap, we conduct an empirical study to identify the drivers and obstacles for coffee producers in Colombia in adopting blockchain. We base our research on an event-driven and permissioned blockchain model, specifically designed for this research. Applying the Participation Capacity Framework and conducting semi-structured interviews with coffee producers and key informants, we analyze adoption attitudes towards the blockchain application. We further identify opportunities and drawbacks from the producers' perspective. We set these findings in the context of the Global Value Chain research, considering the existing power relations in the coffee value chain. The top-down nature of blockchain projects raises distributive concerns, as resource investments, implementation burden, and risks are significantly higher upstream, whereas downstream lead firms will benefit most. We identify data squeeze as an additional channel of sustainable supplier squeeze relevant in the case of blockchain initiatives. Data squeeze implies lead firms turning the data obtained through, likely unpaid, labour of blockchain participants into a monetizable assets and marketable value through branding and advertisement. Based on the findings, we identify potential design dimensions and implementation features that can contribute to materializing producer benefits, thus mitigating the risk of a sustainability-driven supplier squeeze.

KEYWORDS

blockchain, sustainability supplier squeeze, Colombia, coffee value chain, case study, adoption of innovation

1 Introduction

Coffee is the second most popular beverage globally, with a daily consumption of three billion cups. In 2019, global coffee production exceeded 10 million tons, 60% of which is grown by smallholder producers in over 70 tropical and sub-tropical countries (International Trade Centre, 2021). 75% of the total coffee production is exported, equaling an annual value of 20 billion USD on average in recent years.

While the total industry value is estimated at 200 billion USD, only 10% remains in the producing regions (Panhuysen and Pierot, 2020). In fact, coffee producers often operate at a loss, due to low and volatile global market prices (Panhuysen and Pierot, 2020). In response, coffee producers have over time shifted from agroforestry systems to dense, monoculture plantations with full sun exposure. While increasing yields in the short-term, this production system places stress on the coffee plants and is more prone to spread of pests and diseases, requiring constant agrochemical input (Grabs, 2020). Further, this management practice is greenhouse gas emission intensive, and contributes to deforestation, thereby driving climate change, ecosystem decay and biodiversity loss (Grabs, 2020; IDH, 2020).

Coffee is produced, processed, and traded in global value chains that are fragmented and scattered across actors and locations, often exhibiting a high degree of informality regarding labor contracts and farm-gate transactions (Grabs and Ponte, 2019). Informal and complex supply-chains imply conditions of production become inscrutable for downstream consumers, making it difficult to assess the overall sustainability performance (Ponte et al., 2019; IDH, 2020). Voluntary sustainability standards (VSS), such as Fairtrade and Rainforest Alliance, emerged as a reaction to the increasing complexity and adverse sustainability impacts of global value chains (Lambin and Thorlakson, 2018; Grabs, 2020). VSS comprise "requirements that producers, traders, manufacturers, retailers or service providers may be asked to meet, relating to a wide range of sustainability metrics" (UNFSS, 2013, p. 4). While the design and conceptualization of VSS heavily relies on the expertise and legitimacy of non-governmental organizations (NGOs), adoption and implementation are driven by upstream value chain actors (Lambin and Thorlakson, 2018).

Recent research has focused on the effectiveness of VSS in delivering social, economic and environmental sustainability outcomes for agri-food commodities in general and for coffee specifically, finding positive and neutral impacts in equal parts (Bray and Neilson, 2017; Meemken, 2020, 2021; Marx et al., 2022). While Meemken (2020) found that producers that are certified under a VSS obtain 20–30% higher prices, Bray and Neilson (2017) found that only Fairtrade and organic certification schemes deliver positive economic outcomes for coffee producers.

Further, asymmetrical power distribution in global supply chains lead to limited market access, price volatility risk, and lack of agency for smallholders. These combined disadvantages result in an uneven distribution of profits across the value chain, with actors upstream receiving the lowest share (Miatton and Amado, 2020). In this context, VSS can result in a supplier cost squeeze, as producers bear costs of certification schemes, alongside disproportionate business risks (Ponte, 2020). While placing the burden of adopting and documenting sustainable practices on the producers, the value added from sustainability initiatives is captured by powerful downstream companies (so-called "lead firms") that reap the benefits in terms of branding and market share (Ponte, 2020). Consequently, Meemken et al. (2021) conclude that while VSS help improve sustainability in agri-food supply chain, they are insufficient to drive transformational change of production systems and value chains, due to limited uptake. Supply chain mapping and data systems, including distributed ledger technologies (DLT) such as blockchain, enable tracing the source of all products, therefore potentially delivering more granular and source-specific sustainability information than VSS. Such tools can be integrated in VSS, thus potentially accelerating efficiency and uptake while reducing transaction costs (Tröster, 2020; Köhler, 2021).

Due to its tamperproof properties, blockchain is a suitable technology to facilitate collaboration in global value chains mitigating the risk of fraud and corruption (Kshetri, 2017; Wang et al., 2019; Bullón Pérez et al., 2020; Tröster, 2020). Blockchain is a decentralized system maintained across several computers that are linked in a peer-to-peer network. This specific type of database records all transactions and the data entered is immutable (Pavlić Skender and Zaninović, 2020). Vadgama and Tasca (2021) identified 271 different blockchain projects over the past decade, the majority of them within agri-food commodities and freight and trade. While the authors observed lower failure rates over the years, major challenges regarding the achievement of sustainability goals remain; technological infrastructure and know-how among commodity producers, data quality and validity in particular due to self-reporting and linking a digital record to a physical commodity, maintaining provenance throughout large scale processing, and high resource requirements (Bager et al., 2022b).

So far, research has mainly focused on the technical aspects of blockchain implementation. However, if blockchain is to have a real-world impact, we must also understand the social and behavioral aspects (and challenges) of implementing blockchain systems (Schmidt and Wagner, 2019; Köhler and Pizzol, 2020). Coffee supply chains are already suffering from large power asymmetries between actors (Fischer, 2017; Bager and Lambin, 2020). Depending on the design, adoption, and application, blockchain technology can exacerbate or alleviate these power asymmetries. Köhler and Pizzol (2020, p. 8) stress that the "system architecture of blockchain-based technologies can be designed to benefit specific actors", and Howson (2020, p. 5) suggests that, so far, blockchain technology is mainly "enabling larger companies to cost effectively protect their brand images". Thus, the implementation of DLT such as blockchain yields different consequences and incentives along the value chains in the context of the existing power relations.

Effective implementation of blockchain in supply chain management requires collaboration and coordination of actors across the whole value chain, a process that is both time and resource intensive. At the same time, companies place high hopes on the positive outcomes that these technologies could deliver in terms of social, economic, and environmental sustainability. However, a crucial knowledge gap remains, namely identifying the distribution of these outcomes and what benefits and drawbacks the use of the technology yield for different actors across the global value chain (Schmidt and Wagner, 2019). Our empirical study contributes to addressing of this knowledge gap, by analyzing the case of Colombian coffee producers' intention to adopt a blockchain model that was designed as part of an interdisciplinary research project. We utilize the Participation Capacity Framework (Wojewska et al., 2021) in the context of existing power relations in the coffee value chain to identify the key drivers and obstacles from the perspective of coffee producers see to successful adoption of the blockchain model.

2 Materials and methods

2.1 A research project to assess the potential of blockchain for sustainable supply chains

This paper is one of the outputs of the research project "Using blockchain to accelerate sustainability, transparency and traceability in bio-based value chains". The project was funded by the COWI foundation and implemented by an interdisciplinary project team. Project partners included the consulting company COWI (project lead), Copenhagen University (Departments for Geosciences and Natural Resource Management, and Computer Science), the IT University of Copenhagen, and Chalmers University of Technology, as well as the Swedish coffee importer and roaster Löfbergs, and their Danish subsidiary Peter Larsen Kaffe respectively.

The overall objective of this project is to assess the potential of blockchain technology to accelerate sustainability in bio-based supply chains and demonstrate the real-world applicability of blockchain technology. To reach this objective, we conducted scoping, data collection and literature review and developed an event-driven blockchain model.

Using the case of coffee, we conducted a pilot test with Peter Larsen Kaffe's value chain from Antioquia, Colombia involving six coffee producers and report the finding in a series of peer reviewed papers including this one. Bager et al. (2022a) describe the programming-related aspects of the model, while Bager et al. (2022b) describe the full case study, including the challenges and opportunities of employing blockchain to address sustainability issues for each supply chain node. Instead of examining an existing and fully operational blockchain solution for supply chain management, we hence map Peter Larsen Kaffe's supply chain in Colombia, including stakeholder consultations, and develop a prototype.

This paper is devoted to the upstream actors of the value chain; the coffee producers. We study their adoption attitudes regarding the event-driven blockchain model in the context of the existing power dynamics in the coffee value chain.

2.2 A theoretical framework for analyzing blockchain adoption

As a conceptual framework for this paper, we employ an adapted Participation Capacity Framework (Wojewska et al., 2021) to explore the potential participation of coffee producers in blockchain-based digitization of their transactions. Based on two theories - the Theory of Planned Behavior (Ajzen, 1991; Ajzen, 2012; Ajzen and Kruglanski, 2019) and the Diffusion of Innovation theory (Rogers, 2003)—the framework assumes that cognitive and affective factors, in an interplay with the external context, influence the decision of an individual to participate in a planned project or policy (Meijer et al., 2015). We apply this framework in the context of global value chains to analyze the potential participation of coffee producers in supply chain transactions involving blockchain-technology. We do not measure actual participation in a blockchain project, as the producers are faced with a hypothetical scenario of an application roll-out. Instead, we focus on the process of forming intentions to participate and how that is likely to determine participation in a blockchain project.

While, in this paper we are interested in outcomes for a specific stakeholder group—the coffee producers - the multi-stakeholder nature of blockchain projects requires a broader look at the dynamics in the whole chain which is addressed in Bager et al. (2022b). In our analysis and discussion, we draw upon Global Value Chains literature, which analyses how geographies of production, input-output structures, institutional setting and power and governance struggles between actors in the chain interact and influence dynamics of production and trade (Gereffi, 1995). In particular, we draw upon a concept which has also been applied in studies of tropical commodity production—"sustainability-driven supplier squeeze" (Ponte, 2019, 2020).

The concept of "sustainability-driven supplier squeeze" describes a dynamic where upstream producers bear the costs of sustainability initiatives in the value chain, while the lead firms

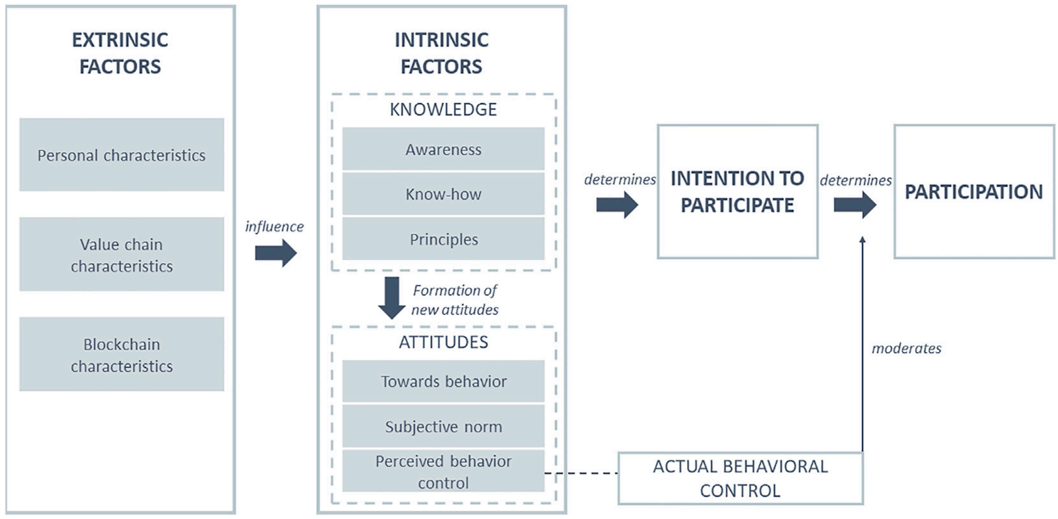

FIGURE 1
Participation Capacity Framework linking the Theory of Planned Behavior (Ajzen, 1991; Ajzen, 2012; Ajzen and Kruglanski, 2019) and the Diffusion of Innovation theory (Rogers, 2003), based on (Wojewska et al., 2021).

TABLE 1 Overview of the components of extrinsic factors.

Extrinsic factors	Components
Personal characteristics	• Demographic factors
	• Socio-economic factors
	• Personality-related factors
	• Position in social networks
Value chain characteristics	• Geographies of production
	• Input-output structure
	• Actors and institutions
	• Power and governance
Innovation characteristics	• Design elements
	• Implementation
	• Ideological background
	• Costs and benefits
	• Risks and challenges
	• Communication channels

capture greater value from the sale of "sustainably-produced" commodities or goods (Ponte, 2019, 2020). We apply this lens to elaborate on the characteristics of the blockchain project in the context of the existing power relations in the coffee value chain from the perspective of coffee producers. In our analysis, we discuss how power relations in the global value chain relate to the potential social and economic sustainability outcomes of employing the blockchain model.

The proposed framework (Figure 1) suggests that an individual's intention to adopt a given innovation or not is determined by a set of intrinsic and extrinsic factors. Extrinsic factors fall into three categories—personal characteristics, value chain characteristics and innovation characteristics. The components of each factor are detailed in Table 1. Extrinsic factors contribute to the intention to participate as they are assumed to provide a structure within which knowledge and attitudes of an individual are formed.

Intrinsic factors, which lie at the center of the framework, can generally be defined as cognitive and affective elements of the intention to participation formation. The Participation Capacity framework draws upon two typologies: types of knowledge distinguished by Rogers (2003) and types of attitudes following (Ajzen, 1991; Ajzen, 2012; Ajzen and Kruglanski, 2019).

In this framework, knowledge is broken down into two components: 1) "know-how," i.e., the technical or practical knowledge of the processes related to the innovation, and 2) principles knowledge, that is the information about theoretical and functioning processes underlying how the innovation works which later allows the participants to judge the effectiveness of the innovation.

Based on the Theory of Planned Behavior, we distinguish three attitude components. First, the attitude towards behavior is a collection of individual's personal thoughts and feelings about the behavior and reflects expectations and evaluations. Second, the subjective norm is the social context surrounding that behavior and individual's beliefs of how social referents want

TABLE 2 Variables that proxy intrinsic factors in the context of blockchain adoption.

Intrinsic factors	Components	Variables in the context of blockchain
Knowledge	Know-how	Current documentation practices regarding production and business transactions as a proxy for know-how of processes related to participating in the blockchain
	Principles	Intersection between sustainability, the coffee market (including premia for fair trade certification and high-quality coffee), and the role of technology in general and blockchain more specifically as proxies for ability to judge the value of transparency and traceability provided by blockchain
Attitudes	Towards blockchain	The first impression, as well as reflections and expectations related to blockchain for coffee supply chains
	Subjective norm	Significant others relevant for the adoption of blockchain include the neighbors and fellow coffee producers
	Perceived behavioral control	Subjective descriptions of capabilities, resources (time, money, and know-how), and confidence

the person to behave. Third, perceived behavioral control relates to the perceived ability to perform a certain behavior, i.e., it expresses the extent to which a person believes they have the means and resources necessary (such as time, money, skills, and cooperation of others) to perform the behavior and refers to people's confidence in their own ability (i.e., self-efficacy). The perceived behavioral control is a subjective reflection of the individual's actual behavioral control, which is the degree to which a person actually has the skills, means, and other prerequisites that are necessary to participate. Table 2 lists the components of both knowledge and attitude and details the variables in the context of this study. The participation is moderated by actual behavioral control; however, it is not an observable (Ajzen and Kruglanski, 2019). Therefore, we use current behaviors exhibited by the producers as a proxy for actual behavioral control.

2.3 Data collection and analysis

As part of the project, we conducted initial field research in the coffee producing region Antioquia in January 2020, facilitated by the cooperative of coffee producers from Antioquia and the National Federation of Coffee Growers (FNC). During this visit, we conducted interviews with various value chain actors: five coffee producers and two staff from the cooperative that manage purchasing points and held two focus groups and one transect walk with staff from the cooperative's headquarters and AlmaCafé at the dry mill.

From the 270 cooperative-associated coffee producers in Titiribí and Heliconia, we randomly selected 31 producers for semi-structured interviews. Due to the COVID-19 pandemic, the project team could not return to Colombia; therefore, we engaged a local field assistant to conduct one-on-one structured interviews in Spanish during November–January 2021. We recorded and transcribed the interviews and coded these with MaxQDA.

We structured the interview guide with the aim of generating data about household composition, coffee production practices and management, technical endowment, and production documentation habits, as well as attitudes and intentions towards using a blockchain-based application for coffee transactions ("attitudes towards blockchain"). We did not expect any prior knowledge about blockchain[1].

In addition, we organized follow-up interviews with the two managers of the purchasing point and a focus group with six staff from the cooperative's headquarters to obtain qualitative data on the cooperative's perception of blockchain for supply chain management. The field assistant conducted the interviews with the purchasing point managers in Spanish and we facilitated a Spanish-speaking focus group online *via* Google Meet. These interviews inform our assessment of the extrinsic factors in the results section.

3 Results

Below we analyze the results from the coffee producer interviews, structured according to the theoretical framework for understanding blockchain technology adoption decisions. Extrinsic factors include socio-economic factors, features of the environment in which coffee producers reside in and characteristics of the blockchain intervention. These features, more quantifiable in nature, provide a structure within which we discuss the interplay of intrinsic factors in determining the intention to participate.

1 Blockchain was introduced as follows: A specific type of database that is managed decentralized and where it is impossible to manipulate the data after entering it. Blockchain technology can be helpful for sharing and receiving information among participant across the value chain. Coffee buyers, for example, can get information about the farms from which they source their coffee and farmers can obtain information about quality, pricing and production methods. We brought the prototype with us to test it with Löfbergs' coffee sourced from Antioquia.

TABLE 3 Summary of socio-demographic characteristics of the interviewed producers.

Municipality	No of producers	Gender *proportion female*	Age *mean years*	Education *mean [median] years*	Size of coffee plantation *mean ha*
Heliconia	19	0.16 (3/19)	55	5.67 [4.5]	1.86
Titiribí	12	0.33 (4/12)	63.67	9 [9.5]	2.06
Total	31	0.23 (7/31)	58.35	6.9 [5.5]	1.95

3.1 Extrinsic factors

3.1.1 Personal characteristics

Table 3 provides an overview of the interviewees' gender distribution, average age, education level, and the average size of their coffee plantation. Coffee is a highly relevant income source for farmers in the area. Except for two business owners, the interviewees' main occupation is coffee production. Only five households are engaged in multiple income generating activities, with secondary income from other formal employment.

All interviewees farm their own land and devote it almost entirely to coffee. Twenty interviewees cultivate coffee on their entire land and only four producers have less than 2/3 of their land under coffee production. The majority grows more than one coffee variety, often on the same plot; most popular is Castillo, followed by Colombia. Coffee producers hire labor (for COP 39,100 per day, ca. EUR 8.68) for their production and additionally rely on family members; producers have issues finding labor during peak harvest. In addition to the lack of qualified labor, coffee producers were worried about unpredictable weather patterns, as well as pests and diseases cause harvest losses and jeopardize the quality of their produce, all factors that increase the producers' vulnerability while directly impacting the producers' livelihoods.

The average age of the coffee producers is quite high (58 years), therefore likely influencing the learning capacity, moderated by a higher level of education among interviewees in Titiribí (on average). The cooperative organizes trainings in the municipalities, though they encountered challenges related to the socio-demographic characteristics of their associates: "There are 11,000 associates, most of them are of advanced age, 60–65 years old and low levels of formal education. [. . .] Our greatest challenges are connected to teaching good practices, as we do not always see that farmers apply what they learned", one employee of the cooperative explained.

Coffee producers live in areas with poor road infrastructure and unreliable phone and data network. Almost all producers had internet access, but 35% of the interviewees reported problems with a stable connection. While mobile phones were widespread, only half of the interviewees had smartphones.

3.1.2 Characteristics of the coffee value chain

Figure 2 shows the value chain of Peter Larsen Kaffe's coffee sourced from Antioquia, split by business operations, actors and coffee processing steps. The figure additionally displays when the blockchain saves an event, including data input.

Antioquia is in central Colombia and is an important coffee producing area, with much of the rural population being involved in coffee production. The main coffee harvest falls between October and December; however, harvest takes place all year round.

The coffee producers of Antioquia are largely smallholder farmers with farming plots of 2 ha. Being members of the Cooperative of Antioquia's Coffee Growers, producers obtain the Fairtrade certification. Typically, producers in the region have their own wet mills to de-pulp the harvested coffee berries. They ferment the berries for 15 h, wash, sun-dry and sort them. These processes take approximately 15 days.

Afterwards the parchment coffee is transported and sold to the closest of the 57 municipal purchasing points that the cooperative operates. The staff at the purchasing point weighs the coffee and samples the coffee to determine quality and checks the size and color of the coffee beans and check for pests. The producer is paid by the kilo, according to a quality-adjusted base price–Fairtrade Minimum Price at USD 1.40 per pound of green coffee, adjusted by the current market price (Fairtrade, 2019).

From the purchasing point, a small-scale logistics company transports the coffee by truck to the central dry milling facility in Medellín, run by AlmaCafé, the exporting partner of the FNC. The dry mill has a maximum storing capacity of 24,000 tons and processes 75 tons every 8 hours. The coffee is stored in silos based on quality, certification, and origin. The milling process transforms parchment coffee to green coffee and classifies it by density, weight, size and color to identify and separate lower grade coffee. After dry milling, the beans are packed for export. The shipment takes 3–4 weeks to reach Karlstad in Sweden, from where it is sent to Viborg in Denmark to be roasted and packaged in Peter Larsen Kaffe's facility.

3.1.3 Producers' perspectives on power relations in the coffee value chain

Some producers reflected on the functioning of the coffee market and their position in the value chain. It was mentioned that the agricultural sector in Colombia, and the coffee producers specifically, do not receive any support and are left with little bargaining power subjected to the interests of bigger market players. One producer exclaimed: "We are just working,

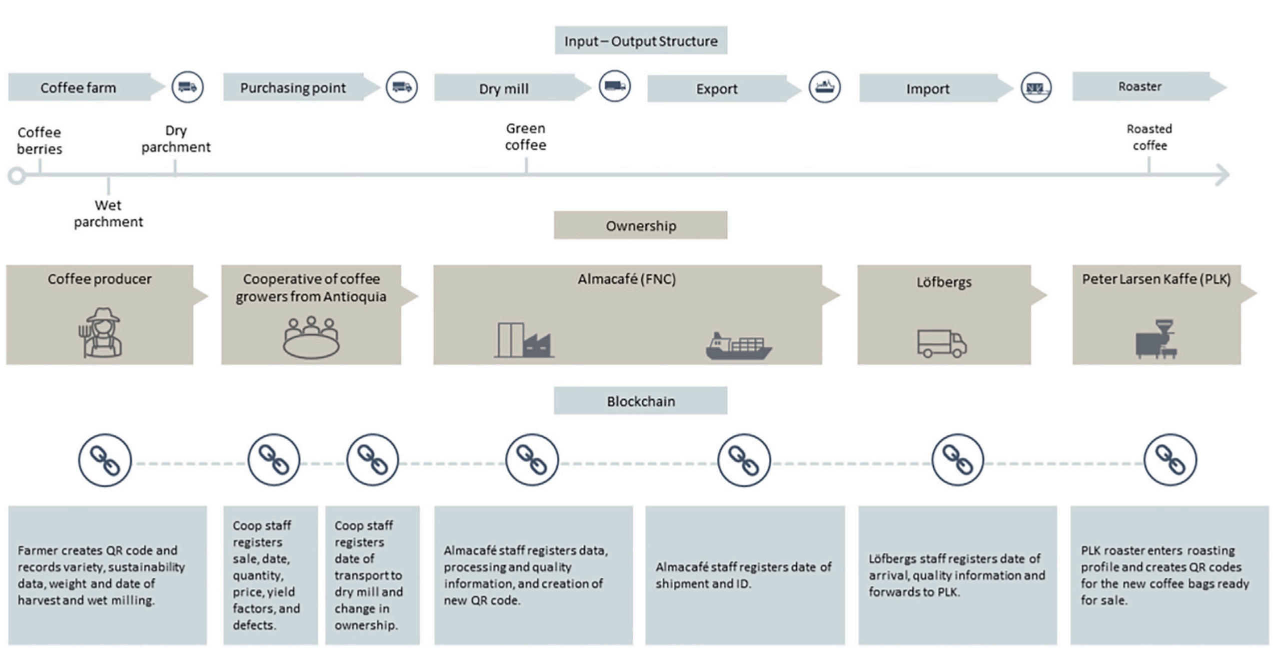

FIGURE 2
The coffee value chain of Peter Larsen Kaffe's coffee sourced from Antioquia and blockchain data entry points.

producing to pay obeisance to these companies, to the cooperative, to the federation and so on" and others realised that the market is governed by fierce competition. Here, opacity was identified as a major barrier: "We coffee growers are blind. We don't notice anything. We just think: 'Well, I'll sell it on Sunday and that is it." Another producer stressed: "You take your coffee to the cooperative, but you don't know where they are taking it next." Several producers acknowledged their low agency with resignation or sarcasm: "Ah, no. Let them do whatever they want with that coffee, let them pay for it what they want, but don't you dare cheating, this will fall on you. They will reject your coffee, for whatever reason they make up."

Two producers realised that the lack of transparency suits the downstream value chain actors, they reflected: "Transparency is what we need, but it doesn't suit those who buy coffee from you." and "I don't believe that a company or those who are implementing this technology, send you complete information about everything."

The cooperative would be a key stakeholder when it comes to the diffusion of blockchain technology for coffee supply chains for being the primary buyer of coffee in the region and trusted among the associates.

Coffee producers stated that the cooperative offers the best purchase price. However, there are a few private buyers in the area that have less rigid quality requirements and offer a better price for lower grades. In addition, the private buyers can provide finance to coffee producers with liquidity constraints. Five interviewees thought that the cooperative acts as a price regulator, ensuring fair pay, while four appreciated the proximity, ease, and good network of purchasing points, including reliable opening hours. Another recurring theme was the stability of dealing with the cooperative as a business partner. One producer elaborated: "I will always sell to the cooperative because I trust them. There may be private individuals that pay you a little more, but I still go to the cooperative." Two producers said that there was a lack of private buyers in their vicinity, while only three producers had the impression that private buyers take advantage of them.

The cooperative receives a fixed Fairtrade Premium at USD 0.20 dollar per pound of coffee (Fairtrade, 2019), which it uses for trainings and workshops, physical assets that service educational, productivity, or environmental purposes, and to provide financial services to the members. 38.7% of the producers mentioned the farm and household support that the cooperative provides as a key factor for engaging in business with it. One producer explained: "We are entitled to certain projects, and we have some benefits, for example a credit for fertilizers."

The overwhelming majority of producers saw the cooperative as a source of support and guidance and appreciated the feeling of togetherness (97%). One producer said: "They are our friends who guide us". Only one producer was generally critical of the cooperative, saying "All these quality certificates give the cooperative a bonus. But where is that bonus? Why doesn't the member get a share of that bonus? Do they spend the money on bureaucracy? People say that the cooperative is bankrupt." Despite the critique, he and another producer emphasized the importance of maintaining the cooperative regardless of circumstances–"if we let the cooperative end, what happens? The cooperative leaves and we are left with the few private buyers that dictate low prices.", one of them said. All producers (excluding one who did not answer the question) stated that endorsement of a blockchain application by the cooperative would encourage them to adopt the model, with one emphasizing: "I think that is the most essential thing. Because we, in a way, as members, must continue to have the backing of the cooperative."

3.1.4 Characteristics of the blockchain model

The blockchain-based application has been modelled according to the REALISTIC modelling framework that is built on McCarty's Resources-Events-Agents (REA) accounting model and uses etherium (Bager et al., 2022a). The application is event-driven, which means that new data blocks entered represent time stamped events or transactions, backed by evidence for each event type (e.g., harvest, purchase, dry milling and roasting) (Bager et al., 2022a).

The blockchain follows a permissioned approach where different actors can enter different events. Second and third parties can verify evidence in the form of photos and documents tied to the events. Data is publicly available, which enables both producers and consumers to track and trace product units from farm to cup, while a rich data visualization enhances the experience (Bager et al., 2022a).

As part of the scoping, the project team determined the following design features for the blockchain application (Bager et al., 2022b):

- Transparency and traceability: Coffee origin, product provenance and location tracking
- Prices: Promoting producer payments equity
- Quality: Variety, cupping score, yield factor, *etc.*
- Certification and Validation: Certification standards, auditing
- Sustainability: Covering social parameters such as gender, age, labor conditions and environmental parameters such as agro-chemical use, shade trees and intercropping, and water treatment.

The blockchain model was piloted with six producers, establishing a chain-of-custody, including time of transactions, and connecting coffee to specifics lots and producers. Therefore, the model enables both traceability and transparency in agro-food supply chains, yet several caveats and limitations remain (Bager et al., 2022b). The operational procedures within the coffee value chain involve product transformations (i.e., from coffee cherry to parchment coffee to roasted coffee). This renders the link between digital record and physical commodity challenging. We resolved this by printing QR-codes on the coffee bags, which in theory allows for replacing the coffee in the bags with lower grades i.e., the data on the blockchain might not reflect the actual product characteristics (Bager et al., 2022b). Furthermore, the operations along the value chain are of large scale and involve mixing several lots from different producers. To maintain provenance to producer, these large-scale operations need to be broken down to micro-lot processing which increases costs and lowers efficiency (Bager et al., 2022b).

3.2 Intrinsic factors

3.2.1 Know-how–documentation of coffee production and business transactions

Figure 3 shows the current documentation practices, where only a few producers use technological tools for documenting sales and expenses and general farm management, which relates to the limited endowment with smart devices and the low network reliability in parts of the producer regions.

Half of the coffee producers interviewed use a notebook provided by the cooperative to keep track of farm performance; two of them also use their mobile phones, e.g., for taking pictures of crops or receipts. Only one producer uses a computer for managing his farm, including activity schedule, balance sheet and tracking of plantation performance, summarizing his approach: "You have to manage this like a company, know how much it costs to produce, how profitable it is [. . .] And being organized can be profitable, as you will know where to reduce production costs".

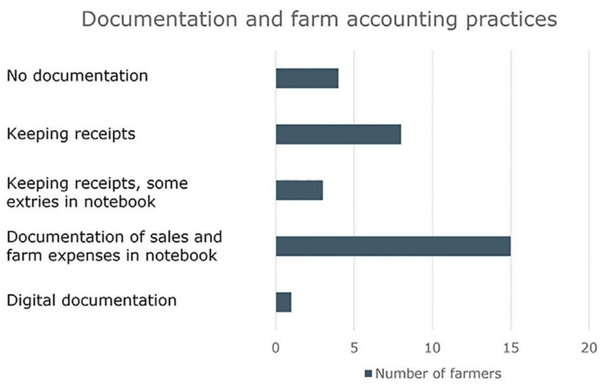

FIGURE 3
Current documentation and farm accounting practices. The vast majority of the interviewed coffee producers (87%) keep track of their coffee sales. Eight producers keep the receipts as a form of documentation and three producers occasionally use their notebooks to complement the receipts. Sixteen producers register additional information on inputs, such as labor requirements and fertilizer costs on a regular basis.

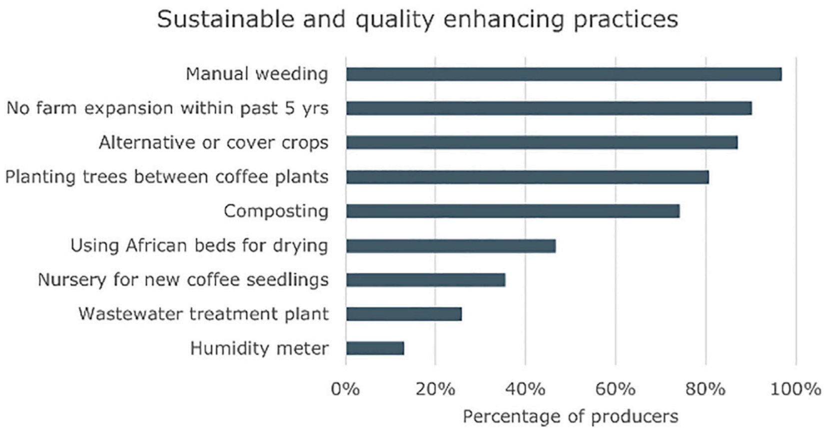

FIGURE 4
Sustainability and quality enhancing practices. The majority of interviewees conduct manual weeding, did not clear forests for additional cropland and plan alternative or cover crops, as well as trees between coffee plants. Composting is also a widespread practice. A "humidity meter" is a portable measuring instrument for the determination of the absolute water content of coffee beans. An "African (drying/raised) bed" is a wood frame stretcher with a suspended netting holding the beans above the ground to allow air circulation above and below the beans, often covered with a tent.

3.2.2 Principles knowledge—understanding of sustainability concerns in production

Figure 4 provides an overview of sustainability and quality enhancing practices that producers undertake. In addition to planting shade trees, easily adoptable practices such as manual weeding and composting prevail. For installing farm equipment such as wastewater treatment plants or African beds, coffee growers rely on the cooperative. Therefore, diffusion of these practices is less advanced.

Despite conducting certain practices, the producers did not associate sustainability directly with higher income (either through better yields or higher prices). This is contrasted by the direct connection that half of the producers drew between quality and price: "According to the quality and the way you handle the coffee, you will be paid better or worse." In addition, nine producers aimed for good quality produce to remain relevant for costumers, and only nine producers did not mention quality as an important feature in the interview. Interestingly, more than half of the coffee producers interviewed were not aware that they were certified by Fairtrade (58%), five of them confused the Fairtrade certification with the yield factor defined by the National Coffee Association, which determines the quality of their coffee. The producers observe the quality checks at the purchasing point to determine the yield factors that decides the price. In contrast, the Fairtrade certification is automatically given to them, for being members of the cooperative. The cooperative in turn ties membership to the Fairtrade certification requirements and scrutinizes its members' business and farming practices accordingly. One producer reflected on the Fairtrade certification in terms of risk of non-compliance: "We have to fulfil certain requirements to keep the label. If you go below the average, you're out."

Half of the interviewees identified unpredictable weather patterns and the outbreak of extreme weather events as obstacles to their production. Some associated this with the risk of unpredictable yields of varying quality: "Sometimes, we don't have a good cup because of the weather; this affects our earnings that season." Most producers established a link between the changing climate and the vulnerability to pests and diseases. For twelve interviewees, prevalent pests and diseases pose a challenge to their coffee production. Here, producers mostly mentioned the coffee borer beetle ("la broca"), alongside other pests such as fungi and coffee leave rust ("la roya"). One producer remembered: "Last year all of a sudden, the broca broke out, and we were not ready to address it."

3.2.3 Attitude towards blockchain—producers' impressions, reflections, and expectations

Nearly all interviewees displayed a positive attitude towards blockchain for coffee supply chains, which stems from their first generally affirmative impression. Out of the 31 coffee producers, only one producer clearly stated that she is not interested in using a blockchain-driven application, while five coffee producers expressed cautioned interest, and would like to know more.

Figure 5 shows the expectations and perceived advantages that led to the positive attitude towards blockchain. Coffee producers mostly appreciated the opportunity of knowing more about the coffee value chain, and the further processing, consumption, and sales price of their product. One producer reflected: "My life revolves around coffee, so naturally, I would

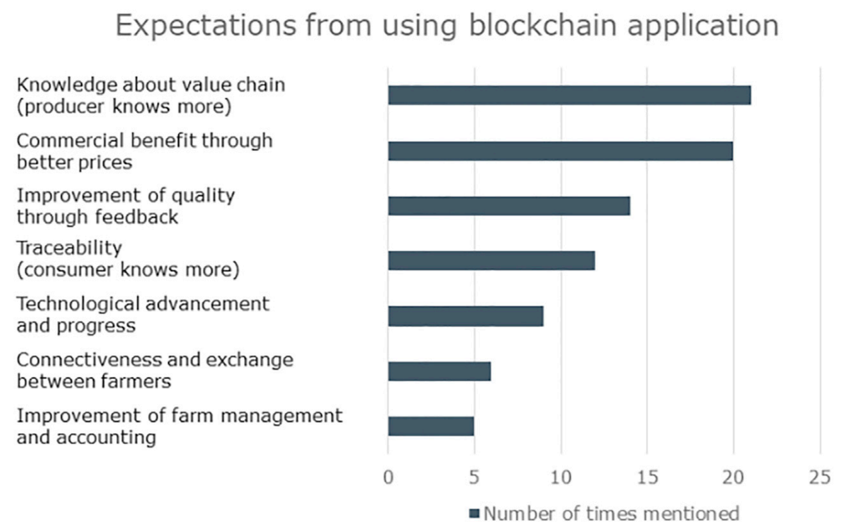

FIGURE 5
Expectations associated with the positive attitude towards innovation. Learning more about the coffee value chain has been mentioned 21 times, commercial benefits through better prices 20 times, improvement of quality through feedback 14 times, traceability by consumers 12 times, technological advancement and progress 9 times, connectiveness and exchange between producers 6 times and improvement of farm management 5 times.

like to stay informed." In addition, producers also hoped for a commercial benefit from using the application in form of higher prices, with some explicitly stating that feedback from the cooperative or customers could lead to quality improvements. Traceability by final consumers was another theme that emerged from the interviews. One producer said: "For me, it is an achievement to be recognized or that someone says 'Ah! This coffee is from this part and that guy'" and another producer appreciated the branding effect that traceability could have. Despite the high average age of the interviewees and the low level of current technological endowment (see Section 3.1.1 and Section 3.2.1), producers appreciated the introduction of new technologies to the countryside and felt the need to become part of the technological progress, while five producers acknowledged that they could benefit from the application for documentation and farm management purposes.

Despite general positive attitudes across the sample, the respondents also acknowledged possible disadvantages of a blockchain model. Four were hesitant about the type of data that the blockchain model would require and data confidentiality: "Some information is very confidential, for example expenses. If someone asks you: how long does it take you to pick a load of coffee? It is ok. But to say how many workers it takes, no." Producers expressed that sharing more detailed information could bring increased attention from governmental agencies, which they saw as a significant drawback of a blockchain model. Two producers also saw the fact that customers could link the product to their farm *via* blockchain as a disadvantage: "If consumers can access data about producers and regions, it would be detrimental to be associated with coffee that smells bad or is of low quality" and added "the more information you provide, the more organized you have to be. There would be many more elements you will have to consider."

3.2.4 Subjective norm—networks and social referents relevant for blockchain adoption

The relationships of individual producers with their neighbors define the subjective norm. Most of the interviewees discussed coffee-related issues with their neighbors. One producer provided a number of examples: "We talk about what fertilizer you are applying, because many do not do soil analysis [. . .] If we have problems with broca, then we tell the neighbor, or if you are collecting or not collecting, whether you are picking the fallen fruits from the ground or not, whether you are spraying or not, because spraying can affect the neighbor." Six interviewees mentioned that such exchanges helped them improve their practices: "And one listens, and one learns from the others. We are all teachers." However, there is an understanding that every producer has their own way of working; producers share ideas but may or may not follow the advice from others. Only four producers explicitly stated that they talked very little with their peers, e.g., one of them explained that "neighbors are always distant."

Regarding adoption of the blockchain model, 64% of the producers emphasized that if others used the application, it would encourage them to use it too, seeing neighbors as a potential source of support; "together, in partnership, it is easier. You support each other", one said. One producer who held a negative overall attitude towards blockchain, said that seeing others use it would maybe influence her to change her mind but summing up "I would first need to see the change before I start believing it." 35% of the producers expressed indifference to whether others participating in the blockchain would influence them in any way. One clearly stated that in his decisions, he relies more on the cooperative than on his neighbors: "I enter my details, and he enters his, so it is as if he has his Facebook and I have mine [. . .] more than anything you rely on the extension officer." Another producer summed up that these kinds of decisions are personal, and everyone knows what is the most beneficial to them, while another added "everyone is free to like it or not".

3.2.5 Perceived behavioral control—subjective descriptions of capability, resources, and confidence

Several coffee producers expressed doubts concerning their capabilities to implement blockchain. In total, twenty producers were uncertain whether they can manage the technology—in this group fourteen producers did not own any technological devices and six owned either a smartphone or a laptop (see Section 3.1.1 and Section 3.2.1 for more detail on technological endowment). One producer for example explained: "This sounds excellent, but one needs to know how to handle the new technology and I am terrible with that". On the other hand, 35% of the producers were confident about their ability to use blockchain technology, all of them having experience using their smartphone and/or other devices. For example, one producer said: "I have not had any issues with this kind of things until now." Almost all producers show willingness to learn the new technology (84%). Several producers showed optimism, providing statements like: "Everyone is capable of everything.", "As long as you're positive, you'll achieve what you set out to do" or "There is nothing difficult in life. Whatever you set your mind to, you do it", while some expressed willingness to learn, but with less confidence "I would like to learn to use new technologies but it is complicated." Producers acknowledged their need for support in learning the technology, as provided by peers, family, or the cooperative. For example, nine suggested that implementing such a technology necessitates simultaneous training and capacity building. One summarized the importance of training for improving confidence in producers' own capabilities: "we have to help people to lose their fear of technology because there are many people who don't know how to use a mobile phone, a smart device. So, first of all, training, helping them to face their fear."

Only two producers doubted that they would live up to the documentation requirements imposed through the application. They called themselves careless and being "very bad at writing things down every day". Considering that most producers keep track of their farming business (see Section 3.2.1), this does not seem to be a constraining factor for most other coffee producers.

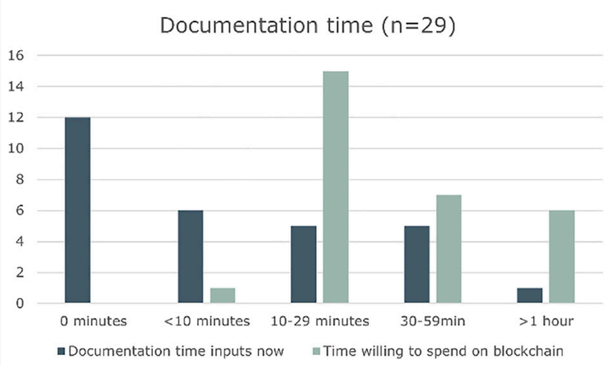

FIGURE 6
Documentation time. On average, producers spend 10.5 min on documentation. Some producers reported ranges of times, while some gave total time a week. We have translated the numbers into minutes per day for comparability. Two producers did not answer the question. 12 producers described that they did not spend any time daily on managing documentation (i.e., they do not document at all or only store receipts). Six producers spend less than 10 min per day on documentation, while five producers reported spending between 10 and 29 min, another five between 30 and 59 min. One producer reported spending more than 1 hour per day on documentation activities.

However, the perception of available time is an important element of adoption of blockchain. Producers had mixed feelings about investing their own resources (e.g., time, money) to use the blockchain model. We asked producers whether they would be willing to pay to use the blockchain application. Thirteen producers were willing to pay, while three producers stated that they would not pay for using blockchain, one of them saying: "No. It is hard for coffee producers to incur in new expenses." Thirteen producers were more hesitant in their assessment and said it depends on other factors, such as the precise benefits received (n = 9), and price to be paid for the application (n = 4). Two producers said they would have to compare the costs and benefits to decide whether they would pay for blockchain, one of them stating he would participate "only if the benefits outweigh the costs."

We asked producers how much time they currently spend on documentation (see Figure 6). Five producers saw it as a disadvantage to dedicate time to work on the blockchain, with one producer stating: "The bad side? At harvest time, in the afternoons, sometimes at 6 or 6:30 p.m., will I really sit down and type in all that information, yes, or no?." Another producer described a possible situation: "Maybe you don't have access to the internet every day or go and sit in an internet cafe and I sit in an internet cafe and take one or three hours."

Apart from the current time resources used on documentation, we inquired about the time the producers are willing to spend on documentation in a blockchain application. On average (excluding two producers who did not answer the question), the coffee producers expected they could allocate 32 min to managing and inputting data into the blockchain, as compared to 10.5 min on average spent on documentation today (see Figure 6). The biggest difference is observable for producers who reported not spending any time on documentation currently—on average, they envision themselves spending approximately 26.5 min per day on blockchain documentation activities.

4 Discussion

We analyze the case of Colombian coffee producers and their intention to adopt blockchain technology, thereby focusing on the social and behavioral aspects of implementing blockchain for more sustainable supply chain management. While the benefits of a blockchain can only be achieved if the solution is considered across the whole chain, producers have least agency in global value chains and are likely exposed to the risk of a sustainability-driven supplier squeeze (Ponte, 2019, Ponte, 2020). In light of existing power imbalances in coffee supply chains perceived by the coffee producers, blockchain technology may further exacerbate the distributional unevenness (Bernards et al., 2022). Most blockchain projects are designed and implemented top-down, representing a form of governance that does not challenge the existing power relations and unevenness of distribution of benefits in the value chain, unless developed in a collaborative process in which all actors can contribute to negotiating its design, implementation, and planned outcomes (Miatton and Amado, 2020). Therefore, we identify a number of design dimensions and implementation features that would contribute to a more equitable distribution of benefits along the value chain.

4.1 Blockchain design—drivers and obstacles

Any equitable blockchain solution would need to increase the benefits for the majority of stakeholders and simultaneously distribute them across suppliers in the chain. Our analysis revealed a general initial enthusiasm towards blockchain, as well as a nearly unanimous willingness to adopt the technology by coffee producers. Coffee producers presume a range of benefits, such as greater knowledge about the other value chain actors, visibility, an opportunity to brand their own product, as well as the possibility for higher commercial benefit *via* improvements in the quality of their product through consumer feedback. The presumed benefits provide a good indication of important design features for an equitable blockchain application: a user interface that shows coffee producers where and to whom their products are sold, a feedback mechanism for roasters to share ideas for alternative farming and processing techniques (e.g., fermentation time) and ample space for own storytelling and branding.

Producers clearly would like more information about the remainder of the value chain, seeing this as a large benefit of the blockchain. However, the design of blockchain in global value chains operates on an expectation of producers being willing to share very detailed data (Eliason, 2022). In our case, the farms whose locations would be recorded in the blockchain are most of the time also places of residence. Few producers perceived concerns around data confidentiality as a drawback of the blockchain model. In addition, producers were wary of sensitive data reaching unwanted parties, as well as being personally associated by customers with a poor-quality product. In addition, coffee producers perceive the increased workload related to mastering a new technology and the burden of inputting very detailed data about their businesses and households as relevant costs associated with the intervention. A blockchain project design should take into account these considerations and seek to overcome them, for example, by limiting the data input to the bare minimum, and by agreeing with the participants on a certain degree of anonymization of data in a multi-stakeholder participatory process. In addition, the focus of system developers could lie on environmental sustainability and quality data to accommodate the producers' reservations on sharing socio-economic information. Furthermore, labor associated with technology and data management should be considered and financially reimbursed, as it is seen as a significant cost by the producers.

Setting these results in the context of the broader global value chain dynamics indicates that the costs of maintaining a blockchain model are likely not distributed evenly. The producers were confident in what kind of benefits they would like to obtain from the blockchain project, as they see opaque power relations in the global value chain, as well as their own low degree of agency and empowerment as problematic. While, overall the producers were enthusiastic, some pointed to the design features of the blockchain technology that allow it to be mobilized as a tool of greater control over the practices they employ or even leading to exclusion of certain producers, who do not meet the standards imposed by the lead firm. When utilized in this way, the blockchain initiatives risk representing another channel of sustainable supplier squeeze (Ponte, 2020), which we term data squeeze. Data squeeze implies lead firms turning the data inputs of producers into monetizable assets and marketable value for their brands *via* advertising, but also obtaining this data through unpaid extra labor of coffee producers.

4.2 Blockchain implementation—drivers and obstacles

Köhler and Pizzol (2020) identified the usability of the blockchain application as a key success factor for implementing blockchains for agri-food supply chain management. The producers would generally be willing to dedicate time to use the blockchain application. However, we observe a significant gap between the current time spent on documentation practices and time willing to be spent on documenting on a blockchain. This indicates a gap between perceived and actual behavioral control and affect the likelihood of long-term participation, especially for producers who currently do not spend any time on documentation. Crucially, some producers indicated that even if they are willing to spend some time on the application, they may not have the capacity, as they already have several immediate tasks related to coffee production.

For a successful integration of blockchain technology in their current documentation practices, coffee producers could rely on their neighbors and identified the cooperative as an important facilitator. This provides a solid basis for the introduction of blockchain technology, through which producers could compare and learn from each other's practices and monitor outcomes (Tröster, 2020). The cooperative is well liked and respected—a suitable change agent (Mitiku et al., 2018). However, the organization may have limited capacity to implement the blockchain model, and training would occur at the cost of other important practices that would immediately improve the sustainability outcomes of coffee production (Bager et al., 2022b). Today, it is already challenging for the cooperative to teach their curriculum due to the associates' age, limited educational background, as well as seasonal pressures on the cooperative's capacity related to coffee sales periods. For the cooperative to assume the role of a change agent, the institution needs to receive additional resources. In the long run, this could be financed through the additional value created by the blockchain solution.

Correct data input into the blockchain and interpretation of data displayed in the application could constitute obstacles (Vadgama and Tasca, 2021). The data is self-reported, and producers have different documentation habits. In any case, blockchain adoption would require diligent documentation practices and additional efforts and time spent (Bager et al., 2022b). Producers expressed concern regarding their limited capabilities to use the technology, which constitutes a high entry barrier. Due to variable connectivity and lack of smart devices, the immediate participation in the blockchain model would be impossible for a significant share of the producers interviewed. Uploading the data at the purchasing point could alleviate this concern. Apart from practical issues related to capacity constraints at the purchasing point on weekends during peak harvest, in such a scenario the producers do not receive the full range of benefits of using the blockchain. They provide their data but cannot so easily access information about other value chain actors and producers.

Our study showed that producers already pursued many sustainable practices in their farming, partly due to Fairtrade requirements. Even though, not all of them were aware that they were Fairtrade certified, as the cooperative handled documentation and compliance, they did reap some monetary and other benefits of the certification scheme. On contrary, in the case of blockchain, it is not clear both how the model would further endorse sustainable production practices, but also whether producers would be directly rewarded for it, while having to manage the additional reporting burden.

In addition to reinforcing existing power relations between supply chain nodes, as discussed in the context of data squeeze, blockchain technology bears the risk of exacerbating inequalities locally. Already prosperous coffee producers that are able to meet technological and sustainability requirements might be the main beneficiaries, while their peers with lesser access to resources are excluded, as already observed in the literature on VSS labels (see e.g., Meemken, 2021). On the one hand, blockchain technology constitutes a useful tool for ensuring living wages for farm workers (Eliason, 2022), on the other hand, some smallholder farmers are likely excluded from participation due to lacking capacities.

Exclusion could also be driven by "conscious consumer choices", when costumers choose coffee with a better sustainability performance without reflecting the reasons behind or having a chance to support lower scoring producers to adopt sustainable farming methods. Recent policy developments such as the German Supply Chain Due Diligence Act, the proposal for an EU Regulation on deforestation-free products, and more rigid and encompassing carbon pricing policies indicate increased focus on mandatory corporate disclosure and new standards for human rights and environmental due diligence for global supply chains. Hence, systems need to be devised such that power imbalances are mitigated not exacerbated, to avoid inequalities both locally and globally.

Our study explored a hypothetical case based on a pilot study with particular focus on the primary producers. A question arises whether producers could harness greater access to information and find ways to use it to gain agency and bargaining power, and if so under which circumstances. Therefore, future research needs to scrutinize our findings against established and fully operational blockchains implemented in global value chains and test applied mitigation mechanisms for critical issues such as top-down governance, cross-chain collaboration and trust and the data squeeze. While this study focused on a particular group and their perspective on the blockchain model in the context of existing power relations, ideally future studies include perspective of multiple stakeholders along the value chain to provide a greater insight into the distribution of benefits and costs along the chain.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. Informed verbal consent was collected from all participants and they were aware of their right to withdraw from the study and/or decline to answer at any point.

Author contributions

CS, SB, and UP contributed to conception and design of the study. CS and AW organized the database and performed the statistical analysis. CS and AW wrote the first draft of the manuscript. UP wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

Author CS was employed by the company Cowi A/S.

The remaining 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.

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