Digital technologies and ecological transition of food systems: A grounded theory analysis of blockchain's contributions to stakeholder engagement in the food transition

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Keywords
blockchain, ecological transition, food waste, food systems, Grounded Theory, stakeholders, traceability, transparency

Abstract
Food systems face a dual challenge: meeting the growing demand for food products while reducing their environmental impact. This situation calls for ecological shifts to foster a transition toward more responsible behaviors. Such an ecological transition requires greater collaboration among producers, processors, distributors, policymakers, and consumers within food supply chains. However, these chains are often characterized by opacity, mistrust, and difficulties in mobilizing all stakeholders around shared objectives. This article aims to provide an abductive understanding of how blockchain influences stakeholder engagement in food supply chains within the context of the socio-ecological transition of Quebec's food systems. To this end, a grounded theory approach was adopted from an interpretive epistemological perspective. Ten semi-structured interviews were conducted with stakeholders from food supply chains to validate the emerging theory. The findings highlight three main functions of blockchain technology: traceability, transparency, and the reduction of food waste. These functions led to the proposition of an emerging theory whereby blockchain acts as a lever for engagement at three levels (micro, meso, and macro), respectively encouraging changes in behaviors, practices, and governance within food systems. From a scientific standpoint, the study strengthens Freeman's stakeholder theory and Geels' multi-level perspective. It also contributes to research on ecological transition, technological innovation, and stakeholder engagement. From a managerial perspective, the study provides an analytical framework to guide project leaders involved in the implementation and/or adoption of blockchain technology in agri-food systems.

Introduction

The ecological transition of food systems requires behavioral changes across all stages of the food supply chain. Beyond reducing greenhouse gas (GHG) emissions, Feng et al. (2020) argue that such changes must also enhance consumer trust and strengthen their engagement in responsible purchasing choices. Consumers are increasingly aware of social, environmental, and health issues in their consumption decisions, paying closer attention to the origin of the products they consume (Li et al., 2023). This evolution in consumer expectations lies at the heart of innovation in the agri-food sector, as it encourages actors to adopt more transparent and responsible practices (Majou, 2020). In this context, the integration of digitalization into the agri-food sector has become a priority.

According to Zarbà et al. (2024), digitalization modernizes the agri-food sector and can contribute to a faster and more effective ecological transition. This digital transformation relies on the integration of innovative technologies, such as blockchain, which facilitate transparency and collaboration within supply chains while reducing the environmental impact of agricultural practices (Li et al., 2023). However, despite these advances, only 10% of food products are currently traced, verified, and certified according to the International Food Fair of Paris (SIAL Paris, 2022). In this context, digital technologies offer promising solutions to the environmental and health challenges facing food systems. Through digitalization, real-time communication networks are established, connecting people, objects, and machines to optimize processes throughout the supply chain (Rousseau & Mondin, 2020).

One of the most promising technologies for ensuring transparency and traceability in food supply chains is blockchain technology. Blockchain is an innovative technology used to store and share information securely and transparently across a network of users (Monica et al., 2019). It is based on a fundamental principle: a distributed and immutable database composed of a chain of encrypted "blocks" (Fiore & Mongiello, 2023). The integration of blockchain technology into the food transition requires collaboration among all actors involved in the food supply chain. Blockchain can also play a key role in managing relationships among supply chain stakeholders by facilitating collaboration and strengthening their commitment to environmentally responsible practices.

Although blockchain offers significant opportunities for the ecological transition of food systems, its adoption remains limited (Rousseau & Mondin, 2020) and requires active stakeholder involvement to maximize its benefits (Antonucci et al., 2019). Actors in the sector—whether farmers, processors, distributors, or consumers—must collaborate to develop appropriate solutions and foster collective engagement in more sustainable practices (Antonucci et al., 2019). Stakeholder engagement thus emerges as a key factor in ensuring the success of this transformation, enabling effective information sharing, improved coordination, and informed decision-making (Gudek et al., 2024; Mysore et al., 2019).

Recent research highlights that the ecological transition of food systems requires collaborative governance and greater transparency among supply chain actors (Antonacci et al., 2019; Kamilaris et al., 2019; Tripoli & Schmidhuber, 2020). Stakeholder theory (Freeman & McVea, 2001; Huttunen et al., 2022) emphasizes the importance of engaging producers, processors, distributors, consumers, and regulators to reconcile often divergent economic, social, and environmental objectives. From this perspective, blockchain technology appears as a strategic lever for improving traceability and data integrity throughout the supply chain (Rousseau & Mondin, 2020; Zarbà et al., 2024), thereby strengthening trust among stakeholders through a shared, tamper-proof, and decentralized ledger (Monica et al., 2019; Fiore & Mongiello, 2023).

The main objective of this study is to explore how blockchain technology influences stakeholder engagement in the ecological transition of food systems. Drawing on the core elements of ecological transition, the study seeks to understand how blockchain can foster behavioral change among stakeholders toward more sustainable food practices through three key attributes of blockchain: traceability, transparency, and the ability to reduce food waste. It also examines how this technology can serve as a lever to strengthen collaboration among different stakeholders, particularly those with a direct impact on food production and consumption. Accordingly, the research problem is articulated around the following question: How do digital technologies, particularly blockchain, influence stakeholder engagement in the ecological transition of food systems?

More specifically, the study seeks to understand:

- how traceability and transparency in supply chains influence stakeholder behaviors toward the ecological transition of food systems;
- how blockchain technology promotes food waste reduction through stakeholder involvement;
- how blockchain facilitates collaboration among different stakeholders to promote more sustainable food systems.

Theoretical background

The theoretical framework of this study is based on two foundational theories: the modeling of stakeholder engagement categories in transitions (Huttunen et al., 2022), grounded in Freeman's stakeholder theory (1984, cited in Bonnafous-Boucher & Rendtorff, 2013), and Geels' modeling of sociotechnical transitions and innovation (2004, 2019), known as the Multi-Level Perspective (MLP).

Huttunen et al. (2022) conceptualize citizen engagement (as civil society stakeholders) in transitions through a framework that emphasizes actors' values and perceptions, the integration of local and practical knowledge, empowerment and learning facilitation, and the mobilization of citizens as resources for knowledge creation. According to Huttunen et al. (2022), stakeholder engagement in sociotechnical transitions is structured around four main objectives (Figure 1):

- identifying public values, preferences, acceptability, and the impacts of the transition, and assessing public preferences;
- envisioning a sustainable future through direct citizen engagement in visioning exercises;
- developing participatory methods to facilitate transitions, including innovative approaches to support transition processes; and
- implementing (local) transitions through learning and empowerment processes within living labs.

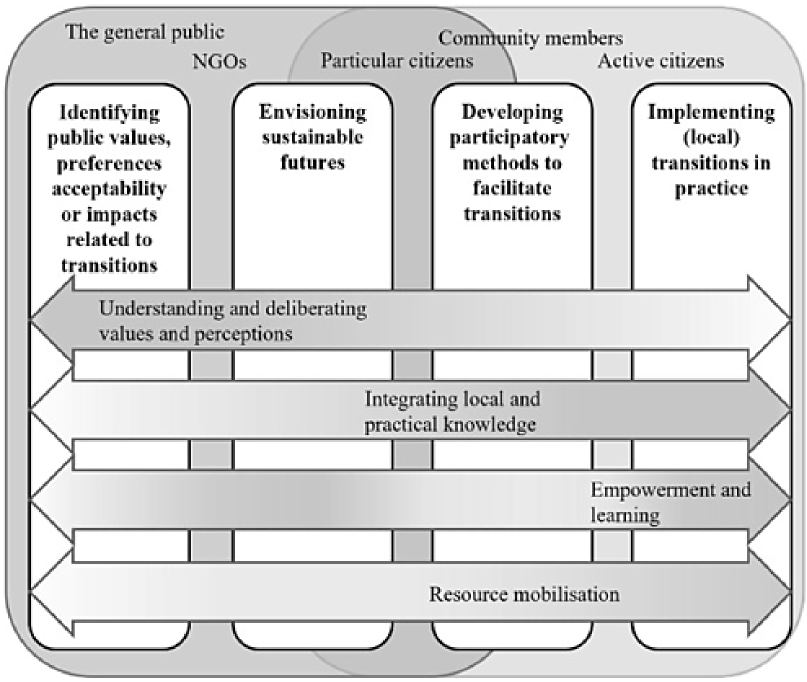

Figure 1: Categories of citizen engagement in transition research. © Huttunen et al. (2022)

Within the scope of this study, the relevance of this theory lies in its ability to enhance understanding of stakeholder engagement in transitions. The objectives of stakeholder engagement developed by Huttunen et al. (2022) constitute essential elements for apprehending research on citizen engagement in transition and sustainability.

The Multi-Level Perspective (MLP), the second theory mobilized in this study, represents a key theoretical framework for understanding transitions (Köhler et al., 2019). It is one among several approaches in the academic debate on social transformations toward sustainability, focusing on transitions within systems (e.g., energy, transport, housing, agri-food systems) that provide societal functions or end-use services (Geels, 2004, 2019).

The MLP distinguishes three levels in transition processes. Transitions initially emerge in niches, then evolve within regimes, and ultimately reshape the socio-technical landscape (Figure 2).

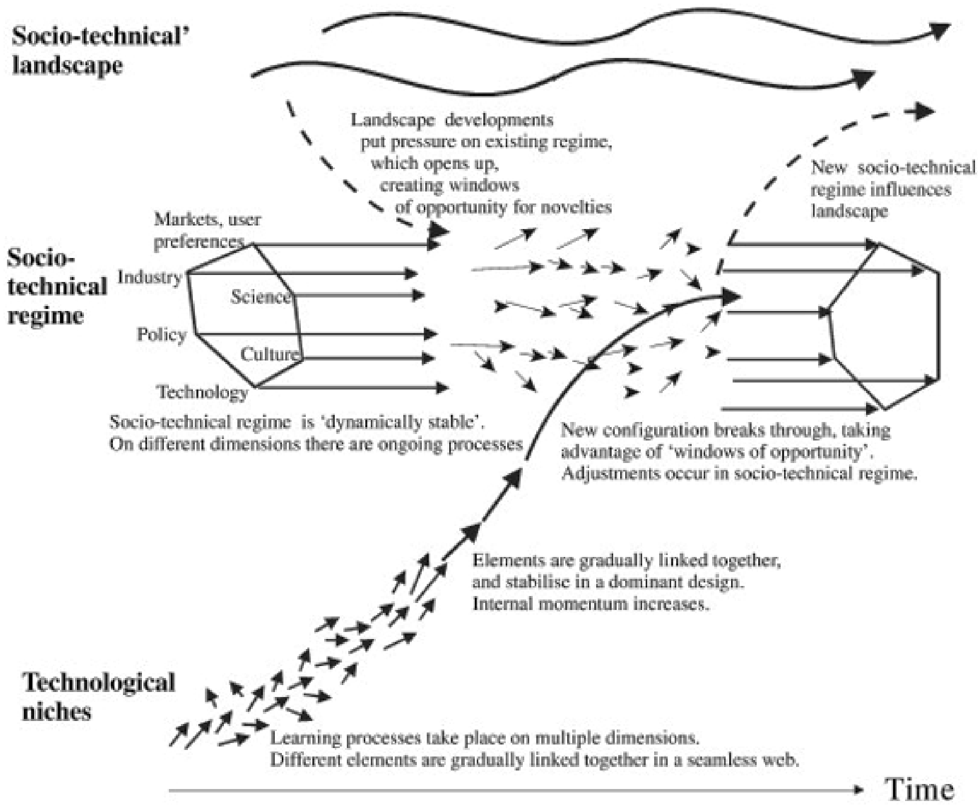

Figure 2: Modeling of transitions in socio-technical systems. © Geels (2004, 2019)

According to El Bilali (2019), the integrative conceptualization and operationalization of MLP elements are necessary to account for the complexity of sustainability transition processes and the particularities of the agri-food system. For this reason, the MLP has become a leading framework in research on agri-food sustainability transitions (El Bilali, 2019; Köhler et al., 2019).

The relevance of using this theory is further justified by its frequent adoption of technology and other innovations as the primary analytical entry point (Geels, 2019). It is a multidimensional approach because, according to Geels (2019), "the analytical strategy of following innovation trajectories inherently draws attention to diverse actors and struggles rather than privileging a single social group or dimension, as disciplinary approaches tend to do." The MLP focuses on transitions within socio-technical systems (Geels, 2019), including food supply chains. According to Geels (2019), it allows the analysis of blockchain impacts on the food transition across three levels: the micro level, corresponding to innovation niches; the meso level, referring to transition regimes; and the macro level, representing the socio-technical landscape.

Methodology

This study falls within the field of management, more specifically within the framework of stakeholder integration management in a socio-ecological context. The methodological choices and tools employed are guided by an interpretivist framework, appropriate for the social sciences and humanities.

The data collection approach is based on a qualitative methodology, consistent with the interpretivist epistemological stance adopted. Grounded Theory (GT), as developed by Glaser & Strauss (1967, cited in Guillemette, 2006), was employed to conduct this research. This theory was chosen for its ability to place actors' perspectives at the center of the inquiry, allowing the emergence of new theoretical insights (Guillemette, 2006). Furthermore, according to Guillemette (2006), it represents an innovative research approach grounded in an epistemological choice that enables the understanding of sociotechnical phenomena that are poorly theorized. GT follows an iterative process of phenomenon development (Paille, 1994), as in the case of blockchain use in the agri-food sector and its potential to enhance stakeholder engagement in the ecological transition of food systems.

The Grounded Theory approach differs from other qualitative methods in that it places strong emphasis on empirical data to explore the study object beyond mere descriptive analysis, without necessarily developing a fully elaborated theory (Paille, 1994). It enables the construction of an emerging theory. Its implementation involves conducting multiple interviews to foster the emergence and saturation of concepts (Charmaz, 2006, cited in Royer & Zarlowski, 2014). Data saturation criteria are based on the repetition of coded themes.

To validate the research, data were collected ed from a small sample of 10 participants representing diverse characteristics, selected through purposeful sampling. Data collection was conducted via semi-structured interviews. More specifically, participant selection followed a snowball sampling technique. Initially, participants meeting the predefined selection criteria were identified. These participants were then asked to refer additional participants, and the process continued until data saturation was reached (Royer & Zarlowski, 2007). The initial participants were chosen following a stakeholder identification phase, focusing on individuals directly involved in the food supply chain (producers, distributors, processors, and consumers) and/or those involved in blockchain implementation projects in the agri-food sector in Quebec, as well as actors with a vested interest in these domains.

The study was conducted in the province of Quebec, a relevant context for studying food systems and ecological transition due to public policies and local sustainability initiatives. The fieldwork encompassed individual contexts (consumers, project managers), institutional contexts (universities, research groups), and companies and local organizations involved in technological innovation and/or ecological transition. While blockchain technology was first used in cryptocurrency in 2008 (Compagnucci et al., 2022; Patel et al., 2023), its application in agriculture is relatively recent. Therefore, the timeframe for this study starts from the first uses of blockchain in the agri-food sector around 2016.

Data collection followed an iterative process. The 10 semi-structured interviews conducted with the various stakeholders aimed to gather detailed accounts of their knowledge and understanding of blockchain technology, their perception of the importance of stakeholder engagement in the ecological transition of food systems, and the roles blockchain can play in this transition. All interviews were guided by a flexible interview protocol, which was adjusted throughout the data collection process. Interviews conducted in person lasted 45 to 60 minutes, while those conducted via videoconference lasted 30 to 45 minutes.

The data analysis was conducted following the same approach used for data collection: Grounded Theory analysis, as outlined by Paille (1994), and consistent with the interpretivist epistemological stance. Data collection and analysis were carried out simultaneously, following a circular interaction between the two processes (Guillemette, 2006; Paille, 1994). Analysis thus began with the first interview. According to Paille (1994), this analytical process involves six main steps: coding, categorization, establishing relationships, integration, modeling, and theorization. Coding was conducted according to the principles of Grounded Theory in three phases: open, axial, and selective coding (Mongeau, 2008; Tchankam et al., 2020).

The verbatim extracted from the interviews constituted the corpus of data analyzed. To extract these, the semi-structured interviews were fully transcribed, and the data were analyzed through categorization and thematic code emergence (Mongeau, 2008). The coding process followed an abductive approach, as qualitative research, in addition to being inductive, is “a process of understanding that involves moments of logical deduction” (Anadón & Guillemette, 2007, cited in Hallee & Garneau, 2019, p. 129). This approach allowed for the use of inductive codes emerging from the verbatim data and deductive codes derived from theoretical concepts. This dual approach enabled the analysis of data both considering existing theories and in the exploration of new phenomena.

N'Vivo software (version 14) was used for data processing. N'Vivo is a CAQDAS (Computer-Assisted Qualitative Data Analysis Software), chosen for its ability to create interconnected networks of data (Fortin & Johanne, 2022).

Findings

This study follows a qualitative approach based on Grounded Theory, as developed by Glaser and Strauss (1967), and adapted to research contexts in the applied social sciences. The results are based on an exploratory analysis of 10 semi-structured interviews conducted with diverse stakeholders involved in the food supply chain in Quebec. The objective was to develop an empirical understanding of the role blockchain technology can play in the ecological transition through stakeholder engagement. To this end, three attributes of blockchain were considered: traceability, transparency, and its capacity to reduce food waste.

This section first presents the themes defined for coding the relevant verbatim excerpts. Subsequently, the interview results for each of these themes are presented.

Coding themes overview

Following an abductive approach, both inductive and deductive codes were determined. Some codes were defined based on the literature, while others emerged from interviews conducted with stakeholders in the food supply chain participating in the study.

The central theme of the study is sociotechnical transition in food systems, expressed through behavioral change among actors in the food supply chain. This theme is perceived both as a driver and a consequence of introducing blockchain technology into food systems. It encompasses two sub-themes: first, more responsible and sustainable practices in consumption choices, production methods, and distribution processes, facilitated by blockchain as a lever for sociotechnical transition. On the other hand, behavioral change as a mechanism of incentives and influence, whereby stakeholders are encouraged to reconsider consumption norms, trust criteria, and intersectoral relationships.

Another theme identified for coding is blockchain's potential contribution to reducing food waste. This theme is mentioned as an indirect but strategic effect of blockchain in food supply chains. Through improved information flow and authentic traceability, both consumers and retailers can adjust their behavior to minimize losses. The associated sub-theme is responsible and mindful consumption choice.

Furthermore, stakeholder engagement emerged as an important theme for the study's objectives. This engagement is shaped by stakeholders' ecological awareness, whether for consumer health or environmental protection. Two additional themes are directly linked to blockchain attributes: traceability and transparency. Sub-themes for traceability include the origin, production, packaging, and transportation conditions of products. The transparency category is expressed through information availability and reliability, as well as stakeholders' access to this information along the supply chain.

Table 1 presents the coding of the initial themes and sub-themes. The first column lists the code names, the second column shows the number of occurrences across interviews, and the third column indicates the number of verbatim excerpts associated with each theme or sub-theme. Note that the occurrences of parent codes do not necessarily equal the sum of the child code occurrences, as some references for parent codes are not captured in child codes.

Table 1. Themes and sub-themes of the initial coding process

Code names	Files	References
Behavior change	7	16
Responsible and sustainable practices	1	1
Incentive and influence	2	4
Food waste	4	4
Consumer choices	2	2
Stakeholder involvement	7	12
Ecological awareness	3	6
Traceability	9	18
Production conditions	4	5
Product origin	5	7
Transparency	9	24
Accessibility of information	5	5
Availability of information	5	5
Reliability of information	4	6

Source: Created by the authors

The participants are anonymized and designated by the respective codes IN01, IN02… IN10. The following section presents the results and analysis of the coded themes, followed by a summary table showing the categories that emerged from the interviews.

Perception of Product Traceability

Excerpts from interviews underscore the importance of traceability in food supply chains. Most participants believe traceability is fundamental to any study or project related to the ecological transition of food supply chains. This belief is reflected in consumers' desire for information on products' origin, production conditions, packaging, and distribution, as well as in their interest in blockchain technology's potential to provide this information. Some participants emphasized consumers' interest in knowing the origin of the products they consume. IN01 highlighted this interest: "I personally like to know where my products come from, whether it's coffee, mushrooms, or whatever. I want to know its origin, how it was grown, who produced it, and whether it is fair trade."[1]

The desire to know a product's origin is often motivated by social considerations, sometimes linked to territoriality. By favoring local products or choosing a product because of its territorial origin, consumers are interested in its origin. Participant IN02 discussed the interest of certain consumers in consuming products of Quebec origin in this excerpt from his interview: "[...] Because traceability, as we talk about in ... what they wanted was to be able to identify the Quebec origin of the product."

To identify a product's origin, the necessary information must be available. Product labels guarantee this availability of information. Therefore, labeling is an element related to product traceability. According to IN04's interview, consumers are becoming interested in provenance, which requires the availability of this information on the product label:

... As I said earlier, we need more information, with labels being translated into French and all that. And then, of course, there's the question of origin, because people are starting to be very particular about that. Where do the products come from? ... We're really starting to take an interest in that. (IN04)

Through these quotes, participants demonstrate that product origin, a sub-theme of the "traceability" category, is the type of information consumers seek. The theme of "product origin" is also linked to trust,

[1] The verbatim quotes are translated by the author from Quebec French.

an important element of the food supply chain for some. IN01 believes that: “It is crucial to be able to prove origin. That is the basis of trust today.”

Additionally, consumers are concerned about production conditions. Some participants believe that consumers who take an interest in product origin are implicitly interested in production, packaging, and distribution conditions. This is particularly the case for IN08, who explains: "[...] customers are passionate about local products and passionate about knowing how much energy has been used to produce them."

Other sub-themes also emerged during the interviews in the "traceability" category. First, the quality of labeling is an important factor in determining traceability. IN01 emphasizes that clear, standardized labels can serve as important vehicles for nutritional information and marketing:

... we will see labels that indicate the amount of salt, sugar, and fat. So, these organizations, which I know work every day to help companies improve their products to ensure that they are properly labeled and that consumers are attracted to their products. (IN01)

Two other sub-themes, certification and label, emerged during the interviews. According to some participants, certification and/or label helps to reinforce the authenticity of information between the various stakeholders in the supply chain. Like traceability, certification and labeling can also build trust. Participants IN05 and IN02 told us more about this:

“...The role of the label is to provide a guarantee to the person who says, ‘Well, this product looks good, but I don't know the people behind it, so I need certification.’ That's why I also think that blockchain can play a role in longer chains.” (IN05)

“... that's where certifications become important. Certification will guarantee, or at least help to guarantee, because there are lots of serious certifications with inspections or with evidence.” IN02

Regardless of their familiarity with blockchain technology, all participants agree that traceability is a major concern for everyone in the food supply chain.

4.1. Transparency in food supply chains

Participants view transparency as a fundamental element of food systems. All key stakeholders — producers, distributors, and consumers — should have real-time access to the same information. In food supply chains, transparency relies on three key attributes: the availability, accessibility, and reliability of information. Verbatim quotes reveal how these sub-themes intersect and highlight stakeholders' expectations of digital technologies, such as blockchain.

Availability refers to the ability to make product data visible and accessible at all stages of the supply chain. Availability is considered a prerequisite for transparency and secure transactions. Some participants associate transparency with open data, while others associate it with clear communication or the possibility of verification. For example, IN02 expresses this idea to show the sources of information in supply chains and how this information circulates thanks to blockchain:

So here we see that the information was going into registers. From the blockchain at the bottom with information that could be public and information that could be private, to be determined by the participants in the blockchain... What the blockchain does is transport the information and then make it visible at all stages. (IN02)

The available information must be accurate and useful to consumers. Not only must the information be accurate, but it must also cover everything stakeholders need to know. Participant IN08 expressed this concern, stating: "[a]t present, we wanted additional information. We want to see the products and the sugar content displayed in larger print. “Participant IN09 added:” The more traceable the process is, the more transparent it is for stakeholders."

Accessibility to information refers to the ability of different stakeholders to access this data directly, easily, and equitably. Some participants believe that food supply chains must be transparent and that all stakeholders must have equal, real-time access to information. Participant IN02 pointed out that blockchain technology can guarantee this access:

When blockchain technology arrived, we found it interesting because it included the notion of... the notion of transparency, and then the notion of being able to manage information, of being able to make it either public or private in the blockchain. (IN02)

Blockchain could offer consumers and other actors in the food supply chain access to data, which is an interesting service. According to IN03, everyone is interested in this access. However, he wonders whether it will be equitable: "What I find interesting is the possibility of access to data. Would everyone have this access?"

Ultimately, the availability and accessibility of information alone does not guarantee transparency if the information is unreliable. Participants express reliability as the guarantee that the displayed data is accurate, representative of reality, and not subject to manipulation. Participants familiar with blockchain technology consider it a tool that promotes immutability. Unlike current supply chains, where data can be falsified, IN03 believes blockchain guarantees data immutability:

as you know, there are different blockchains, probably thousands of them today, well, it's access to information now and then the automation of all that, so the fact that it's immutable and can't be changed because currently documents can be falsified. (IN03)

However, having information from the blockchain does not guarantee the total reliability of that information. Participant IN05 does not rule out the possibility of fraud before the data is entered. However, this fraud will not take place on the blockchain, but rather among the actors. The following excerpt from the interview with IN05 explains this concern: “It's not just about having the information, it's about it being reliable and accessible [...] If there is fraud at the point of entry, there's nothing we can do about it, but at least it can't be changed. "

Once the information has been entered, it cannot be falsified because any modification would affect all links in the chain. This concept is further explained in the following excerpt from the interview with IN06:

.. [A]nd to maintain transparency, before changing anything, the person who has to modify the data on the blockchain must, how should I put it? consult or verify the information they are going to modify. (IN06)

To consolidate transparency, which is becoming an increasingly important consumer requirement and strategic issue for other sector players, some participants believe good governance is needed to guarantee information's authenticity and control. Based on the interviews, several other transparency-related categories emerged. Some mentioned information governance. Others mentioned the risk of incomplete or manipulated information if it remains in the hands of a single actor or sector.

Reducing food waste

Food waste was chosen as the starting point to demonstrate how blockchain technology can enhance stakeholder engagement in the ecological transformation of food systems. During the interviews, several participants mentioned food waste as a problem that blockchain technology could help solve. Blockchain technology can optimize production, distribution, and consumption flows in food supply chains thanks to its attributes. Some participants emphasized the importance of good information management in facilitating the adoption of more environmentally friendly consumption behaviors. IN01 confirmed this, saying: "[...] And it also allows you to make choices. Take that portion, and I won't take that one. Exactly, it can reduce food waste by creating more accurate information about quantity and product." Other participants agreed. For example, IN09's verbatim comments include the following:

[...] Where information is conveyed throughout the chain, ultimately, this will reduce waste because if the producer has provided information about the quantity of products [...] then the distributor, at the end of the chain or the penultimate link, is already aware of this. This is the approximate quantity I will receive from such-and-such a player, etc. So, it reduces waste, it allows for faster decision-making, and it also reduces waste. (IN09)

Another theme that emerged during the interviews with participants was consumer choice. Participants believe that blockchain can optimize consumer choices and shift flows. One participant pointed out that blockchain brings supply closer to demand, thereby reducing transportation-related losses. "Eventually, blockchain can bring supply closer to demand and send signals about demand," said IN02. The emphasis is on using blockchain to regulate supply and demand, which could prevent overproduction and unsold goods by optimizing real-time inventory adjustments. IN09 believes that facilitating communication between stakeholders can reduce food waste: “[T]he way information is conveyed throughout the chain [...] also reduces waste.”

Behavior changes in food systems

During interviews with participants, several perceptions regarding the adoption of responsible behaviors in food supply chains were raised. Some participants mentioned strategies to encourage such behaviors. These strategies relate to three levers of action that can contribute to behavioral change: incentives, influence, and adoption of these behaviors. The interesting quotes selected provide an overview of the perceptions and conditions necessary for these transitions, as expressed by the participants.

Public awareness, achieved through information, education, or labeling, is considered a means of accelerating behavioral change. In this context, IN06 emphasizes the need to raise awareness among stakeholders about blockchain technology. According to him, this awareness can encourage stakeholders to take an interest in labeling information and lead to an awareness of possible behavioral changes:

It can help bring about change, but we need... how can I put it? Awareness campaigns or education to encourage people to look at the products they consume? It won't happen overnight; it requires a lot of work. (IN06)

IN02 agrees and emphasizes that stakeholders could encourage each other to change their behavior. During his interview, he said: "We look at how to encourage behavior that is good for the environment, whether in terms of consumption, production, or processing. "

Responsible behaviors are often adopted due to regulatory or incentive frameworks, such as certifications or labels. These mechanisms create an environment conducive to change by regulating practices and modifying economic incentives. Several respondents emphasized the need for the government to play a significant role in promoting new behaviors, primarily through regulation and control. Regarding the role of government actors, IN03 stated: “If the government required information to be provided for all agricultural products and all food products, whether on the front of the packaging or in some other form, such as an environmental score, that could really influence behavior.”

The respondents present certification as a mechanism that encourages responsible practices within the food supply chain. As IN02 points out, recognizing certifications is important to guaranteeing the legitimacy of actions and stimulating compliance with requirements. This idea is made clear in the following excerpt from his interview:

[..] [T]hat's where certifications become important. Certification will guarantee, or at least help to guarantee, because there are lots of serious certifications with inspections or with evidence. […] If production is certified as sustainable […] people are bound by requirements. (IN02)

Certifications help frame the commitment of actors in the food supply chain within a framework of verification by subjecting them to standards and controls. They enable actors to comply with the principles of change. This is what the following excerpt from the interview with IN07 indicates “The rules are getting stricter, and companies are forced to comply.” Labels also differentiate products in the marketplace. They signal to consumers which products are produced in accordance with standards, such as those for sustainable development. Thus, while serving as a lever to encourage responsible behavior, certification and/or labeling are part of a balance between the normative promise of actors, material proof that products are designed according to a certain standard, and social perception that reinforces consumer confidence.

The ability to adopt responsible behavior varies according to values, available resources, and motivations (Huttunen et al., 2022). Some view it as an ethical commitment, while others see it as an economic or strategic constraint. “It depends on the company's values; some go further than the standards,” said IN07. Additionally, some consumers mention economic constraints that can be considered inhibiting effects on incentives. "It's often the more educated and affluent consumers who can afford to buy responsibly," said IN05. Participant IN01 agreed, arguing that means play an important role in food choices and, consequently, behavioral change. He stated:” people who eat better often do so for their health, but also because they can afford to."

The adoption of responsible behaviors by actors in the food supply chain regarding ecological transition cannot be viewed as a simple individual transformation but rather as a systemic process influenced by a combination of structural and functional societal factors. Empirical data from interviews conducted as part of this study show that the adoption of responsible practices is based on multiple factors, including institutional incentives, such as certifications; awareness-raising mechanisms; social norms; and economic constraints. This dynamic underscores the necessity of an integrated approach to managing stakeholder engagement in the food supply chain.

Stakeholder involvement in the food transition

Involving actors in the food supply chain in the transition to sustainable practices is essential to effectively using digital technologies, such as blockchain, to engage stakeholders in the ecological transition of food systems. Participant IN06 emphasizes that: "actors need to be committed to achieving an ecological transition." Several other participants share this view and emphasize the need to mobilize actors at all levels of the chain.

However, some participants believe that actors' interests and influence are not equal. Regarding this issue, IN03 states that: "stronger actors should really commit themselves because they have the opportunity to do so [...] those who are most responsible for environmental destruction." At the same time, several verbatim quotes highlight the difficulty of ensuring longitudinal management throughout the chain, particularly when transformations involve logistical investments. Participant IN02 mentioned this in their comments: "Other partners in the sector need to get on board. Distributors and retailers need to get on board, which becomes very complicated."

The involvement of various actors in the food supply chain is essential for implementing technological innovations, such as blockchain. The results highlight four emerging categories based on the verbatim quotes collected: collective commitment, differentiated responsibility, challenges in stakeholder management, and the role of public institutions.

Emerging categories

The interviews conducted with participants enriched the initial coding by bringing out other categories and/or subcategories, as shown in Table 2, which summarizes the initial categories with subthemes and emerging categories. The first and second columns present the themes and sub-themes from the initial coding. The third column presents the categories that emerged from the discussions during the interviews with participants.

Table 2. Summary table of emerging themes, sub-themes and categories

Initial codes		Emerging categories
Product traceability	Product origin	Quality of product labels
	Production conditions	Certification/labelling
		Consumer trust
Transparency of information in the supply chain	Availability of information	Information governance
	Accessibility to information by all actors	Checking authenticity of information
	Reliability of information	Trust-building transparency
Reducing food waste	Consumer choices	Bringing supply and demand closer together
		Logistics optimization
Behavior changes in food systems	Influencing and encouraging responsible behavior	Environmental Labelling
		Mandatory certification
	Adoption of sustainable behaviors	Internal values
		Socio-economic factors
Stakeholder involvement	Awareness of the need to get involved	Collective commitment of actors
		Differentiated responsibility based on interest/influence
		Stakeholder management challenges
		Role of public institutions

Source: created by the authors

Category selection and relationship mapping

Based on the Grounded Theory analysis process proposed by Corbin and Strauss (2015, cited in Fortin & Johanne, 2022), behavioral change in food systems was identified as the central category. Subsequently, selective coding allowed the identification of a set of categories to be linked. The following categories were thus selected as the foundations of the emerging theory: information transparency, product traceability, food waste reduction, differentiated stakeholder engagement, leverage of influence and incentives, mandatory certification/labeling, values and socio-economic factors, the role of public institutions, and differentiated responsibility according to stakeholder interests and influence.

These categories were retained due to their recurrence, centrality in the collected narratives, and their ability to illustrate the relationships between blockchain adoption in food systems and behavioral change among stakeholders in the food supply chain. The links between the selected categories are illustrated in Figure 3.

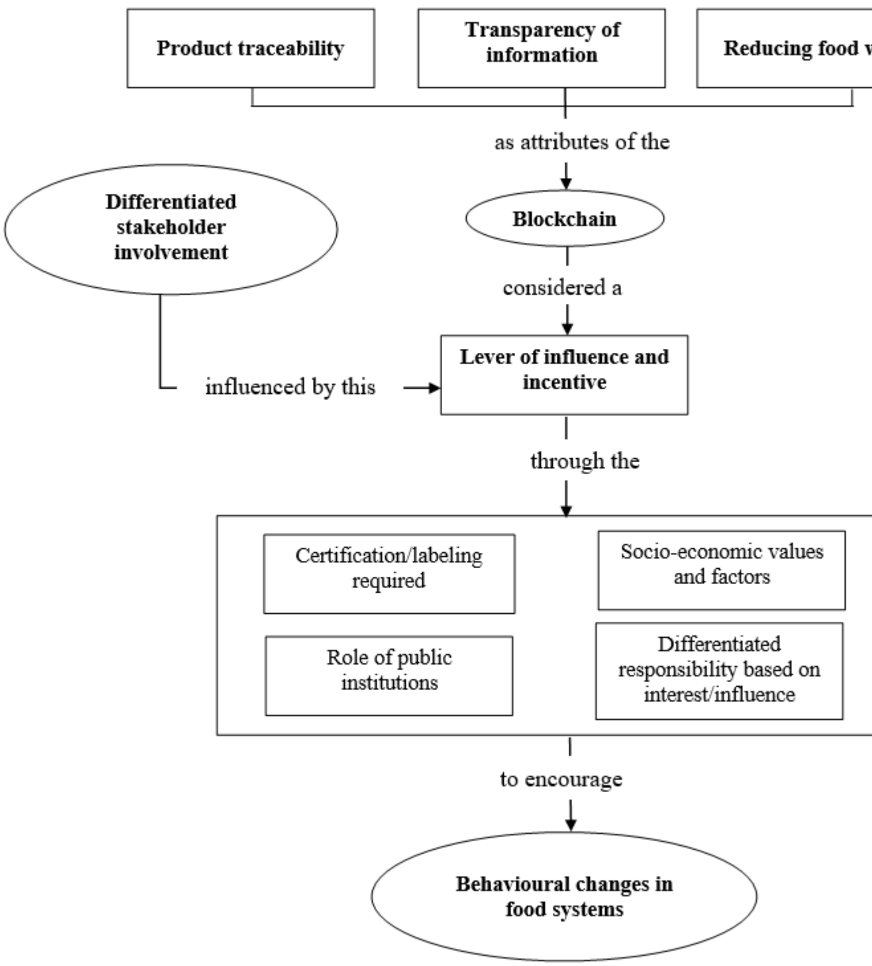

Figure 3: Linking of selective categories. © Authors' achievements

Emerging theory of stakeholder engagement in the transition through blockchain

This section aims to address the central research question: how does blockchain technology influence stakeholder engagement in the ecological transition of food systems in Quebec? By applying a grounded theory approach, the study sought to provide an abductive understanding to propose an emerging theory grounded in both field reality and existing theoretical frameworks.

The analysis is based on the linking of empirical data from interviews with the study's theoretical-conceptual foundation—drawing on Geels' Multi-Level Perspective (MLP) theory (2004, 2019) and Freeman's stakeholder theory (1984, cited in Freeman & McVea, 2001), with a focus on citizen engagement as elaborated by Huttunen et al. (2022)—as well as on the conceptual framework developed in the complementary narrative literature review conducted by the author. The discussion centers on the contributions of blockchain attributes to stakeholder engagement in the ecological transition of food systems.

Blockchain and stakeholder engagement

One of the first emerging categories from the empirical data concerns product traceability, viewed both as a requirement from consumers and as an incentive for producers and distributors. Respondents perceive blockchain as a tool capable of making stakeholders' ecological commitments visible by providing access to verifiable and shared data. This implicitly enhances transparency and thereby builds trust among stakeholders in the food supply chain.

This function of blockchain has been highlighted in prior studies, such as Feng et al. (2020), who emphasize the reconfiguration of responsibilities through traceability mechanisms. Similarly, Kamilaris et al. (2019) and Tripoli & Schmidhuber (2020) confirm that blockchain enables the integration of environmental criteria into daily operations, establishing a framework of automated transparency. Thus, the analysis links empirical findings with theoretical interpretations, highlighting traceability and transparency as key contributions of blockchain to stakeholder engagement in the ecological transition of food systems.

Blockchain and behavioral change in food systems

A second emerging category, also derived from the empirical data, concerns the potential of blockchain to influence the reconfiguration of organizational behaviors and practices across all stages of the food supply chain. Empirical data from discussions with multiple participants highlight concrete ways in which blockchain can contribute to improve logistical planning, reduction of food waste by guiding consumer and stakeholder choices, and the selection of environmentally responsible suppliers.

These findings align with Zarbà et al. (2024), who show that blockchain acts as a catalyst for coordination and efficiency in promoting sustainability within food systems. However, this efficiency relies on a collaborative dynamic among stakeholders, as reflected in participants' accounts. This indicates a distributed responsibility rather than a centralized control of transition actions. This form of bottom-up adjustment, driven by consumer concerns, is fully consistent with the logic of transition niches described by Geels (2019) and provides a foundation for understanding stakeholder engagement as a key element in implementing ecological transition in food systems.

Asymmetry of blockchain adoption in food systems

The collected data reveal a marked heterogeneity in stakeholder engagement through blockchain. This diversity led to the emergence of a third category: differentiated engagement, influenced by inequalities in resources, roles, and perceptions among actors in the food supply chain. The stakeholder typology proposed by Desjardins et al. (2024) – distinguishing economic, civic, community, and institutional stakeholders – provides further insight into this dynamic. Community and civic actors tend to prioritize engagement based on territorial proximity and social ties, whereas public and economic institutions adopt a more normative and systemic approach. In this context, most participants viewed public institutions' engagement, for example through certifications and labeling, as an important factor in enhancing blockchain's role as a lever for transition.

However, Desjardins et al. (2024) have already highlighted the risks of a transition that is too technology-centered, which explains the socio-economic factors that limit local stakeholders' capacity to implement technologies such as blockchain. Therefore, engagement should not be interpreted as a homogeneous variable, but rather as a relational construct, marked by asymmetries arising from the diversity of actors.

Enhancing stakeholder engagement in the ecological transition of food systems

Based on the emerging codes and selective categories, an emerging theory is proposed. Through traceability, transparency, and its capacity to reduce food waste, blockchain can foster stakeholder engagement in the ecological transition across three dynamics at three levels of analysis, following Geels' Multi-Level Perspective (MLP) sociotechnical theory (2004, 2019).

At the micro level, traceability and transparency are presented as levers of influence and incentives for stakeholders in the food supply chain to adopt more sustainable behaviors. The data show that traceability, certification, and information accessibility enhance trust and encourage stakeholders to engage in responsible behaviors. Transparency goes beyond the mere sharing of information (access and availability); it also functions as a social norm contributing to behavioral change, thus becoming a lever for stakeholder engagement.

At the meso level, the reconfiguration of practices by various actor groups links blockchain to the ecological transition in food systems. This reconfiguration concerns production, processing, and distribution practices. Blockchain thus introduces a new dynamic for change management in food supply chains, notably through improved planning, the ability to monitor food waste, and the revision of supply processes.

At the macro level, stakeholder engagement is differentiated according to actor characteristics and the broader sociotechnical landscape, which define adoption capacities, including the heterogeneity of actor profiles and their socio-economic factors. Technological inclusion and the participation of public institutions are therefore seen as essential conditions for the effective adoption of blockchain in the sociotechnical landscape.

The emerging theory developed from this study presents blockchain as a lever for stakeholder engagement in the ecological transition of food systems. This engagement occurs at three levels and depends on actor types and the socio-economic factors of the sociotechnical landscape. Figure 4 presents the conceptual model of the emerging theory.

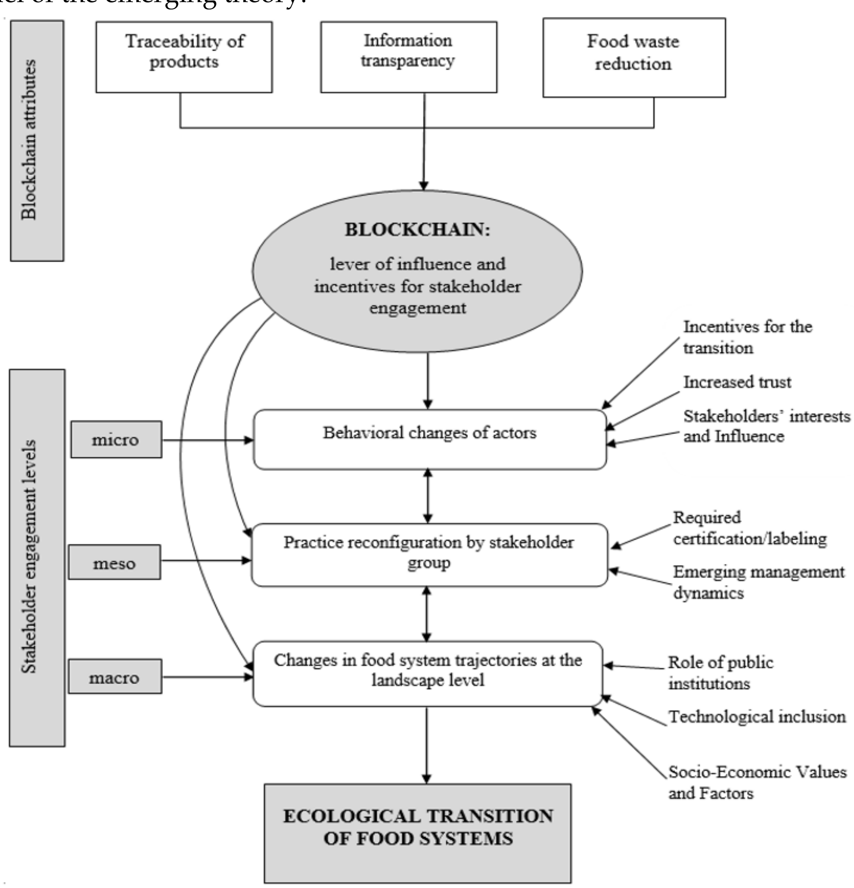

Figure 4: Theoretical framework of blockchain contributions to stakeholder engagement in the ecological transition of food systems. © Authors' own elaboration

This theoretical proposition builds upon the conceptual framework developed in the complementary review article on the links between blockchain technology, stakeholder engagement, and the food system transition, which positioned blockchain at the center of stakeholder engagement dynamics toward the ecological transition. The empirical results confirm the relevance of the three identified attributes in this framework – traceability, transparency, and food waste reduction – as levers of influence and incentives for actors to adopt blockchain technology and to implement behavioral changes.

Conclusion

This study is of significant interest for advancing research on stakeholder management in ecological transition projects. From a scientific perspective, it provides a theoretical framework that links the benefits offered by blockchain technology to the motivation and accountability of actors within food supply chains. Furthermore, the study contributes to the body of research on the two foundational theories underpinning the analysis: Stakeholder Theory (Freeman, 1984) and the Multi-Level Perspective (MLP) on ecological transition. The emergent theory developed enhances the scientific understanding of blockchain's contribution to stakeholder engagement in the ecological transition of food systems.

The study also opens avenues for future research on stakeholder engagement considerations in the transition enabled by digital technologies. Future studies could adopt a confirmatory quantitative approach to measure the actual impacts of blockchain on the ecological transition of food supply systems, thereby reinforcing the emergent theory developed in this research.

Moreover, beyond the common perception that technological advances in agriculture, particularly in the agri-food sector, are often considered anti-ecological processes, this study demonstrates that blockchain acts as a lever to facilitate understanding of the positive impacts that digital technologies can have on ecological transition, especially within food systems. This contributes to strengthening the knowledge base regarding the relationship between digital technologies and food systems.

From a managerial perspective, this study offers several contributions that can benefit all actors involved in food supply chains. First, as the results highlight the conditions that may facilitate blockchain adoption in food systems, the study provides a foundation for guiding the implementation of blockchain projects within food supply chains. It can thus serve as a practical tool for project managers in designing and managing initiatives in this domain. Moreover, by exploring the role of blockchain in stakeholder engagement, the findings indicate to decision-makers the importance of integrating all stakeholders in the co-construction of food system projects involving this technology. Project managers can better organize relationships among various actors in the supply chain while considering the impacts that blockchain may have on these interactions.

For producers, the study not only strengthens the foundation for blockchain adoption in the production process but also encourages the promotion of ecological intensification. The results emphasize that, through certifications and labels, blockchain can incentivize more sustainable upstream practices by enhancing traceability and transparency in food supply chains.

Regarding distributors and retailers, the study highlights blockchain's capacity to enhance control over the management of both products and their accompanying information. This can assist in improving inventory management, information flows, and relationships with suppliers and customers.

Finally, the study contributes to strengthening consumer trust by providing reliable information regarding the origin, production, and handling conditions of products throughout their lifecycle, enabling consumers to better trace the products they purchase.

Despite its scientific and managerial contributions, this study presents certain limitations from both theoretical and methodological perspectives that should be acknowledged. From a theoretical standpoint, the study does not consider all elements necessary for the application of blockchain technology to food systems, particularly regarding technological, economic, and legal dimensions. This limits the interpretation of the results and the understanding of the emergence of the socio-technical phenomenon represented using of blockchain in the agri-food sector to enhance stakeholder engagement in the transition.

From a methodological perspective, the empirical validation of the research is based on a small sample within a specific geographic context: Quebec. This constrains the transferability of the findings to other territorial contexts beyond Quebec. Moreover, as Paillé (1994, p. 180) notes, "any theorization, regardless of the care with which it has been developed, remains partial, limited, and relative (...)." Thus, the qualitative analysis using Grounded Theory in this study, which led to the development of an emergent theory, remains partial, limited, and relative. This limits the use of the study's findings as a definitive explanation of the phenomenon under investigation.

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