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Using Blockchain Technology in Advancing Information Flow in Kenya's Avocado Value Chain

Davis Milimo and Elizabeth Naududu

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Using Blockchain Technology in Advancing Information Flow in Kenya's Avocado Value Chain

Davis Milimo and Elizabeth Naududu

Kenya Institute for Public Policy
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Abstract

Blockchain technology (BCT) can provide a channel for efficient information flow that is necessary. This study sought to advance information flow in the avocado value chain using BCT. Despite developments such as contract farming, integration of ICT systems, and extension services; the avocado value chain faces numerous challenges among them inadequate market information, weak vertical-horizontal linkages, and post-harvest losses. This has negative impacts on avocado production and export sales due to uneven distribution of profits among the producers. The study identified that for the implementation of BCT in the avocado value chain, various driving forces directly influence its use. The key drivers include little expertise and insufficient knowledge of using BCT either at a single point or multiple points of the value chain, and low scalability of BCT limits the number of users and volume of transactions. High initial costs associated with acquiring BCT, especially for smallholder farmers, can lead to a monopoly situation over time for those who can pay for it. There is a need for immutable records for the avocado value chain to help store information safely and permanently. The presence of intermediaries can lead to information asymmetry in local and international avocado markets. Limited policies and laws on BCT pose challenges to compliance concerning food safety, traceability, and transparency. Standardization for integrating BCT seamlessly with the current system is inadequate while issues of data privacy and cyberattacks among others require solutions. The impacts of these driving forces on each other can lead to effective use, early adoption, late adoption, or low use of BCT. To address the future scenarios of low use and late transition of BCT, the study recommends formulating comprehensive legal and regulatory frameworks to govern and support innovations while mitigating potential risks. This will improve compliance and guarantee fair compensation to smallholder farmers. Building capacities for strengthening the national ecosystem through technical skills development for professionals, education, and training for farmers will accelerate the adoption of BCT thus improving avocado yields. Increasing the engagement with global digital governance through supporting investments and partnerships in BCT use, will promote sustainability in the avocado value chain.

Abbreviations and Acronyms

AFA	Agriculture and Food Authority
ARUD	Agriculture Rural and Urban Development
BCT	Blockchain Technology
BETA	Bottom–Up Economic Transformation Agenda
CA	Communications Authority of Kenya
CBK	Central Bank of Kenya
GCP	Gross County Product
IFC	International Financial Cooperation
KIAMIS	Kenya Integrated Agriculture Management Information System
NGOs	Non-Governmental Organizations
WEF	World Economic Forum
UAE	United Arab Emirates
OECD	Organisation for Economic Co-operation and Development

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1. Introduction

Information sharing, business processing, and trade facilitation are critical issues in the avocado value chain. Technology plays a significant role in facilitating information sharing for improved decision making. Blockchain technology (BCT) is one of the technologies that play an integral role in supporting effective information sharing. BCT is a distributed-ledger system that validates records and transactions without the need for a central database and in a way that cannot be erased, altered, or tampered with. Such technology allows enterprises to run entirely by autonomous computer software. This fosters effective governance since trust between actors is created cryptographically (Zyskind et al., 2015). BCT gives an unprecedented level of integrity, security, and reliability to the information it manages, lowering the risks associated with a single point of failure (WEF, 2018). It is advantageous because it eliminates the need for intermediaries, decreases bureaucracy, and lowers the possibility of making an incorrect decision. It also enables the tracking and tracing of transactions, which can be used by law enforcement and government auditors.

Avocado is one of the emerging export crops that the country seeks to expand as highlighted in Kenya's Medium-Term Plan IV. It is the fourth most important fruit crop after mangoes, bananas, and pineapples. A report on agricultural outlook by OECD and FAO predicts avocados will become the second-most traded tropical fruit after bananas by 2030. The counties that majorly grow avocados include Murang'a, Kisii, Nyamira, Kiambu, Nakuru, Meru, Kirinyaga, Embu, and Nyeri (AFA, 2023). Avocado is primarily grown for the fresh fruit market, with a majority of the buyers being from domestic markets (formal markets, informal markets, and supermarkets) and export markets.

Recently, the fruit has gained importance in the export market, with European markets and the Middle East being the major export markets. Kenya's avocado has a competitive advantage in the export market as its production peaks between January and February when other countries' produce has not attained maturity yet. Private investors are also increasingly buying Kenya's avocados for value addition and processing into other products such as edible oils.

Kenya grows and exports Hass and Fuertes varieties of avocados with many of the farmers being smallholder farmers. Alongside the farmers, the avocado value chain is made up of actors including researchers, extension officers, fruit tree nursery operators, intermediaries, traders, retailers, processors, exporters, and local consumers together with other supporting institutions such as NGOs, counties, and the national government. These actors need information on accurate seasonal weather forecasts; the quality of avocado seedlings to be grown; market information; planting and harvesting calendars; the availability of farm inputs; existing agricultural extension services; and the required sanitary and phytosanitary standards. Information flow among these actors is important as it allows for the efficient and effective utilization of resources leading to increased productivity and better outcomes of the avocado value chain.

The nexus between BCT and the avocado value chain is premised on the ease of access to information, business processing, and trade facilitation. The avocado value chain can greatly benefit from the use of accurate communication, and this requires collaboration from all major actors. Furthermore, innovative information technology interventions are needed to improve the quality of production, as well as transparency across all levels. The World Bank (2016) established a roadmap outlining how advanced information and communication technology, such as BCT, can be used in agri-food production systems to improve primary results. Given the rising demands for food market information, transparency, traceability, and food safety, there is a need to digitize the avocado value chain. This can be made possible by the implementation of BCT which offers a potential decentralized and transparent ledger solution (George and Al-Ansari, 2023).

The avocado value chain refers to the set of actors and activities that bring a basic agricultural product from production in the field to final consumption (see Figure 2.1), where, at each stage, value is added to the product to enhance profitability. Value addition occurs during agricultural production and related off-farm activities such as food processing, food storage, aggregation, post-harvest handling, transportation, processing, distribution, marketing, disposal, and consumption. Consumers are concerned about food safety due to increasing cases of food contamination from pesticide misuse during production, poor sanitation practices at the market level, and unhygienic handling of food items during transportation. This has consequently led to outbreaks of foodborne illnesses (Yen et al., 2018).

The most crucial factors in the avocado value chain are efficient information flow, reliability, traceability, safety, and ethical production. Efforts have been made to advance these factors along Kenya's avocado value chain. For instance, contract farming of avocados has been witnessed in the major production areas. This is where smallholder farmers form groups and get into contracts with retailers and traders, thereby allowing them to trade in the export market (Johnny et al., 2019). This has brought some structure and organization of markets that offer better prices to avocado farmers. Here, farmers can get into two major types of contracts: the informal contract model where contracts are made on a verbal basis between farmers and traders; or the intermediary contract model where processing firms engage an intermediary such as farmers' cooperatives or village elders who then connect them to avocado farmers.

These contracts are, however, limiting in that there is minimal autonomy for the processing firms and farmers since the quality, quantity, and price of avocados are heavily controlled by the intermediaries (Amare et al., 2023). Furthermore, appropriate training and the sharing of information about market prices is still minimal despite the contract agreements. This is especially true for avocados grown for export as they have unique requirements regarding quality, quantity, handling methods, production, and harvesting times to enable the products to meet sanitary and phytosanitary standards. This has partly contributed to the low performance of the avocado value chain (Oduol et al., 2013).

The incorporation of extension service officers in the avocado value chain has also promoted information sharing to farmers as many get educated and adopt effective inputs, grow high-yielding avocado varieties, and better storage, marketing, and harvesting techniques. However, not all farmers get access to these extension services, and this greatly impedes production in the avocado value chain (George et al., 2018). Advances in mobile connectivity and infrastructure have accelerated the adoption of digital communication technologies along the avocado value chain. The mobile sim penetration rate in Kenya is 132.7 per cent (CA, 2023). This plays a significant role in business development among various actors. For instance, using M-pesa cash transfers has ensured efficient payments along the avocado value chain and this has partly reduced the cases of fraud. BCT, on the other hand, has been described as a transformational ICT that could eliminate the need for intermediaries and ensure system trust (Lin et al., 2017).

Food safety and traceability have also been promoted through the enforcement of standardization initiatives such as the KS 1758-2: 2016, which applies to vegetables and fruits (Kenya Bureau of Standards, n.d.). As defined by the International Standard Organization, traceability is "the ability to trace the history, application, or location of an entity" (ISO, 1994). Food safety, especially in the case of perishable foods, substantially impacts food quality.

Despite these efforts, the avocado value chain is still experiencing significant hurdles that can be attributed to inefficiencies in the value chain and inadequate information retrieval mechanisms. For instance, the current infrastructure in the avocado value chain makes traceability a lengthy and difficult task. This is because some information is recorded manually, and this makes it difficult to trace activities and products back to their origins. The value chain is also centralized and heavily influenced by intermediaries. Due to this, actors across the avocado value chain do not get fair compensation for their input and work (Kramer et al., 2021; USAID Kenya, 2016).

At the farm level, pre- and post-harvest losses continue to be experienced due to strained access to inputs, inadequate incentives for upgrading, weak vertical/horizontal linkages, unpredictable market prices, and inappropriate transport facilities. This prompts farmers to sell their produce at lower prices to avoid further losses (Shivachi et al., 2023). Consumers, being important stakeholders in the value chain, have also witnessed unethical practices that have compromised the safety of the avocados they consume. This has risked consumers' health and led to sales losses and unfair competition.

Inefficient information sharing in the avocado value chain has exposed farmers to challenges of limited knowledge about markets, strained access to inputs, no incentives for upgrading weak vertical and horizontal linkages within the value chain, and lack of trust among value chain actors, unreliable markets, poor transport systems, and exploitative prices. While formal and organized information sharing is pronounced among intermediaries, retailers, processors, and exporters; farmers, consumers, and tree nursery operators still operate with minimal information about the value chain. For instance, farmers' limited knowledge about fruit standards, has led to the production of low-quality fruits (Malekela, 2022). This is evidenced by reported cases of Kenya shipping avocado fruits that were disease-infested (fruit fly and false codling moth infestation). In other instances, there has been mistiming in shipment leading to the fruits being spoilt or arriving under-ripped, thereby negatively affecting the integrity of Kenyan avocados (AFA, 2023). This limits the avocado value chain from reaching its maximum potential in both the local and export markets (Oduol et al., 2013).

To advance Kenya's avocado value chain, there is a need to address these challenges. This can be accomplished by incorporating BCT in the avocado value chain. Globally, Walmart has pioneered a blockchain project to establish a farm-to-grocery food supply chain (Nash, 2018). BCT promises a conducive environment for efficient information flow that is necessary for coordinating and monitoring activities across the avocado value chain. This is because it will allow all actors to enter immutable contracts, supply chain transactions can be integrated in real-time, and the origin of goods can be identified and audited at every link in the chain, thereby enhancing effective communication and sharing of information that is required for the advancement of the avocado value chain (Pizzuti, 2015; IFC, 2019; Malekela, 2022).

The overall objective of this study was to identify pathways through which information flow in Kenya's avocado value chain can be advanced using blockchain technology. This was achieved by assessing the effects of BCT on information flow in the avocado value chain and examining the future scenarios of BCT application in Kenya's avocado value chain.

The paper is organized into six sections. after the introduction, the second section provides stylized facts on the status of avocado production in Kenya. The third section highlights the theoretical and empirical reviews of literature relevant to the study. The fourth section outlines the study's methodology. The fifth section provides the results, and the sixth section gives the conclusion and policy recommendations.

2. Status of Avocado Production in Kenya

2.1 Avocado Farming

Avocado growing in Kenya is mainly done by smallholder farmers who comprise over 91per cent of avocado farmers as registered in Kenya Integrated Agricultural Management Information System (KIAMIS) and who farm in under five (5) acres of land. This is illustrated in Table 2.1.

Table2.1: Registered avocado farmers

Acreage categories	Farmers	Total acreage
A: Under 1	149,640	27,112.92
B: 1-2	11,819	15,006.44
C: 2-5	2,095	7,179.48
D: 5-10	375	2,819.93
E: 10-50	134	2,829.49
F: 50-100	9	743
G: Over 100	5	916.4
No acreage	1	-2
Total	**164078**	**56,605.66**

Source: Kenya Management Information System (KIAMIS, 2024)

The major avocado-growing counties are Murang'a, Nyamira, and Kisii. The value of avocado production has been growing steadily as reported by the Agriculture and Food Authority (See Table 2.2). For instance, the value of avocado production in Kisii County grew from Ksh 28,830 million in 2018 to Ksh 60,743 million in 2022. This is attributed to an increase in metric tonnes of avocados produced (illustrated in Table 2.3), which can partly be explained by the increase in land under production (see Table 2.4).

Table 2.2: Avocado production (values in Ksh millions)

		2018	2019	2020	2021	2022
1	Murang'a	123555	136080	137561	115774	121450
2	Kisii	28830	73728	73102	67177	60743
3	Nyamira	29280	30270	31269	38710	37476
4	Kiambu	37964	49125	51584	33531	33982
5	Nakuru	1664	10982	24501	21037	30594
6	Meru	8553	24054	17499	29404	26430
7	Kirinyaga	5892	12965	12940	16435	15935
8	Embu	14543	8297	18727	16040	15650
9	Nyeri	5784	7404	34199	9890	13549

		2018	2019	2020	2021	2022
10	Bomet	10590	12897	11566	7803	9120
11	Trans Nzoia	1065	3862	1047	5915	8932
12	Uasin Gishu	3027	4167	2117	6759	7384
13	Nandi	2073	2719	7661	7661	3236
14	Bungoma	6028	7450	7300	8648	3236
15	Others	38239	36430	61651	48184	67562
	Total	**317087**	**420430**	**492724**	**432969**	**455279**

Source: AFA (2023)

Table 2.3: Avocado production (metric tonnes)

	2018	2019	2020	2021	2022
Murang'a	2544	2899	2924	2748	2922
Nakuru	42	235	701	945	1566
Kisii	430	1195	748	1544	1416
Kiambu	682	1204	989	1237	1167
Nyamira	309	489	552	838	670
Meru	210	462	387	1209	641
Uasin Gishu	61	153	106	490	481
Bomet	218	485	363	426	435
Kirinyaga	147	321	348	372	402
Trans Nzoia	17	113	21	271	397
Nyeri	113	173	311	420	329
Embu	217	166	355	330	313
Bungoma	201	173	105	147	186
Nandi	57	117	258	258	114
Others	680	818	1375	1157	1601
Total	**5927**	**9003**	**9542**	**12391**	**12642**

Source: AFA (2023)

Table 2.4: Avocado production (hectares)

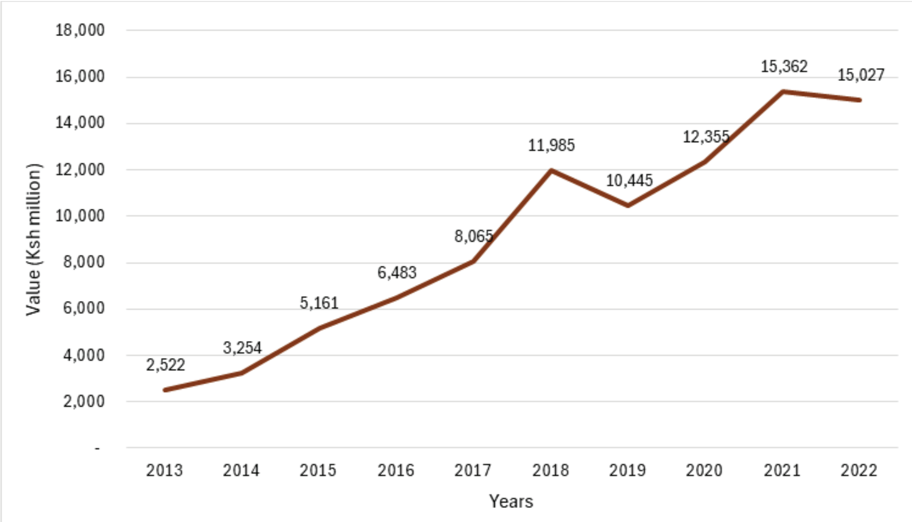
	2018	2019	2020	2021	2022
Murang'a	4321	4882	5890	6128	6208
Meru	755	1208	2575	2545	3021
Nyamira	1482	1597	2660	2768	2970
Nakuru	371	483	1553	1589	2069
Kisii	1532	2294	2641	2746	1891
Kiambu	1819	1637	1676	1770	1830
Uasin Gishu	230	253	511	834	775
Kirinyaga	367	718	709	687	713
Nyeri	584	657	1352	669	655
Embu	709	553	538	563	585
Bomet	474	672	687	398	559
Trans Nzoia	106	455	296	349	380
Bungoma	299	464	273	466	355
Nandi	127	238	368	368	240
Others	3325	4129	5413	4681	5555
Total	**16501**	**20240**	**27141**	**26561**	**27807**

Source: AFA (2023)

2.2 Kenya Avocado Market

Eighty-five (85) per cent of Kenya's avocado produced is consumed locally. However, its export market has gained importance with the value of exports in the year 2022 registered as Ksh 15,027 million. This is a significant growth compared to the year 2013 when a value of Ksh 2,522 million was registered (See Figure 2.1). Kenya mainly exports to the European and Middle East countries. In the year 2022, the major avocado export markets were the Netherlands (28.5%), United Arab Emirates (15.6%), France (14.4%), Spain (8.4%), Saudi Arabia (6.7%), Turkey (6.5%), Germany (5.1%), Russian Federation (2.3%), Egypt (1.8%), and the United Kingdom (1.7%) (International Trade Centre, 2024). The avocado export market is dominated by five major exporters: Kakuzi, Vegpro, Sunripe, Kenya Horticultural Exporters, and East African Growers. These companies source their avocados primarily from smallholder farmers, some from larger growers, and others own plantations.

Figure 2.1 Value of avocado exports in Kenya shillings millions



Source: KNBS (2023)

2.3 Policy, Legal, Regulatory, and Institutional Frameworks in the Avocado Value Chain

2.3.1 Policy, legal and regulatory frameworks

As illustrated in Table 2.5, there exist various policy, legal, and regulatory frameworks that govern the avocado value chain at the global, regional, national, and county levels. At the global level, Sustainable Development Goals Two (2) and 12 seek to double agricultural productivity among smallholder farmers and significantly reduce post-harvest losses respectively. At the regional level, policies such as the African Union Agenda 2063, East African Community Vision 2050, and AfCFTA seek to enhance agricultural productivity through initiatives such as value addition, developing marketing infrastructure, and supporting innovations for agricultural development.

Similarly, policies at the national level have been designed to facilitate and support advancements in the avocado value chain. For instance, the Crops Act No. 16 of 2013 seeks to promote the production, processing, marketing, and processing of scheduled crops, including avocados, through effective communication and transportation channels. Leading counties in avocado production have also prioritized the value chain in their County Integrated Development Plans (CIDPs) 2023-2027. The CIDPs have vowed to enhance the productivity of the avocado value chain through investing in training initiatives, cooperatives development, infrastructure development, marketing structures, and value addition practices.

Table 2.5: Policies at the global, regional, and local levels

Policy	Goal	Key areas of focus related to the avocado value chain
Global level		
Sustainable Development Goal Two (2)	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture	• By 2030, double the agricultural productivity and incomes of small-scale food producers through the provision of productive resources, inputs, knowledge, financial services, markets, and opportunities for value addition. • Increase investment in agricultural research, extension services, and technology development to enhance agricultural productive capacity in developing countries. • Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, to help limit extreme food price volatility.
Sustainable Development Goal 12	Ensure sustainable consumption and production patterns	By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.
Regional level		
Africa Union Agenda 2063	Achieve modern agriculture for increased productivity and production	Enhanced agricultural productivity and production.
African Continental Free Trade Area (AfCFTA)	Enable the free flow of goods and services across the continent and boost the trading position of Africa in the global market	Promote industrial development through diversification and regional value chain development, agricultural development, and food security.
East African Community Vision 2050	Increased investment and enhanced agricultural productivity for food security and a transformation of the rural economy	• Increasing production of crops, livestock, fisheries, and edible forest products. • Developing markets and marketing infrastructure. • Reducing post-harvest losses. • Promoting value addition through agro-processing.

National level		
National Food and Nutrition Security Policy (2011)	Coordinate the implementation of investments and interventions in the country's nutrition environment.	• Increasing the quantity and quality of food available, accessible, and affordable to all Kenyans always. • Protecting vulnerable populations using innovative and cost-effective safety nets linked to long-term development.
Agricultural Marketing Strategy (2023-2032)	• Transform the agricultural sector into a vibrant, productive, and efficient sector.	• Modernizing agricultural market infrastructure through the integration of ICT facilities. • Facilitating compliance with agricultural produce and products standards. • Achieving a sustainable supply of agricultural produce and products that meet market demand. • Improving the value of agricultural produce to increase market access. • Enhancing adoption of modern and innovative systems for marketing agricultural produce and products. • Developing an efficient and reliable transport infrastructure and logistics for the movement of agricultural produce and products to markets. • Increasing market access through innovative use of agricultural market intelligence and technology. • Improving efficiency in the marketing of agricultural produce and products. • Enhancing and maintaining market position and competitiveness of agricultural produce and products in new and established markets.
Agricultural Sector Transformation and Growth Strategy (2019-2029)	Drive Kenya's agricultural transformation through an evidence-based approach.	• Increasing agricultural output and value addition practices. • Increasing household food resilience.
Agricultural Policy (2021)	Provide guidelines to the National and County Governments regarding the agricultural sector.	• Increasing agricultural production and productivity through the use of appropriate good quality and affordable inputs. • Facilitating access to premium domestic, regional, and international markets. • Reducing post-harvest losses while promoting agribusiness, value addition, and product development.

The Crops (Horticultural Crops) Regulations, 2022	Regulate the production, quality, handling, and selling of horticultural crops in both the domestic and export markets.	• Governing contract farming. • Ensure information keeping for traceability. • Ensuring quality production of horticultural crops that meet international standards.
Crops Act No. 16 of 2013	Recognizes avocado as one of the scheduled crops that should be promoted at the County and National level.	Promote the production, processing, marketing, and processing of scheduled crops through effective communication and transportation channels.
County-level		
Murang'a County Integrated Development Plan 2023-2027	Strengthen agriculture through economic, infrastructure, and value addition investments	• Increase productivity and profitability of flagship cash crops like avocado. • Support county-based processing and packaging hubs such as avocado processing plants. • Access funds and roll out Global Gap and Organic EU certification for export avocado in the next three (3) years. • Establish and/or maintain a model farm for commercial enterprises like avocado. • Introduce and strengthen cooperatives for farm produce such as avocados.
Kisii County Integrated Development Plan 2023-2027	Enhance crop production, productivity, and profitability	Promotion of avocado through the provision of high-quality farm inputs, capacity building, and reduction of pre- and post-harvest losses through agro-processing, infrastructure, and market linkage.
Nyamira County Integrated Development Plan 2023-2027	Increase income from the avocado cash crop sector	• Training of farmers in modern technologies. • Formation of cooperatives and marketing structures. • Support farmers by supplying them with avocado seedlings and other raw materials.

The Kenyan government also seeks to digitize various sectors of the economy, including the agricultural sector which the avocado value chain is a part of. This has been backed by various policies and regulations in the ICT sector that seek to enhance efficient information flow for a seamless digital economy. For instance, the National Information Communication and Technology (ICT) Policy of 2019 and the National Digital Masterplan of (2022 – 2032) support the development of digital infrastructure across all sectors of the economy for efficient information storage, sharing, and enhanced efficiency in service delivery. While understanding the threats of cyber-attacks that may arise due to the promotion of a digitized agricultural economy, Kenya also enacted a Computer Misuse and Cybercrimes Act in 2018 to help prohibit, prevent, investigate, and prosecute cybercrimes in the country.

2.3.2 Institutional frameworks

Kenya has established institutional frameworks that help to implement the above-mentioned policies and support the advancement of the avocado value chain. The Agriculture and Food Authority (AFA) is the overall institution that is tasked with regulating and promoting the development of scheduled crops' value chain, including avocados. The Horticultural Crops Directorate operates under AFA, and it is mandated to provide guidelines on contractual agreements between dealers and producers, provide licenses to actors, and oversee the promotion, development, and regulation of the horticulture value chain. The Directorate also works together with the Kenya Plant Health Inspectorate Service (KEPHIS), which is tasked with assuring the quality of agricultural inputs and produce.

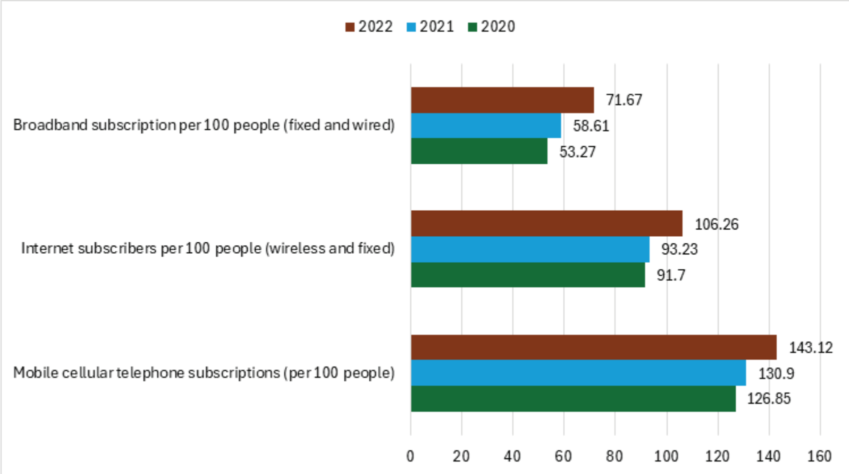
Once quality production is achieved, the Kenya National Chamber of Commerce and Industry (KNCCI) together with the Kenya Trade Network Agency (KenTrade) promote the sale of these horticultural products in both the domestic and international markets. Other actors such as the Avocado Society of Kenya (ASOK) and the Fresh Produce Exporters Association of Kenya also work to link the various actors of the horticultural value chains while aiming at promoting efficiency, marketing, and profitability of the value chains.

To enable them to enhance the productivity of the horticultural sector, these institutions have also developed platforms and systems that have integrated ICT. For instance, the AFA Integrated Management Information System (AFA IMIS) has been implemented to enable the automation of business processes of the Horticultural Crops Directorate. This, in turn, allows traders importing and exporting crops to acquire regulatory documents remotely. The Kenya Integrated Agriculture Management Information System (KIAMIS) was also established to facilitate farmer registration. To enhance trade in the domestic and export markets, iSoko and Kenya TradeNet Systems have been implemented. These systems and platforms have supported efficient recording of information, thereby enhancing efficiency, traceability, and transparency in the horticultural value chain.

2.4 Relationship between BCT and Avocado Value Chains

There has been an increase in internet connectivity in Kenya, as measured by the number of subscribers to the internet of 106 per 100 people. This is in line with the increased number of mobile cellular subscriptions, as measured by the number of mobile cellular telephone subscriptions of 143 per 100 people as illustrated in Figure 2.2.

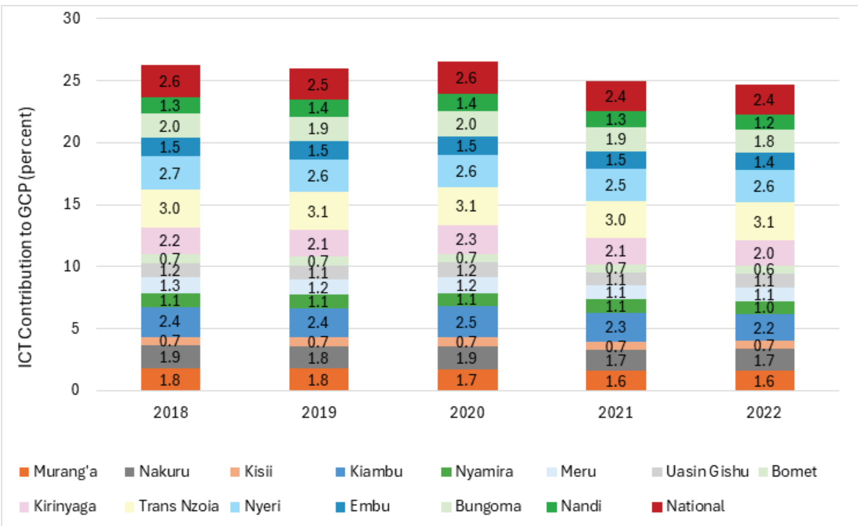
Figure 2.2 Individuals using the internet (% of the population)



Source: KNBS (2024)

Several ICT interventions exist in the agriculture value chains such as the transmission and use of information, like weather information that can be used by farmers for determining when to plant and harvest and informing farmers about the proper use of fertilizer among others. There is potential for incorporating BCT in the country's avocado value chain. Figure 2.3 shows ICT sector contributed about 2.4 per cent to Kenya's economy in 2022, which varies between 0.7 per cent in Bomet and Kisii counties, and 3.1 per cent in Trans Nzoia County.

Figure 2.3 ICT contribution to GCP (percentage) among major avocado production counties



Source: KNBS (various)

3. Literature Review

3.1 Theoretical Literature Review

3.1.1 Agency Theory

Agency theory was proposed by Michael Jensen and William Meckling in 1976. The theory is concerned with resolving two possible problems in agency relationships. First, the principal-agent conflict may arise because it is difficult for the principal to verify the activities of the agent. Second, the different risk attitudes between agents and principals may prevent risk sharing (Onjewu, 2023). It assumes self-interest, conflicting goals, bounded rationality, information asymmetry, efficiency, and the tendency of risk in the principal-agent relationship (Bendickson et al., 2016; Arrow, n.d.).

Self-interest implies that agents are inherently inclined to pursue and satisfy their interests. Conflicting goals presume that principals and agents have divergent objectives in that principals seek to maximize their return whereas agents wish to maximize their income. Bounded rationality implies rationality in decision making to achieve satisfactory rather than optimal economic outcomes. Information asymmetry means more information and knowledge by the agents than the principals. Efficiency means that the contract between the principals and agents uses cost-benefit analysis. On the tendency of risk, agents are deemed to be risk averse whereas the principals are risk neutral.

Table 6 shows principal-agent relationship is a contract between shareholders and directors in the private sector, elected representatives and the public in the government, or donors and directors in NGOs. The principals appoint agents to manage affairs on their behalf and delegate decision-making authority to directors and representatives.

Table 3.1: Summary of principal-agent relationship

	Private sector	**Public sector/government**	**Non-government organizations**
Purpose	Maximization of shareholder wealth	Implementation of government policy	Achievement of benevolent purpose
Agents	Directors	Elected representatives	Directors and managers
Principals	Shareholders	Public	Donors and users

Source: Authors (2024)

As the value chain grows, BCT reduces information asymmetry, and tracks inventories and ownership rights of products thus enhancing coordination between stakeholders i.e. smart contractual agreements (Allen et al., 2018; Harvard Business Review, 2020; Lohmer, 2021). Through disintermediation, end-to-end visibility, and equal rights, the agri-food value chain is transformed, and existing risks are reduced.

3.1.2 Transactions Cost Theory

Transaction cost theory was proposed by Ronald Coase in 1937. A transaction involves stages that add value within a firm and buyer purchasing from suppliers (Schmidt and Wagner, 2019). Transaction costs can be divided into four (4) categories: search, contracting, monitoring, and enforcement costs. Search costs comprise the costs of gathering information to identify and evaluate potential trading partners. Contracting costs are the expenses incurred during the negotiation and writing of an agreement. Monitoring costs are the expenses associated with monitoring an agreement to ensure that each party fulfils the predetermined set of obligations. Enforcement expenses relate to the cost associated with ex-post bargaining and penalizing a trading partner who fails to perform according to the agreement (Williamson, 1985; North, 1990; Hennart, 1993; Dyer, 1997).

Two assumptions in the Transaction Cost Theory are bounded rationality whereby the inability to process information restricts the rationality of a decision (Grover and Malhotra, 2003), and opportunism, which involves withholding information, cheating, and other contract violations for primarily self-interest (Gulbrandsen et al., 2009).

Blockchain can eliminate opportunistic behaviour in transactional relationships through transparency and visibility, as well as the automated execution of smart contracts (Schmidt and Wagner, 2019). It makes it more difficult for companies to withhold information or conceal their true actions. Information sharing has improved, allowing for a more efficient movement of goods and services (Babich and Hillary, 2020).

3.1.3 Technology Acceptance Model

Davis proposed the Technology Acceptance Model (TAM) in 1989, which describes how a person accepts and uses technology. The TAM begins with the introduction of a new technology and concludes with its acceptance and use by end users. According to the TAM, users prioritize perceived usefulness and perceived ease of use when choosing a technology, and their decision to use a technology can also be influenced by social factors, training, and individual differences that determine a user's attitude toward technology.

The TAM emphasizes the reasons why users can accept or reject the BCT, along with a way to improve its acceptance (Aketch et al., 2021). The study will employ the TAM to investigate how the usefulness and simplicity of BCT can best explain users' decisions to accept or reject it along the avocado value chain. User attitudes are shaped by their perceptions of BCT, which are derived from how the user perceives usefulness and ease of use. The TAM states the adoption of BCT can be defined as the perception that a user believes that it will improve their performance within the value chain. However, the TAM has come under significant criticism for emphasizing technology use at the expense of other important aspects of technology, like cost and the structural factors that compel users to adopt the technology (Ozili, 2024).

3.1.4 Diffusion of Innovation Theory

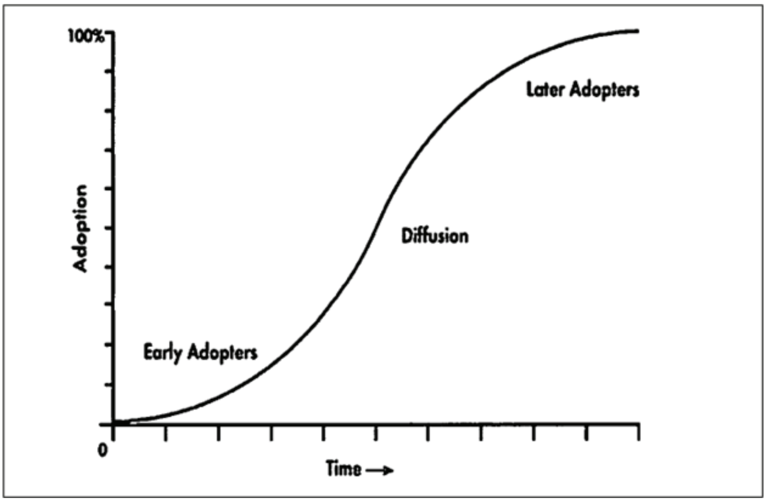
The diffusion of Innovation Theory was put forward by Rogers in 1983. The diffusion theory describes how an innovation spreads through social system channels. The four essential components are innovation, communication channels, time, and the social systems. An innovation is an idea, method, or item that a person perceives to be novel. Further, a person may have heard about innovation for quite some time without having accepted or rejected it, nor acquired a positive attitude about it (Rogers, 1983).

Communication channels are how messages are exchanged between individuals. The information exchange that occurs when one person introduces a new idea to one or more other people is the fundamental component of the diffusion process. Time relates to the diffusion process of innovation involving what it takes for a person to learn about an innovation and either adopt or reject it. An individual's innovativeness refers to the earliness or lateness with which an innovation is adopted compared with other individuals. In social systems, interdependent units solve problems together to achieve a common goal through joint problem solving. In addition, the theory suggests that diffusion of innovation occurs within a social system in which members' adoption of innovations is influenced by norms and roles, highlighting the significance of social networks in influencing decision-making (Rogers, 1983).

The theory is pertinent to the study of the adoption of BCT with innovative examples such as Bitcoin, which debuted in 2009, and intended to establish a currency that is unregulated by governments, banks, and middlemen. Bitcoin has exemplified technology diffusion by offering a more privatized approach compared to traditional payment methods. Bitcoin also cautions users against perceived inflation, and it has a steady supply and appreciation in the market (Ermakova et al., 2017).

Figure 3.1 shows at a certain point the rate of adoption in the diffusion process for any innovation starts to increase at an elevated rate. As a result of this take-off, the S-curve of diffusion is created.

Figure 3.1 The diffusion S-curve



Source: Adopted from Rogers (1983)

3.1.5 Evolution Theory of BCT

A blockchain stores a set of data on each block, comprising transactions, records, and other types of information. These blocks are linked to each other via cryptography such that the information in one block is referred to in the next, forming a chain of blocks that is sequential and continuous (Wu, 2022; Hughes et al., 2019; Scully and Höbig, 2019; Bashir, 2017). Table 7 illustrates the evolution of BCT.

Table 3.2 Evolution of BCT

Year	Innovations in BCT
2009	• Bitcoin • Cryptocurrency • Internet-native money
2015	• Ethereum • Smart contracts • Decentralized autonomous organization • Internet-native contractual agreements
2021	• Tendermint interchain protocol • Smart contracts • Decentralized autonomous organization • Inter-Blockchain Communication Protocol
2022	• Interconnected blockchains • Interchain accounts • Cross-chain composability

Source: UNCTAD (2023)

In 2009, the double-spending problem was the main emphasis of Bitcoin and, later, other cryptocurrencies like Ripple and Litecoin. A double spend problem occurs when the same data or file is present in two places at once in a digital system, making it difficult to ensure that digital money cannot be easily duplicated. Banks and other trusted third parties privately verify every transaction to avoid double-spending. By allowing each user to validate each transaction and using a decentralized ledger that is accessible to all users, Bitcoin helps to eliminate double spending. Additionally, blockchain employs an immutable ledger that cannot be altered thus data and records cannot be easily changed. Transferring data, records, or assets between independent blockchains required having trust in a centralized or pseudo-centralized entity.

Ethereum was developed in 2015 to achieve full computational capabilities, which include not only decentralized databases but also fully operational computational environments that run autonomous software and business logic known as smart contracts. Smart contracts could be used to connect blockchains and ensure communication (Buterin, 2016). Tendermint Cosmos advanced in 2021 by implementing protocols such as Inter-Blockchain Communication (IBC), resulting in fully functional computational and chain capabilities. Tendemint's IBC protocol enabled two or more blockchains to communicate directly and exchange native messages without the need for an intermediary. Interchain accounts (ICAs) were established in 2022 to enable several users on a single chain to query foreign blockchains, issue commands, and execute instructions. This was the first step toward chains that could not only communicate with one another but also allow users to develop cross-compose applications and business logic across multiple chains (UNCTAD, 2023).

3.1.6 Avocado value chain theory

Figure 3.3 is an illustration of the avocado value chain from production to consumption. Caro et al. (2018) provide a simplified version of the process and actors involved in agri-food supply chain management as follows:

Farmer

Background environment (e.g., soil, water, air, and sunlight quality); plant cropping circumstances (for example, seed quality, practices, variety, item number, production area, conditions, planting time, plucking time, staff involvement); and fertilizer and pesticide application.

Packaging

Product information (for example, quantity, packaging date, package condition, and food qualities including weight, moisture, appearance, and texture).

Processing

The information may include the processing environment (for example production date, processing parameters such as temperature and time, packaging information, storage conditions, lab testing findings, safety compliance), additives utilized, and staff.

Distribution

GPS tracking information, ship and delivery details, and transport conditions (temperature, relative humidity).

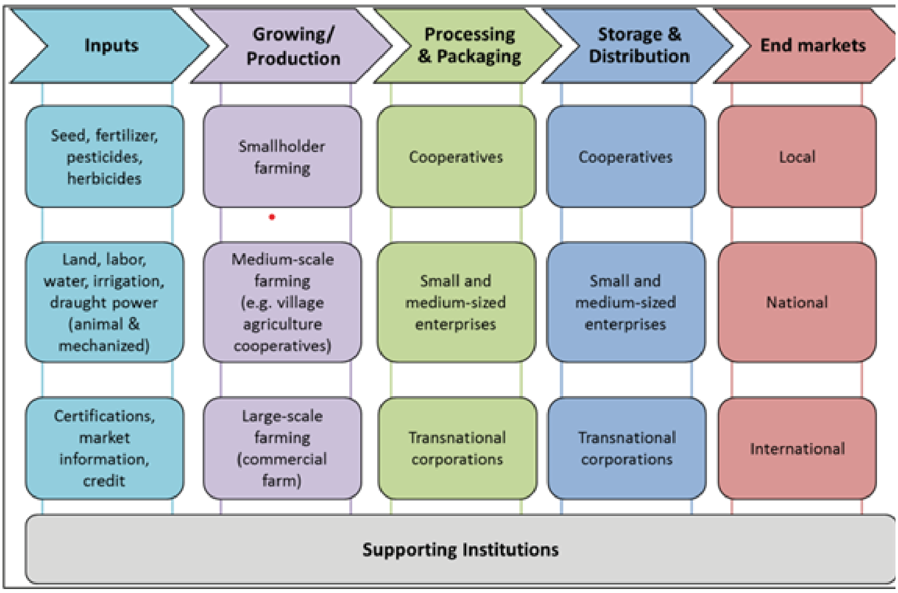
Retailer

Location, labelling (expiration and receiving dates), storage conditions, inventory information, and sanitation practices are all provided.

Consumer

The information on product freshness, longevity, and expiration date. If a food safety issue happens, the causes, location, and responsible personnel can be easily identified.

Figure 3.2 Avocado value chain

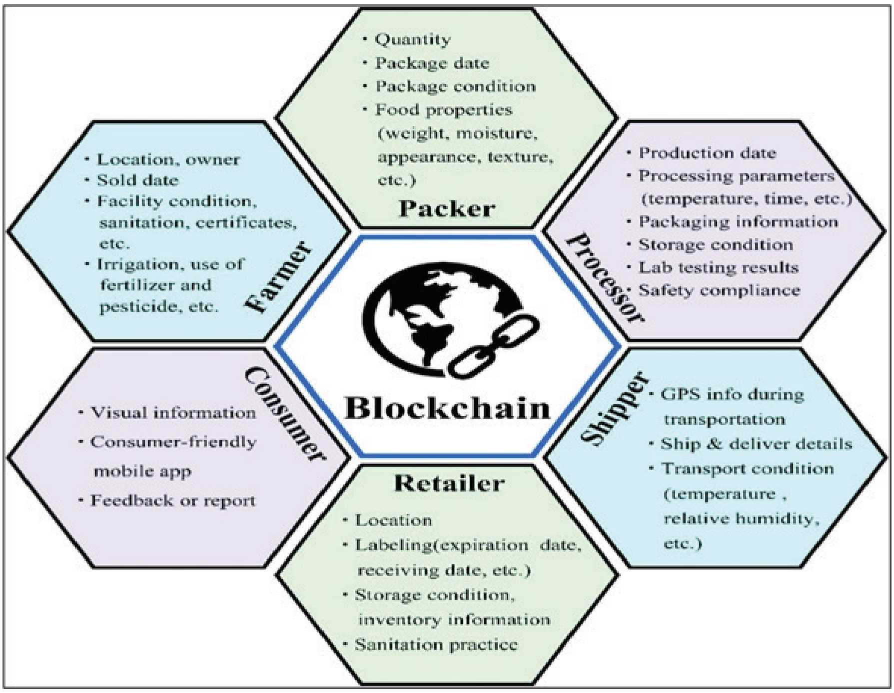


Source: Abdulsamad, A., Brun, L., and Gereffi, G. (2013)

As illustrated in Figure 3.3, BCT helps to connect various players of the avocado value chain ranging from the producers, marketers, suppliers/retailers, consumers, the government, agricultural equipment retailers, logistics companies, and inventory managers among others. These players are key decision-makers who impact the price, quality, shelf life, and nutritional value of avocado products. Therefore, it is important to be informed about the link between the price of an agricultural food product and its quality.

López-Pimentel (2022) described a model made up of three parts: avocado supply chain, audit architecture, and BCT. The avocado supply chain includes several microservices, including farmers, carriers, packers, merchants, and consumers. The microservices transmit and receive data from the API gateway microservice. The farmer oversees the avocado orchard harvest and will pick the order. Carrier transports avocados from one point in the supply chain to the next. A carrier delivers an avocado lot from the orchard to the packers. The retailer receives an avocado lot from the packers and is responsible for introducing the avocado product to the end consumer. Consumers are at the point where avocados are finally considered a consumer good. At this point, it can be used as a raw material to make secondary products like avocado beauty products, avocado oil, and avocado sauce.

Figure 3.3 Connection in the avocado value chain through BCT



Source: Adopted from Xu et al., (2020)

3.2 Empirical Literature Review

Bikoro (2022) conducted a study aimed at understanding how the application of BCT can enhance intelligent agriculture in Africa. Guided by the objectives of understanding the benefits of blockchain in agriculture and analysing the state of African initiatives related to blockchain use in agriculture; the study conducted an empirical review of existing and relevant literature. It reported that the implementation of BCT was mainly concentrated in Sub-Saharan Africa, and it was mainly being carried out by private startups. In addition, challenges such as limited skilled management personnel and insufficient technological infrastructure impede the implementation of BCT in Africa. It was, therefore, recommended that digitization of agriculture, training of agri-food actors, and solving infrastructure challenges should be done. This study identifies opportunities for change that Africa can delve into to enhance the adoption of BCT in the avocado value chain.

Lesiit (2020) conducted a study aimed at developing a BCT system to enhance food safety and traceability in Kenya's agricultural industry. This was guided by specific objectives of examining the actors and stakeholders in Kenya's agricultural industry together with any BCT techniques and models employed in the food supply chain. He reported that Kenya's agri-food supply chain still lacks the aspect of traceability and accountability. This has greatly contributed to foodborne and food-related diseases when contaminated and unsafe foods are distributed. Furthermore, the lack of information management/sharing has made it difficult to hold actors in the value chain accountable for any shortcomings as no evidence can be relied on. Therefore, using BCT can help to streamline the agri-food value chain, and this should be done in collaboration with relevant quality monitoring bodies in Kenya.

Agnew et al., (2022) conducted a study aimed at exploring the use of BCT to enhance food security in Western Kenya's local communities that are actors in the African indigenous vegetables value chain. They employed a non-experimental impact evaluation research design and a Laser Pulse embedded research translation model to fulfil their objectives and answer their hypotheses. The researchers reported improved food security in the study area because efficiency in information sharing was achieved among the participating actors; income increased due to the elimination of corruption and middlemen in the vegetable value chain; and time was saved allowing the value chain actors to also participate in other income-generating activities. It was also reported that BCT enhanced trust and transparency in the vegetable value chain. This study provides a practical example of BCT application in local or small agri-food value chains.

While trying to understand the application of BCT in food supply chains, George and Al-Ansari (2023) conducted a systematic literature review and content analysis of existing literature. This was informed by the objective of identifying the complexities and effects of the adoption of BCT in a food system. The researchers reported positive results in the use of BCT to enhance food security, food safety, and food availability. However, they raised concerns over the lack of regulations to standardize BCT use locally and across borders. In addition, education awareness is still lacking, and this has greatly affected the adoption of BCT use in food systems. They recommended that more research should be done on the scalability and interoperability of BCT in the food value chain. This study identifies the advantages and challenges of employing BCT in food supply chains.

While focusing on Kenya's maize value chain performance, Nzau (2023) conducted a study seeking to understand how BCT advantages can be tapped following the cases of safety concerns, corruption, and fraud reported in the maize sector. Guided by the objectives of understanding the influence of BCT on the maize value chain's transparency, traceability, immutability, and transaction costs; data was collected using questionnaires administered after implementing the snowball sampling research design. He reported that BCT greatly contributes to the improvement of transparency in the maize value chain. However, the aspects of traceability, immutability, and control of transaction costs are not significantly affected by the implementation of BCT. It was, therefore, recommended that, to maximize the benefits of BCT, it is important to incorporate all actors in the maize value chain as this will enhance efficiency.

3.2.1 Benefits of BCT in the avocado value chain

BCT has been used to promote food safety and traceability thereby promoting the integrity of food systems. This is because stakeholders can easily trace outbreaks at specific stages, thereby addressing them appropriately (Lesiit, 2020). With BCT, the issue of untraceable corruption and inefficiencies in the agri-food value chain is addressed (George and Al-Ansari, 2023). The technology has also reduced transaction costs in the agri-food value chain while at the same time promoting transaction efficiency. This way, delays within the value chain greatly reduce leading to increased satisfaction levels by all parties concerned.

Blockchain has also reduced cases of unfairness in the agri-food value chain. For instance, farmers and distributors receive fair and timely payments. This leaves everyone satisfied with their contributions to the value chain. With BCT, consumers also get closure and can trace the origin of the food items consumed. These builds trust among buyers and encourages the distribution of quality agri-food products.

3.2.2 Challenges of BCT in the avocado value chain

BCT is in its developmental stages in Africa, and it has various shortcomings. For instance, it is costly to implement on a large scale, especially in developing nations. This, therefore, needs the intervention of private investors and donors to provide funding. Scalability is also challenging especially when huge datasets are involved. Given the current cases of cybersecurity and evolving technology, it might be difficult to regulate the use of BCT and this will be detrimental to the actors in the agri-food value chain (Alhasan and Hamdan, 2023). It may also interfere with data privacy especially if the blockchain is in the public domain. Implementation of the technology may also be hindered by inadequate skilled personnel, and this leads to heavy reliance on imported skilled personnel that is expensive to maintain (Zhao et al., 2019).

Applications of BCT in the agri-food value chain

Global level

A food safety initiative led by Wal-Mart has attracted several retailers, including Carrefour, to use BCT. By using BCT, the Food Trust organization tracks products from the farmer to the consumer. In addition, 3M uses the internet of Things to make food safety diagnostic equipment, while Emmerson tracks and controls temperatures in the agri-food value chain. In Europe, IBM offers a food trust solution that allows organizations to track food through the supply chain and vendors to monitor and recall any contaminated food.

AgriLedger is an example of a startup operating (Bikoro, 2022) in 18 countries across the world. This startup utilizes BCT to solve challenges along the agricultural value chain thereby promoting seamlessness, transparency, trust, and efficiency of operation among all participating stakeholders. With blockchain, the startup has managed to provide relevant real-time data to producers, streamline financial support for agricultural advancements, streamline logistics in the agri-food value chain, enhance efficiency in agri-food value addition practices, enhance transparency, promote government collaboration, and instil consumer confidence regarding the existing agricultural products in the market. AgriLedger has been successful in streamlining Haiti's fruit supply chain such that it is now possible to verify 98 per cent of the transactions carried out along the chain.

Regional level

Implementation of BCT in Sub-Saharan Africa is still in its early stages and it is being spearheaded by startups that seek to provide innovative solutions across the agri-food value chain. Solutions in the aspect of e-marketplaces, insurance services, financing services, and provision of agricultural credits to farmers have been explored using BCT. For example, in South- Africa, BCT has been implemented to monitor the certification of wine production through a project called "Blockchain for Agrifood". In this project, the supply chain from grapes to wine production is monitored (Kamilaris et al., 2021).

The Great Lakes Coffee company based in Uganda has also implemented BCT in the weighing and grouping of coffee brought to them by farmers. Through the SaaS solution that is based on blockchain, consumers can now track coffee from the production level all through to the consumption level. The technology has greatly enhanced efficiency and timeliness in the payment of Uganda coffee farmers (Kshetri, 2021).

Hello Tractor, another startup operating in Kenya, Nigeria, and Uganda, has also implemented the BCT to connect tractor owners to smallholder farmers. In this case, tractor owners rent their machines to smallscale farmers, and this promotes efficiency at the production level of the agri-food value chain. In addition, tractor owners can also obtain financing using the same technology (Vishakha et al., 2021).

Moyee Coffee company in Ethiopia has also managed to seamlessly connect coffee farmers to consumers using BCT. Here, the coffee supply chain is fully digitized and all employees along the coffee supply chain are paid digitally. In addition, consumers also get a chance to tip farmers via the blockchain and this further promotes value and transparency in the distribution of coffee (Bikoro, 2022).

Local level

Farmshine is a trading startup in Kenya that has employed BCT to connect smallholder farmers, consumers, and service providers in the agri-food value chain. It aims to maximize the profits of farmers. It allows farmers to aggregate their agricultural produce. This boosts their selling power to large buyers. This way, the challenges of low farm produce, market inefficiency due to the existence of middlemen, and lack of traceability of farm products are eliminated (Addison et al., 2019).

Twiga food company employs BCT to keep track of transactions carried out by its clients. Using the data, the clients can assess their ability to access loans. The lending process is transparent to all parties involved, from the lending bank to the borrower's bank and loan applicants themselves (Bikoro, 2022).

In Western Kenya, a project by Laser Pulse in collaboration with USAID was carried out to examine how value chain actors in the African Indigenous Vegetables (AIV) can be effectively compensated using BCT. The AgUnity blockchain app was shared with various actors during the project period. This led to the realization of positive results as it led to a decrease in post-harvest loss, easy access to information by consumers, and improved cooperation among actors along the vegetable value chain. Overall, indigenous vegetable farmers reported good profits and sustainable income while employing the BCT (Agnew et al., 2022).

4. Methodology

This study employed systematic literature review and futures foresight methodologies.

4.1 Systematic Literature Review

Systematic Literature Review (SLR) was employed to answer the study's first objective, which seeks to assess the effects of BCT on information flow in the avocado value chain. SLR as a methodology aims at identifying and evaluating relevant literature on a research problem to enable the answering of specific questions and making the required conclusions. SLR is carried out in five generic steps (Paré and Kitsiou, 2017):

1. Formulating the research questions and objectives

Research questions and objectives act as the backbone for the research and thus, they define the type of information needed, inform the search and selection criteria, and the subsequent analysis. For this study, the research question explored was: what are the effects of BCT on information flow in the avocado value chain?

2. Searching the extant literature

This entails exploring the existing literature and deciding on what literature should be considered for review. For this study, searching the extant literature entailed identifying literature representative of most other works in the field of interest. This was done by identifying articles in scholarly journals published in Google Scholar and SCOPUS databases. The search was guided by the following keywords: BCT in agriculture, BCT and fresh fruit supply chain, BCT and food safety, BCT and food nutrition, and BCT and avocado value chain. Articles at the local, regional, and global levels were considered for review. Since 4IR was introduced in the year 2011, this study restricted the search to articles published between the years 2011 and 2024. ARUD sector reports were also reviewed to establish the status of the avocado value chain. In addition, existing legal and policy documents together with County Integrated Development Plans (CIDPs) were reviewed to map out the policy and legal framework governing BCT use in the avocado value chain and technological efforts that have been identified to advance the avocado value chain at the County level.

3. Screening for inclusion/exclusion

This is done on the selected articles to examine the relevance, and applicability of the identified literature. Screening for inclusion/exclusion is based on a set of predetermined rules to avoid mistakes and bias. Table 4.1 provides the inclusion/exclusion criteria adopted by this study. From this criterion, a total of 30 scholarly papers were reviewed.

Table 4.1: Adopted inclusion/exclusion criteria

No.	Criteria	Decision
1.	The title, keywords, or abstract of the paper contains the predefined keywords either wholly or partially	Inclusion
2.	Paper written in the English language	Inclusion
3.	Papers utilizing primary and/or secondary data	Inclusion
4.	Papers published between the years 2011 and 2024	Inclusion
5.	Papers that are duplicated within the search documents of the predefined databases	Exclusion
6.	Papers with restricted access	Exclusion
7.	Papers published before the year 2011	Exclusion

Source: Modified from Mengist, Soromessa and Legese (2020)

4. Assessing the quality of studies

This is done to assess the scientific quality of the identified materials based on the research design and methodology used in each study. For this study, an assessment of the quality of the selected papers was done by examining whether the objectives were SMART if the methodology used was appropriate, and if the results and analysis fulfilled the needs of the stated objectives.

5. Extracting and analysing data

Data extraction is guided by the study's research questions and objectives. Specifically, this paper utilized the objective of assessing the effects of BCT on the productivity of the avocado value chain to extract the required data. The data was then analyzed using the Drivers, Enablers, Frictions, and Turners (DEFT) approach. According to Gordon (2010), a DEFT approach provides a basis for discerning the type and extent of force underpinning a trend, as well as a framework for organizing and analysing factors that will promote or retard a trend. Drivers are forces that create and sustain a trend; enablers are catalysts that support the drivers; frictions are any resistance that impedes a trend; and turners are events that actively block a trend.

Table 4.2 provides an analytical framework of the variables and indicators highlighting how the DEFT approach was applied.

Table 4.2 Analytical Framework for DEFT Approach

DEFT approach	Variables	Indicators
Drivers	ICT and BCT innovations	Innovation, digital platforms, and applications such as the AgUnity App supporting BCT.
Enablers	Education/awareness level of actors	Actors understanding of the importance of integrating innovative technologies such as BCT along the avocado value chain.
	Skilled personnel	Adequately trained experts ready to implement the BCT along the avocado value chain.
	Policies	Kenya Vision 2030 strategies that seek to drive Kenya into an industrialized country.
		BETA initiatives requiring all sectors in Kenya to digitize their services/work.
	Donors, inventors, and development partners	Funders seeking to support the use of BCT start-ups in the agri-food value chain.
Friction	Data confidentiality	Public BCT entries that can be accessed by everyone, and this may go against data protection laws.
	Cost implications	The cost of implementing and sustaining BCT in the agri-food value chain, especially at the local level.
	Security	Cyber-attacks.
Turners	Laws and policies	No laws and policies in place that hinder BCT use
	People's traditions and culture	Traditions/ways of life that hinder the incorporation of technologies such as BCT in the avocado value chain.

Source: Authors (2024)

4.2 Futures Foresight Methodology

Futures foresight methodology was employed to answer the study's second objective, which seeks to examine the future scenarios of BCT application in Kenya's avocado value chain. As described by the UNDP Global Centre for Public Service Excellence (2014), futures foresight is a methodology that explores plausible and possible futures and visualizes outcomes and consequences amidst uncertainties. It entails strategically thinking about different ways something can be done while not only focusing on desirable outcomes but also undesirable outcomes. By exploring plausible futures, futures foresight is important for developing countries as it empowers policymakers to expound their perceptions regarding future challenges and develop effective policies and strategies to address future problems.

4.2.1 Formulating plausible/possible futures

This step entails applying futures foresight techniques to identify and analyse emerging strategic issues with respect to the trends and drivers identified in horizon scanning. This study applied the Delphi technique, cross-impact analysis, and scenario building to evaluate the key drivers and formulate plausible/possible futures of BCT application in Kenya's avocado value chain.

a. Delphi Technique

This study applied the Delphi technique to evaluate the key drivers of BCT application in Kenya's agri-food value chain. The Delphi technique allows for a certain degree of inter-subjectivity selection of spontaneous and intuitive individual opinions. In this method, the assumption is that a forecast that can be agreed upon by the majority of the experts surveyed on the BCT will have greater credibility than that provided by an individual expert (Pillkahn, 2008).

The Delphi technique was achieved by administering questionnaires to experts along the avocado value chain. The experts were requested to give their opinion on how the drivers of BCT impact each other with respect to information flow in the avocado value chain. A total of 12 drivers were included in the Delphi technique. This included transparency, traceability, security and safety, disintermediation, immutability, lower probability for foodborne diseases, lower transaction costs, high set-up costs, less expertise, scalability issues, no regulations, and no standards.

The study targeted 60 experts from the government, research/academia, farmers, consumers, private companies, ICT professionals, and international organizations. Out of this sample size, a total of 38 responses were received as illustrated in Table 4.3. Therefore, the survey return rate was 63 per cent.

Table 4.3 Composition of Delphi Experts

Experts' occupation	Number of respondents
Government	7
Research/academia	4
Avocado farmers	3
Consumers	6
Private companies	10
ICT professionals	5
International organizations	3
Total	**38**

The Delphi technique was also subjected to Cronbach's Alpha reliability test. This resulted in a Cronbach's Alpha coefficient of 0.978, which is above the recommended 0.7 (see Table 4.4). The Delphi technique was therefore consistent, and the results obtained were reliable (Lim and Kamaruddin, 2023).

Table 4.4 Reliability analysis

	Reliability statistics **Actual Delphi Technique**
Cronbach's Alpha	0.978
Average interitem covariance	0.346
Number of items	132
Number of respondents	38

b. Cross-impact analysis

A cross-impact analysis is a method of scenario design whereby the mutual relationship of the variables is assessed by expert judgments (Ghasemian, 2020). In this study, the impact of each driver on another was evaluated to systematically derive those that had a relatively greater impact on the overall system. This was achieved by developing a cross-impact matrix of the twelve drivers based on experts' responses, that is, transparency, traceability, security and safety, disintermediation, immutability, the lower probability for foodborne diseases, lower transaction costs, high set-up costs, fewer expertise, scalability issues, no regulations, and no standards. The matrix was constructed using the MicMac software.

c. Scenario Building

According to Lehr (2017), scenario building involves generating a scenario based on current trends and events. It is aimed at constructing, interpreting, and formulating plausible/possible future scenarios of using BCT in the avocado value chain after gathering relevant data.

5. Results

5.1 Effects of BCT on Information Flow in the Avocado Value Chain

A total of 30 journal papers (as illustrated in Table 5.1) were reviewed to identify the drivers, enablers, frictions, and turners of BCT.

5.1.1 Drivers of BCT

The Kenya Integrated Agriculture Management Information System (KIAMIS) is an innovative digital platform currently used that, apart from registering farmers, provides e-extension, credit management, and mechanization services (Ministry of Agriculture, 2023). In the avocado value chain, the drivers for the adoption of BCT were transparency, traceability, security and safety, disintermediation, immutability, and lower probability of foodborne diseases. Transparency implies that each block in the chain has a complete audit trail of all transactions. Traceability means that nodes in the network communicate with one another, and each ledger stores and transmits data back and forth. A network with traceability contains nodes that communicate with one another, and each ledger stores and transmits data back and forth. As part of security and safety, all additions use public key encryption to ensure data integrity. In disintermediation, transactions between nodes are secured via secure algorithms, without central control from any node, and eliminates middlemen. A network of nodes that is immutable means that all transactions cannot be changed once they have been entered and the data is permanent and chronologically ordered. A lower probability of foodborne diseases leads to better-quality products.

5.1.2 Enablers of BCT

SDG nine (9) aims to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. Internet connectivity is a primary need in the digital era, and it has the potential to build a strong and cohesive community based on common values and a shared vision. Internet-supported platforms such as Glovo are among the key enablers in the use of avocado blockchain-backed value chains. In the avocado value chain, the enablers for the adoption of BCT were lower transaction costs, policies, investors, and skilled personnel.

Lower transaction costs mean the applications using BCT show decrease transaction costs. Government policies, legislations, and strategies on the digital economy have the potential impact on the usage of BCT in the avocado value chain. The Bottom-up Economic Transformation Agenda (BETA) prioritizes the value chains approach. Policies on the use of BCT are meant to leverage digital currencies and encourage use of the decentralized technology as a form of payment (Ministry of ICT, 2018). The Kenya National Digital Master Plan (2022-2032) focuses on digital infrastructure development and support strategies such as digital literacy to provide universal ICT accessibility. The Blockchain Association of Kenya, a non-profit organization established in 2017, aims to promote the adoption of blockchain and cryptocurrency technology by building a network of skilled local human capital.

Integration of BCT in agri-food value chains by companies such as Twiga Foods and Hello Tractor shows some level of acceptance and applicability. The number of users and digital currency outlets of cryptocurrencies has increased over the last five years. The Crypto industry's growth is attributed to its speed, low transaction costs, and decentralization of finance (CBK, 2023). Decentralization of finance involves the use of smart contracts in blockchain-based financial instruments, which automatically execute transactions based on specific conditions without the need for intermediaries (UNCTAD, 2021). Blockchain startups in Africa raised a total of US dollar 127 million in 2021. Of the funding raised in 2021, 96 per cent went to Nigeria, Kenya, South Africa, and Seychelles, making Kenya deserving of the spotlight when it comes to Blockchain innovation and integration (Disrupt Africa, 2022; Odufuwa and Mureithi, 2023).

Table 5.1 Systematic literature review

DEFT approach	Factors (Articles)	Author (year)
1. Drivers	Traceability (21)	R Kamath (2018); Tripoli and Schmidnuber (2018); Iftekhar and Cui (2021); Salah et al., (2019); Kamilaris et al., (2019); Zhao et al., (2019); Galvez et al., (2018); Jahanbin et al., (2023); Astill et al., (2019); Chen et al., (2020); Jabbar et al., (2021); Menon and Jain (2021); Yadav et al., (2021); Kamble et al., (2020); Panghal et al. (2023); Collart and Canales (2021); Patelli and Mandrioli (2020); Thume et al., (2021); Westerlund et al., (2021); Vern et al., (2024); Astuti and Hidayati (2023)
	Transparency (15)	R Kamath (2018); Tripoli and Schmidnuber (2018); Kamilaris et al., (2019); Galvez et al., (2018); Jahanbin et al., (2023); Kohler and Pizzol (2020); Hewett et al., (2019); Astill et al., (2019); Chen et al., (2020); Feng et al., (2020); Kamble et al., (2020); UNDP (2021); Thume et al., (2021); Vern et al., (2024); and Panwar et al., (2023)

DEFT approach	**Factors (Articles)**	**Author (year)**
	Compliance with legal and regulatory framework (3)	Tripoli and Schmidnuber (2018); Jahanbin et al., (2023); and Kamble et al., (2020)
	Food safety (7)	Iftekhar and Cui (2021); Xu et al., (2020); Chen et al., (2020); Collart and Canales (2021); Patelli and Mandrioli (2020); Vern et al., (2024); and Mohapatra et al., (2021)
	Disintermediation (4)	Salah et al., (2019); Hewett et al., (2019); Chen et al., (2020); and Panwar et al., (2023)
	Non-tampering (1)	Xu et al., (2020)
	Encryption security (1)	Xu et al., (2020)
	Better quality of products (1)	Kamilaris et al., (2019)
	Lower probability for food borne diseases (1)	Kamilaris et al., (2019)
	Immutability (10)	Zhao et al., (2019); Jahanbin et al., (2023); Hewett et al., (2019); Feng et al., (2020); Jabbar et al., (2021); Menon and Jain (2021); Kamble et al., (2020); UNDP (2021); Vern et al., (2024); Astuti and Hidayati (2023)
	Recording transactions in real time (2)	Zhao et al., (2019); Yadav et al., (2021)
	Smart contracts (4)	Astuti and Hidayati (2023); Kamble et al., (2020); Yadav et al., (2021); Hewett et al., (2019)
	Trust in agri-business (7)	Yadav et al., (2021); Jabbar et al., (2021); Kohler and Pizzol (2020); Feng et al., (2020); Panghal et al. (2023); Vern et al., (2024); and Mohapatra et al., (2021)
	Real time information availability to agro-stakeholder (1)	Yadav et al., (2021)
	Certification of agro-products and process (1)	Yadav et al., (2021)
	Monitoring of agro practices and processes (1)	Yadav et al., (2021)

DEFT approach	Factors (Articles)	Author (year)
	Secured and efficient transactions (1)	Yadav et al., (2021)
	Provenance of agro-products (4)	Yadav et al., (2021); Kamble et al., (2020); Westerlund et al., (2021); Menon and Jain (2021)
	Fairness (2)	Panwar et al., (2023); Kamilaris et al., (2019)
	Public safety and security issues (2)	Astuti and Hidayati (2023); Hewett et al., (2019)
	Auditability (1)	Kamble et al., (2020)
	Anonymity and privacy (2)	Kamble et al., (2020); UNDP (2021)
2. Enablers	Data acquisition technol-ogies (1)	Astill et al., (2019)
	Big data technology solu-tions (1).	Astill et al., (2019)
	Internet of Things (1)	Astill et al., (2019)
	Platforms for managing IoT generated data (1)	Astill et al., (2019)
	Cost saving (2)	Astuti and Hidayati (2023); Xu et al., (2020)
	Profit advantages (1)	Astuti and Hidayati (2023)
	Reduce information bias-es (1)	Astuti and Hidayati (2023)
	Builds confidence (1)	Astuti and Hidayati (2023)
	Latency issues and throughput (2)	Panwar et al., (2023); Zhao et al., (2019)
	Reduced transaction cost (5)	Galvez et al., (2018); Kamble et al., (2020); Vern et al., (2024); Panwar et al., (2023); Kamilaris et al., (2019)
	Reduced settlement lead times	Kamble et al., (2020)
	Technical training (1)	Menon and Jain (2021)
	Skills development (1)	Menon and Jain (2021)
DEFT approach	**Factors (Articles)**	**Author (year)**

3. Friction	High costs of blockchain technology (12)	Astuti and Hidayati (2023); Xu et al., (2020); Kamilaris et al., (2019); Zhao et al., (2019); Hewett et al., (2019); Rogerson and Parry (2020); Chen et al., (2020); Menon and Jain (2021); Kamble et al., (2020); Col-lart and Canales (2021); Patelli and Mandrioli (2020); Mohapatra et al., (2021)
	Cyberattacks (1)	Astuti and Hidayati (2023)
	Data security and privacy challenges (14)	Menon and Jain (2021); Panwar et al., (2023); Xu et al., (2020); Kami-laris et al., (2019); Jahanbin et al., (2023); Hewett et al., (2019); Astill et al., (2019); Chen et al., (2020); Menon and Jain (2021); Yadav et al., (2021); Collart and Canales (2021); Patelli and Mandrioli (2020); Mohapatra et al., (2021); Panwar et al., (2023)
	Complexity of smart con-tracts (1)	Menon and Jain (2021)
	Return on investment in BCT (1)	Hewett et al., (2019)
	Lack of impartial educa-tion	Hewett et al., (2019)
	Lack of understanding of the technical aspects	Menon and Jain (2021); Kamble et al., (2020); Mohapatra et al., (2021)
	Limited access to inter-net, telecommunication technologies, or support services (3)	Menon and Jain (2021); Mohapatra et al., (2021); Astill et al., (2019)
4. Turners	Interoperability (12)	Galvez et al., (2018); Jahanbin et al., (2023); Kohler and Pizzol (2020); Hewett et al., (2019); Astill et al., (2019); Feng et al., (2020); Jabbar et al., (2021); Menon and Jain (2021); Kamble et al., (2020); Panwar et al., (2023)
	Compatibility issues and/or lack of global and common standards (10)	Xu et al., (2020); Kamilaris et al., (2019); Jahanbin et al., (2023); Hewett et al., (2019); Feng et al., (2020); Jabbar et al., (2021); Col-lart and Canales (2021); Patelli and Mandrioli (2020); Thume et al., (2021); Panwar et al., (2023)
DEFT approach	**Factors (Articles)**	**Author (year)**

	Low user acceptance (3)	Jahanbin et al., (2023); Astill et al., (2019); Chen et al., (2020)
	Absence of policy, regula-tion, and legislation (8)	Chen et al., (2020); Feng et al., (2020); UNDP (2021); Mohapatra et al., (2021); Kamilaris et al., (2019); Zhao et al., (2019); Hewett et al., (2019); Jahanbin et al., (2023)

5.1.3 Frictions of BCT

Complexity of using BCT and lack of expertise are key drawbacks in the deployment and utilization of BCT. Other forces that inhibit BCT use are inadequate infrastructure, high set costs, scalability, and data privacy concerns. The technology, being relatively new, is facing challenges in gaining wider acceptance among users. The issue can be attributed to insufficient knowledge and users' trust. There is limited competence building to aid developing countries such as Kenya develop the capacity to utilize and customize versions of BCT suited to the conditions and needs. As a result, developing countries continue to lag in technology production and development, which is partly due to the current legislative framework, inadequate digital infrastructure, and limited human resources for technological advancement. Scalability refers to the number of transactions per second that can be processed for example the Ethereum Blockchain can process 20 transactions per second. The scalability of BCT use is partially hindered by a poor connection to the internet and high electricity costs in some parts of the country. In addition, the cost of integrating BCT into the financial infrastructure, such as payments and settlement systems, is high (De Meijer, 2020; Menon, 2018).

5.1.4 Turners of BCT

In Kenya, no legal or regulatory framework exists for the usage of BCT and crypto assets (see Table 13). Inadequate regulations and legislation often limit the capacity to implement BCT. It also hinders technology adoption by entrepreneurs due to uncertainty and associated risks. Blockchain-based technologies that are integrated into a global network add to the complexity. In systems powered by computational power from nodes in different locations, under different laws, and without a central party, who should be held accountable for misbehavior or failure, and how liability can be apportioned? BCT is in the incipient stages of standardization, but there are misconceptions about what it is and its benefits and potential (Deloitte, 2019).

Table 5.2 Regulations and legislations that will promote BCT in the avocado value chain

Measures	Global	Regional	Local (Kenya)

Regulations	In the United Kingdom, Crypto assets are regulated by the Financial Con-duct Authority In the United Arab Emirates, Crypto assets are regulated by the Virtual Assets Regulatory Authority In the United States, the regula-tion of Cryptocur-rency varies by State	In Egypt, Crypto assets are regu-lated by the Central Bank of Egypt In South Africa, Crypto assets are regulated by the Financial Conduct Services Authority In Botswana, Crypto assets are regulated by the Non-Bank Financial Institutions Regulatory Authority	There is no regulatory framework on Crypto assets in place
Legislation	In the United Kingdom, The Financial Services Market Law contains provi-sions on Stable coins and crypto currency In China, cryptocurrency-related transactions are illegal	In South Africa, Financial Advisory and Financial Intermediary Services (2022) was amended to define Crypto assets as financial products, create licensing, Anti-Money Laundering and Combating the Financing of Terrorism, and consumer protection obligations for Crypto assets providers In Nigeria, there is a partial ban on Crypto assets The Central Bank of Nigeria issued a cautionary notice banning financial institutions from holding, or trading in crypto assets In Botswana, there is an Act to regulate the sale and trade of Virtual Assets, licensing of Virtual Assets Service Providers, and issuers of Initial Token Offering (ITO)	Capital Markets (Amendment) Bill (2023) proposed to amend Section 2 of the Capital Markets Act to define Blockchain, Crypto currencies and Crypto miners Al and Blockchain Taskforce Report (2018) agricultural sector will benefit from transparent and auditable supply chains Virtual Assets Service Provider Bill (2024) is before the National Assembly for debate to regulate the digital assets market

Source: Authors' compilation

5.2 Future Scenarios of BCT Application in Kenya's Avocado Value Chain

5.1.1 Cross-impact matrix

Key influence factors are a subset of all influence factors obtained from the experts' responses. Influence factors are classified by their active sum, which considers the direct influence this factor has on others, and their passive sum, which considers the effects of other factors on this factor.

The overall impact of one driver on another as ranked by experts was summarized as follows (see Table 5.3), where 0= no impact, 1= low impact, 2=average impact, and 3=high impact. The factors with computed active and passive sums, influence and dependence respectively were transparency (29, 33); traceability (29, 33); security and safety (29, 33); disintermediation (29, 25); immutability (30, 22); lower probability for foodborne diseases (28, 32); lower transaction costs (28, 32); high set-up costs (29, 22); fewer expertise (29, 22); scalability issues (29, 23); no regulation (28, 33), and no standard (26, 33).

Table 5.3: Impact of each driver on one another

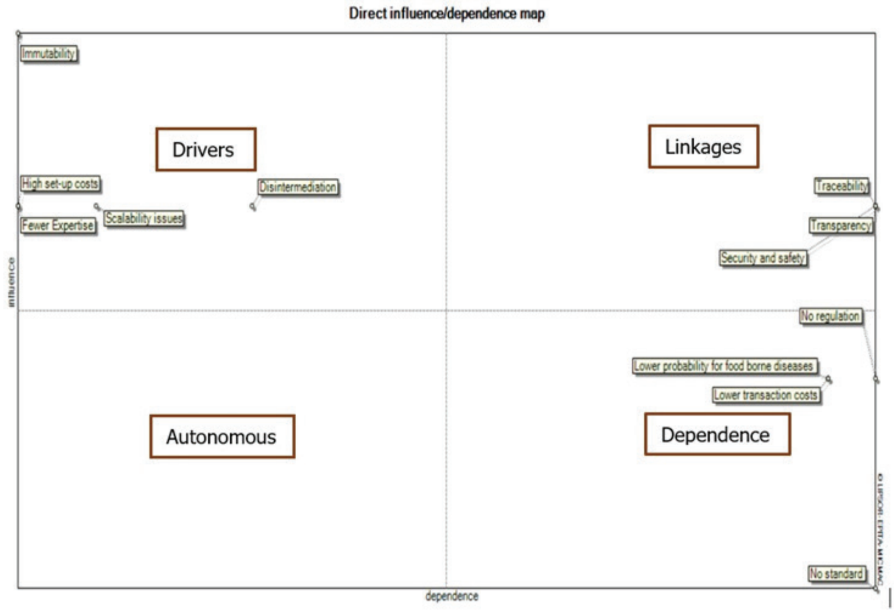
	DEFT elements	Transparency	Traceability	Security and safety	Disintermediation	Immutability	Lower probability of foodborne diseases	Lower transaction costs	High set-up costs	Fewer expertise	Scalability issues	No regulation	No standard	Active sum/influence
1	Transparency	0	3	3	3	2	3	3	2	2	2	3	3	29
2	Traceability	3	0	3	3	2	3	3	2	2	2	3	3	29
3	Security and safety	3	3	0	3	2	3	3	2	2	2	3	3	29
4	Disintermediation	3	3	3	0	2	3	3	2	2	2	3	3	29
5	Immutability	3	3	3	2	0	3	3	2	2	3	3	3	30

6	Lower probability of food-borne diseases	3	3	3	2	2	0	3	2	2	2	3	3	28
7	Lower transaction costs	3	3	3	2	2	3	0	2	2	2	3	3	28
8	High set-up costs	3	3	3	2	2	3	3	0	2	2	3	3	29
9	Fewer expertise	3	3	3	2	2	3	3	2	0	2	3	3	29
10	Scalability issues	3	3	3	2	2	3	3	2	2	0	3	3	29
11	No regulation	3	3	3	2	2	3	3	2	2	2	0	3	28
12	No standard	3	3	3	2	2	2	2	2	2	2	3	0	26
	Passive sum/ dependence	33	33	33	25	22	32	32	22	22	23	33	33	

Source: Authors' computations from MicMac Software

The average active sum and passive sum define the boundaries of the fields for influence factors. Active elements (drivers) included the following factors: immutability, less expertise, high set-up costs, scalability issues, and disintermediation as illustrated in Figure 5.1. These factors are the driving force and depend the least on others. Ambivalent elements (linkages) included the following factors: traceability, transparency, security, and safety. These factors form links and are highly sensitive because they have a high driving and high dependency power and thus, they are difficult to control owing to their nature and require extra care. Passive elements (dependents) included the following factors: no regulation, lower probability of foodborne diseases, lower transaction costs, and no standard. These factors have low driving power but are highly dependent. Non-ambivalent elements (autonomous) have the least importance for the system behavior due to their low dependence and low driving power. No factor was non-ambivalent (Gräßler, 2016). Active and ambivalent elements are more important than passive elements.

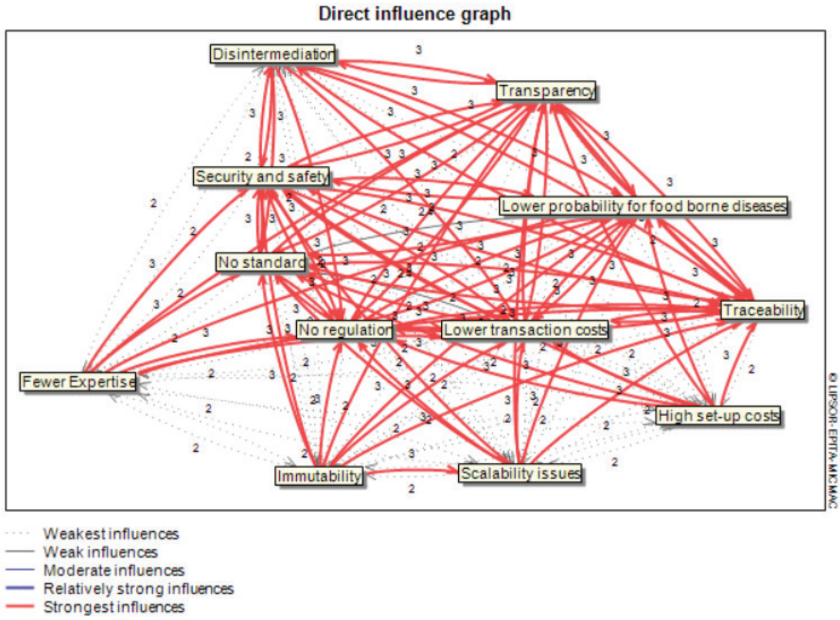
Figure 5.1 Potential direct influence/dependence map



Source: Authors' computations using MicMac Software

Immutability is the most influential factor given that it has eight (8) strongest direct influences on others. On the other hand, no standard is the least influential factor as it has 4 strongest direct influence on others, as shown in Figure 5.2. Other factors with the strongest direct influences on others include the following factors: high set-up costs (7), disintermediation (7), scalability issues (7), less expertise (7), traceability (7), transparency (7), security and safety (7), no regulation (6), lower probability of foodborne diseases (6) and lower transaction costs (6).

Figure 5.2 Potential direct influence of factors on each other



5.1.2 Scenario matrix

Scenario 1 (Disciplined): Effective use of the BCT quadrant is characterized by high scalability and more expertise

The driving forces for the use of BCT in the avocado value chain were scalability and expertise (as shown in Figure 9) and they were used to develop future scenarios. Scalable blockchain technology solutions entail building blockchain platforms capable of processing high-volume transactions per second and accommodate more users. Expertise in Blockchain technology entails investing in skills such as for blockchain developers and experts who can build, deploy, and maintain blockchain solutions that are tailored to the avocado value chain's specific requirements. Interoperability and integration can aid in the seamless integration of current systems and infrastructure within the avocado value chain.

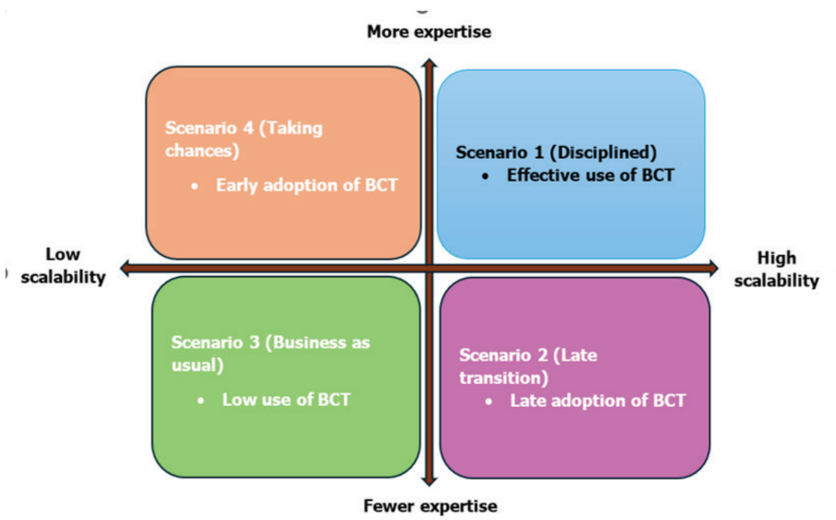
Optimizing blockchain technology solutions involves implementing tools for monitoring, analytics, and performance evaluations to identify challenges, optimize resource utilization, and scale infrastructure according to the users' needs. Deploying a permissioned blockchain network whereby members of the network are generally familiar with one another, and consensus mechanisms are simpler. A permissioned blockchain network is appropriate for enterprise applications where privacy, performance, and compliance are important. In addition, scaling solutions can improve the scalability of blockchain applications without compromising security and decentralization, increasing transaction volume in the avocado value chain.

Immutability guarantees the authenticity of avocados and enhances transparency. Each step of the value chain, from avocado production to consumer, is recorded on a BCT ledger such as transactions, tracking agricultural inputs, monitoring avocados' tree growth, and harvest yields. It is tailored for smallholder avocado farmers to participate in global markets with low set-up cost and low-cost access to decentralized networks. Consumers can scan a QR code and trace the origin of avocados, farming practices, and transportation history ensuring they are ethically sourced and meet quality standards. BCT's disintermediation reduces reliance on intermediaries. Smart contracts automate contract execution and payment upon fulfillment of conditions like delivery or quality inspection. This eliminates delays and reduces fraud such as counterfeit products throughout the value chain.

The Kenyan government in collaboration with trading partners in avocados such as the Netherlands, and UAE established a regulatory framework specifically tailored to blockchain applications in avocado production. This framework encompasses standards for data privacy, security, and interoperability used in farming practices and value chain management. Regulations mandate stringent data privacy and security measures to protect sensitive agricultural data. The audit architecture and compliance checks help to adhere to the standards.

A sustainable production of avocados is achieved. An increasing number of investors are financing the BCT narrative and driving the sustainability agenda. It is expected that avocado farmers will earn a higher income in the future. The avocado market is expanding as smallholder farmers expand production. Innovations emerged to help successfully use the surplus avocado produced. More farmers from different counties are participating in avocado farming. More players, such as transporters and exporters, join the avocado value chain. The sector makes a significant contribution to employment creation and Kenya's economic growth.

Figure 5.3 Future scenarios in the avocado value chain



Scenario 2 (Late transition): Late adoption of BCT quadrant is characterized by high scalability and less expertise

There is a limited understanding and skills of the blockchain architecture, smart contracts development and network management, leading to implementation complexities and delays. Users who adopt the technology later risk security vulnerabilities in blockchain applications which can compromise privacy of information. Uncertainty and regulatory hurdles for users when implementing blockchain solutions in avocado production where data privacy, food safety and supply chain transparency are critical concerns. Limited finances and manpower to support Blockchain initiatives, slows down the adoption process. Additionally, users face challenges in ensuring compatibility, data interoperability and seamless integration with existing systems.

The set-up costs for BCT may be reduced in order to entice people to enhance and invest in it. It is possible to provide incentives and subsidies to encourage the BCT development. Experts may devise novel solutions to aid in the development of the avocado value chain. Efforts to scale up Blockchain technology in the Avocado Value Chain may be undertaken, as it appears promising. This could involve incentives, campaigns, and tax breaks, among other things.

Scenario 3 (Business as usual): Low use of the BCT quadrant is characterized by low scalability and less expertise

Low scalability of BCT solutions can restrict the volume of transactions that can be processed. Fewer expertise in Blockchain technology can impede the development, deployment, and maintenance of blockchain solutions. The users have limited skills and knowledge to design efficient blockchain architecture, develop smart contracts, and optimize performance. This leads to sub-optimal implementation and limited functionality. High implementation cost for BCT which requires significant upfront investment in infrastructure, resources to develop, and maintenance. Users may need to rely on experts or service providers to assist with implementation thus increasing expenses. There is a reduced ability to explore and leverage opportunities such as supply chain traceability, transparency, and data management. This limits the competitive advantage of the farmers and the ability to differentiate themselves from the market. It hinders users' ability to ensure regulatory compliance particularly concerning food safety, traceability, and labelling, as they may struggle to implement robust governance mechanisms, data privacy controls, and audit trails required by regulators.

Low immutability could lead to concerns about the integrity and reliability of data, eroding trust among consumers. The accuracy of continually updated information such as origin, quality, and compliance with regulatory standards is compromised. Intermediaries lead to higher transaction costs for avocado farmers by taking a profit margin, increasing the final cost of avocados for consumers, and reducing the profitability for avocado farmers. Less worry about traceability increases the risk of food safety which erodes consumer trust. Lower concern about transparency reduces accountability and hinders efforts to improve sustainability practices. Without implementation of security and safety measures can lead to vulnerabilities such as unauthorized access, data breaches, or leaks of confidential information.

There will be growth in avocado production but limited markets in the future. Cases of mistiming in shipments, exporting of substandard avocados, and increased post-harvest losses are bound to occur. Intermediaries in the market lead to low returns to the farmers. Farmers may accept their losses and shift to the production of other cash crops.

Scenario 4 (Taking chances): Early adoption of the BCT quadrant is characterized by low scalability and more expertise

Understanding and implementing concepts of cryptographic principles, consensus mechanisms, and distributed systems require a high level of technical expertise, which may limit initial scalability as only those with specialized knowledge can effectively work with the technology. Thus, it requires researchers and specialized professionals who are willing to invest time and resources into experimenting with the technology. Infrastructure challenges in the early stages such as Blockchain networks result in network congestion, high transaction costs, and limited throughput. Regulatory frameworks surrounding BCT are uncertain and evolving, posing challenges for scalability as users may be reluctant to fully commit until there is more clarity on the legislations.

Development of new regulations and legislations by the national government and counties to help address the new reality. Investing in crypto causes reduced transaction costs. Partial implementation of BCT in Avocado Value Chains to help address access to global markets. Early adoption of BCT by the rich farmers compared to the poor in a bid to eliminate intermediaries and make the market more efficient.

Continued implementation of BCT at specific points of the value chain thereby creating weak linkages. However, in the future there will be a monopoly of the market by big entities. Innovations that support further advancement of the value chain are bound to occur. New regulations and legislations to address the new norms will be formulated and existing ones may be revised.

6. Conclusion and Policy Recommendations

6.1 Conclusion

Information flow is important in the avocado value chain that already has over 90 per cent smallholder producers and has gained importance in export markets. Despite its significance, the value chain experiences the challenges of misinformation, inadequate market information, post-harvest losses, production of low-quality fruits, mistiming of shipments in the export market, and weak vertical and horizontal linkages among value chain actors. This has significantly affected the integrity of Kenyan avocados in the export market. BCT, if implemented, can allow for efficient connection and information flow between avocado value chain actors and thus, help address these challenges.

While it is a promising technology, the success of BCT is influenced by various key driving forces. For instance, the level of expertise in operating BCT is still developing. This can lead to actors implementing BCT at a single point of the value chain (say production or distribution level), thereby limiting its potential. The scalability of BCT is another factor that impacts the number of users that can be incorporated into the technology as the value chain grows. Inadequate regulations also influence the adoption of BCT in the value chain. While the country has several enabling policies and regulations, it was reported that there is no regulation to govern the use of BCT in the avocado value chain. Furthermore, BCT has no standard design, and this makes it difficult to implement it and/or expand its use in other sectors of the value chain. This, together with inadequate knowledge of how to incorporate BCT, can significantly reduce its use and adoption in the avocado value chain.

With the uncertainties of the future and depending on how the BCT driving forces interact, four future scenarios are bound to happen. There could be effective use, early adoption, late adoption, or low use of BCT in advancing information flow in the avocado value chain. To effectively prepare for these future scenarios, it is important to formulate a comprehensive legal and regulatory framework to govern BCT use, advance BCT use in avocado production, conduct awareness creation and technical training, and support investments and partnerships in BCT use.

6.2 Policy Recommendations

To advance information flow in the country's avocado value chain using BCT, this study recommends the following:

Develop supportive policy, legislative, and regulatory framework

1. The government can develop policies and legislations to govern blockchain and other upcoming technologies in the agriculture sector by considering the factors influencing and dependency relationship between them. Establishing Blockchain regulations and enforcing rules will require concerted efforts.

With agriculture being a devolved function, it is also recommended that avocado-producing counties formulate and enact policies that will promote collaboration among all avocado value chain actors. This will enhance efficient information sharing leading to improved productivity of the value chain.

Promote the use of BCT use in the avocado value chain

2. Standardization of BCT is an essential step towards a more comprehensive regulatory framework on issues such as data quality, privacy, responsible data sharing, compliance, transparency, and cyber security.

3. Support initiatives that incorporate blockchain technology in information flow to address post-harvest losses and link farmers to markets. This will help facilitate international trade as farmers will meet the necessary sanitary and phytosanitary production standards (SPS). Furthermore, vertical and horizontal linkages among value chain actors can be promoted by providing exhibitions and training avenues in the aspect of BCT implementation. Adoption of BCT can ensure a more transparent value chain. Users can apply BCT to gain a competitive advantage, and better comply with regulations on food safety and quality.

4. Support research and innovations on BCT use in the avocado value chain. This will enhance productivity in the sector leading to better returns to all actors in the value chain. It will also allow value chain actors to explore other uses of avocado such as oil production.

5. Through the implementation of BCT, the government can link farmers directly to markets by supporting avocado farmers' cooperatives. This will reduce overexploitation by intermediaries, raise the farmers' bargaining power, and consequently contribute to fair compensation for farmers.

Carry out training and awareness creation on BCT use and sustainable production

6. Encourage skills training through Science Technology Engineering Mathematics training and enhance technical skills development. This will lead to the development of a talented population that can implement BCT in the avocado value chain sustainably.

7. County governments can also invest in regular training and awareness creation for farmers in the aspects of quality production (sanitary and phytosanitary standards), market information, and digital skills in avocado farming. Putting in place an inclusive digital literacy framework that ensures farmers possess or learn relevant skills for participating is an important consideration. Further, for optimal outcomes in the adoption and use of BCT, farmers need to be involved in development.

Support investments and partnerships in BCT use

8. Increase investments in internet and technology infrastructure. In Kenya, broadband internet coverage remains limited in rural areas. Data on the avocado value chain is manually or automatically entered into the BCT through

the internet. Thus, upgrading the strength and coverage of the internet in these places can be considered. The increasing ownership of smartphones creates an enabling environment for BCT projects.

9. Support public-private partnerships. This will provide an enabling environment for investors, donors, and private entities to support the implementation of BCT. By offering tax relief as an incentive, value chain actors will embrace BCT for quality avocado production.

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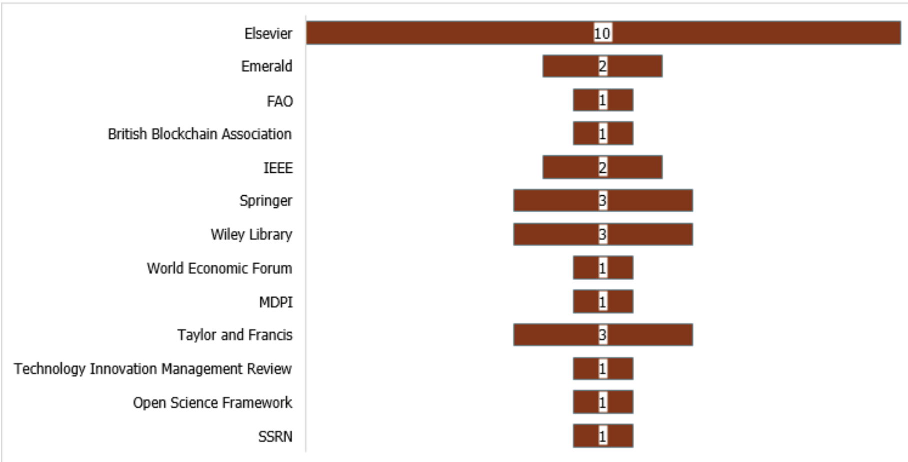
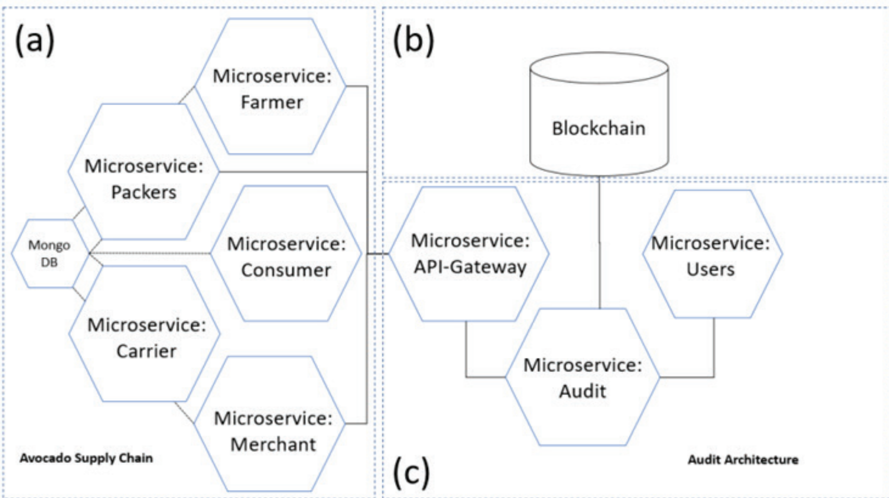
Appendices

Appendix 1: Journal Articles



Source: Authors'computation

Appendix 2: Connection of Avocado value chain the BCT



Source: López-Pimentel (2022)

Appendix 3: Questionnaire

Survey on using Blockchain technology in Advancing Information Flow in Kenya's Avocado Production and Exports

Questionnaire for blockchain technology

Good morning/afternoon/evening. My name is Davis Milimo, and my co-author is Elizabeth Naududu. We are from the Kenya Institute of Public Policy Research Analysis (KIPPRA). KIPPRA is a state corporation mandated with providing quality policy advice to the Government of Kenya.

Today we are conducting a survey on using Blockchain technology in Advancing Information Flow in Kenya's Avocado Chain. Your participation will be highly valued. It will help the researchers advance the Discussion Paper. Any information you share with us will be treated confidentially.

Now I would like to ask questions about key factors that can drive or impede using Blockchain technology in Advancing Information Flow in Kenya's Avocado Production and Exports. This information will be used to help the researchers understand how these factors affect each other in the Blockchain. The survey will take approximately 30 minutes.

Respondent Information

1. Name of the respondent:
2. E-mail address:
3. Phone number of the respondent:

Blockchain technology in advancing information fow in Kenya's avocado production and exports

Transparency

4. In your opinion, to what extent does transparency affect the following factors?

		Very low	**Below average**	Average	**Above average**	**Very high**
1	Traceability					
2	Security and safety					
3	Disintermediation					
4	Immutability					
5	Lower probability for foodborne diseases					

6	Lower transaction costs					
7	High set-up costs					
8	Few expertise					
9	Scalability issues					
10	No regulation on blockchain technology in place					
11	No standard design of the blockchain technology					

Traceability

5. In your opinion, to what extent does traceability affect the following factors?

		Very low	**Below average**	**Average**	**Above average**	**Very high**
1	Transparency					
2	Security and safety					
3	Disintermediation					
4	Immutability					
5	Lower probability of foodborne diseases					
6	Lower transaction costs					
7	High set-up costs					
8	Few expertise					
9	Scalability issues					
10	No regulation on blockchain technology in place					
11	No standard design of blockchain technology					

Security and safety

6. In your opinion, to what extent do security and safety affect the following factors?

		Very low	Below average	Average	Above average	Very high
1	Transparency					
2	Traceability					
3	Disintermedia-tion					
4	Immutability					
5	Lower probabil-ity of foodborne diseases					
6	Lower transac-tion costs					
7	High set-up costs					
8	Few expertise					
9	Scalability is-sues					
10	No regulation on blockchain technology in place					
11	No standard design of block-chain technol-ogy					

Disintermediation

7. In your opinion, to what extent does disintermediation affect the following factors?

		Very low	Below average	Average	Above average	Very high
1	Transparency					
2	Traceability					

3	Security and safety					
4	Immutability					
5	Lower probability of foodborne diseases					
6	Lower transaction costs					
7	High set-up costs					
8	Few expertise					
9	Scalability issues					
10	No regulation on blockchain technology in place					
11	No standard design of blockchain technology					

Immutability

8. In your opinion, to what extent does immutability affect the following factors?

		Very low	**Below average**	**Average**	**Above average**	**Very high**
1	Transparency					
2	Traceability					
3	Security and safety					
4	Disintermediation					
5	Lower probability of foodborne diseases					
6	Lower transaction costs					

7	High set-up costs					
8	Few expertise					
9	Scalability issues					
10	No regulation on blockchain technology in place					
11	No standard design of blockchain technology					

Lower probability of foodborne diseases

9. In your opinion, to what extent does lower probability for food borne diseases affect the following factors?

		Very low	**Low**	**Moderate**	**High**	**Very high**
1	Transparency					
2	Traceability					
3	Security and safety					
4	Disintermediation					
5	Immutability					
6	Lower transaction costs as a result of the reduction in cost for the applications using blockchain technology					
7	High set-up costs					
8	Few expertise					
9	Scalability issues					
10	No regulation on blockchain technology in place					
11	No standard design of the blockchain technology					

Lower transaction costs

10. In your opinion, to what extent do lower transaction costs affect the following factors?

		Very low	Below average	Average	Above average	Very high
1	Transparency					
2	Traceability					
3	Security and safety					
4	Disintermediation					
5	Immutability					
6	Lower probability of foodborne diseases					
7	High set-up costs					
8	Few expertise					
9	Scalability issues					
10	No regulation on blockchain technology in place					
11	No standard design of blockchain technology					

High set-up costs

11. In your opinion, to what extent do high set-up costs e.g. cost of equipment affect the following factors?

		Very low	Below average	Average	Above average	Very high
1	Transparency					
2	Traceability					
3	Security and safety					
4	Disintermediation					
5	Immutability					

6	Lower probability of foodborne diseases					
7	Lower transaction costs					
8	Few expertise					
9	Scalability issues					
10	No regulation					
11	No standard design of blockchain technology					

Less expertise

12. In your opinion, to what extent does less expertise affect the following factors?

		Very low	Below average	Average	Above average	Very high
1	Transparency					
2	Traceability					
3	Security and safety					
4	Disintermediation					
5	Immutability					
6	Lower probability of foodborne diseases					
7	Lower transaction costs					
8	High set-up costs					
9	Scalability issues					
10	No regulation on blockchain technology in place					
11	No standard design of the Blockchain technology					

Scalability issues

13. In your opinion, to what extent do scalability issues affect the following factors?

		Very low	Below average	Average	Above average	Very high
1	Transparency					
2	Traceability					
3	Security and safety					
4	Disintermediation					
5	Immutability					
6	Lower probability of foodborne diseases					
7	Lower transaction costs					
8	High set-up costs					
9	Few expertise					
10	No regulation on blockchain technology in place					
11	No standard design of the Blockchain technology					

No regulation

14. In your opinion, to what extent does lack of regulation in place affect the following factors?

		Very low	Below average	Average	Above average	Very high
1	Transparency					
2	Traceability					
3	Security and safety					
4	Disintermediation					
5	Immutability					

6	Lower probability for food borne diseases					
7	Lower transaction costs					
8	High set-up costs					
9	Few expertise					
10	Scalability issues					
11	No standard design of blockchain technology					

No standard

15. In your opinion, to what extent does no standard design in place affect the following factors?

		Very low	**Below average**	**Average**	**Above average**	**Very high**
1	Transparency					
2	Traceability					
3	Security and safety					
4	Disintermediation					
5	Immutability					
6	Lower probability of foodborne diseases					
7	Lower transaction costs					
8	High set-up costs					
9	Few expertise					
10	Scalability issues					
11	No regulation on blockchain technology in place					

Thank you for your participation in this survey.

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