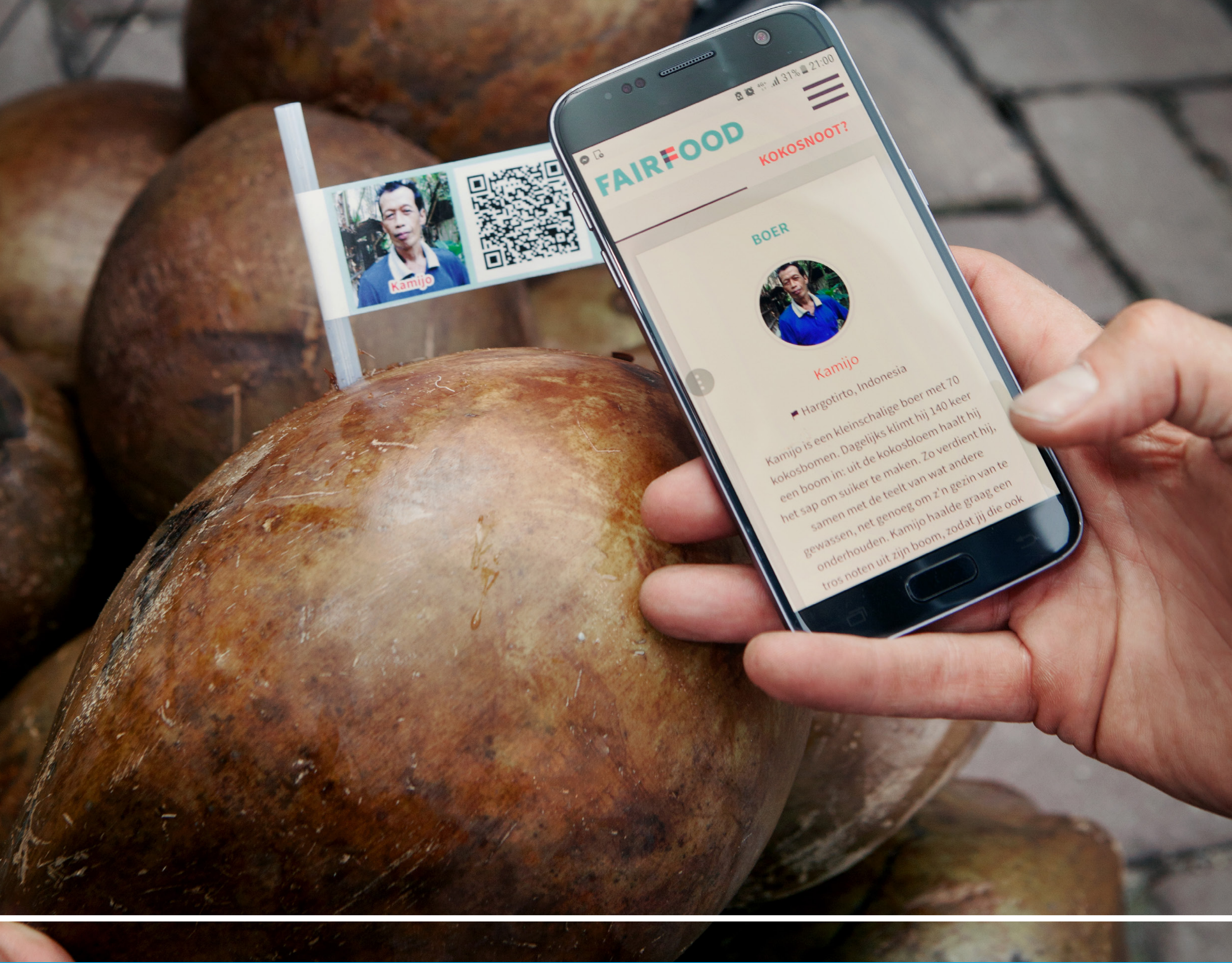

A CHAIN OF POSSIBILITIES

Scoping the potential of blockchain technology for agri-food production chains in low- and middle-income countries

FAIRFOOD

WAGENINGEN UNIVERSITY & RESEARCH

A CHAIN OF POSSIBILITIES

Scoping the potential of blockchain technology for agri-food production chains in low- and middle-income countries

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ACRONYMS

API	Application Programming Interface
BC	Blockchain
BCT	Blockchain Technology
CoP	Community of Practice
DAG	Directed Acyclic Graph
ETN	Electroneum
FAO	Food and Agriculture Organization
F&BKP	Food & Business Knowledge Platform
GIS	Geographic Information Systems
IoT	Internet of Things
KYC	Know Your Customer
LMICs	Low- and Middle-Income Countries
MSME	Micro, small and medium enterprises
PoS	Proof of Stake
PoW	Proof of Work
RFID	Radio Frequency Identification
SDGs	Sustainable Development Goals
WCDI	Wageningen Centre for Development Innovation
WTO	World Trade Organization

I. INTRODUCTION

Blockchain Technology (BCT) is still in the early stages of development. A proliferation of BCT experiments within the agri-food sector demonstrate the high level of interest in the technology, both in public and private sectors. Despite this, there are still several questions surrounding this emerging technology. An article in a renowned Dutch media outlet recently gained traction by arguing that BCT is simply an "over-hyped trend, serves no real purpose and is essentially useless" (Frederik, sd). However, in many cases BCT helps solve or is solving problems in supply chains that most people did not know existed—such as quality issues, non-transparent chains, and violation of workers' rights and low-income levels. Misconceptions surrounding BCT highlight the apparent interest but also the urgent need to develop deeper understanding about what works in emergent BCT applications. Research is needed to establish why it works, what type of challenges it faces, limitations of the technology as well as risks. Only then can these issues be addressed to enhance a performing BCT application with wider institutionalization within the agri-food sector.

This study will provide information on the technology, the decisions that are at the basis of implementing BCT projects, and the potential of BCT for the agri-food sector and value chains originating in low- and middle-income countries (LMICs). This study is an effort to scope for areas of learning and further research, and for forms to shape learning, e.g. a Community of Practice (CoP) or online learning platform.

Both Fairfood and the Wageningen Centre for Development Innovation (WCDI) at Wageningen University & Research work with BCT to enable agricultural workers to strengthen their market position by becoming more active players in supply chains. Due to their joint interest in BCT they have partnered up for this study (funded by the Food & Business Knowledge Platform).

In light of the above, there are two key objectives to this study: 1) Establish a solid understanding of BCT and the core principles behind BCT cases in the agri-food sector; and 2) Identify good practices, challenges, and limitations of BCT use in agri-food chains that are relevant for LMICs.

I.I BACKGROUND

BCT is said to be the next great thing within the domain of sustainable value chains and has garnered a substantial amount of attention both within technology circles and wider communities interested in institutional reform for sustainable economies. BCT is a type of distributed ledger technology[1], a peer-to-peer version of electronic cash, known as bitcoin, which was developed by S. Nakamoto in 2008 (Nakamoto, 2008). BCT has attracted much attention, largely due to its unique way of carrying out financial transactions in a way that eliminates the need for a trusted third party, such as financial institutions (Tapscott & Tapscott, 2017). While BCT has much to offer the financial sector, the agricultural sector is also starting to experiment with the technology as financial transactions are inherent to value chains and food systems.

Agri-food BCT applications currently range from traceability and payments to innovative smart-farming techniques (CTA, 2018). In case of traceability applications, BCT creates a ledger where production and supply chain actors can store and view information at all times. Once logged on blockchain, information is saved in unchangeable "blocks" which trace the path that a certain product took, from the producer, transporter and retailer and eventually to the consumer. Consumers have access to all this information on the blockchain by, for instance, simply scanning a QR code on products they purchase.

In today's technological environment, consumers, policy makers, companies and investors are increasingly demanding transparency and fair supply chain systems. Unfortunately, this is not the reality for most of today's supply chains, which often suffer

1 A distributed ledger is a database held and updated independently by each participant (or node) in a large network

from unverifiable sources, unfair wages for agriculture workers, food safety issues, and so on (Wognum et al., 2011). Many individuals and organizations recognize these issues, and in recent years numerous BCT initiatives within the agri-food sector have emerged. Some of these will be addressed in this report.

BCT has the ability to create transparency in supply chains, the importance of which cannot be understated (Toulon, 2017). Agri-food BCT applications have the potential to benefit actors across the supply chain—through more fair revenue distribution, traceability of products, increased consumer trust, and quality-claim verification. In this way BCT can also contribute to international goals, such as the Sustainable Development Goals (SDGs), which address issues such as poverty (SDG1), hunger (SDG 2), and responsible consumption and production (SDG 12). Overall, BCT has the potential to act as an equalizer, or democratic tool, and can help create trust between actors in supply chains.

I.2 INFORMATION COLLECTION AND STRUCTURE OF THE REPORT

To address the objectives of the study, the following four activities were carried out: create an overview of relevant BCT literature, select a number of cases, conduct interviews with BCT case owners or other BCT resource persons, and initiate a BCT user database:

• **Literature review:** Peer-reviewed articles, reports, blog posts, and web pages from both Dutch and international sources were reviewed to gain a general understanding of BCT principles, to explore BCT practices, applications, key actors in agri-food, and to identify success stories, challenges, and limitations in implementing BCT in agri-food.

• **Collecting BCT cases:** To illustrate the potential of BCT in the context of LMICs, ten BCT initiatives, which are related to LMICs, were selected to be described in more detail. These cases include a diverse spread of use cases including traceability, claim verification, and financial inclusion. The cases are found in Appendix 3 – BCT cases.

• **Interviews:** Semi-structured face-to-face interviews with key informants were conducted to collect their experiences, potential needs and gaps related to BCT. The list of interviewees and the interview questions can be found in Appendix 2 - List of interviewees.

• **Creating a BCT user database in agri-food:** A database, which currently contains around 50 use cases in the agri-food sector and an overview of organizations that build BCT platforms, was created. This database informs interested parties about existing BCT solutions and allows filtering of BCT solutions according to different BCT user types, specific application field, geographical scope, and commodity. It also provides contacts for parties that are looking for organizations that could design and build their BCT applications. The database can be shared upon request and is intended to be expanded in a follow-up of this project.

This report is organized into five chapters and appendices. After the introduction, chapter 2 explains what BCT is, the different types of BCT, and other key information related to the technology. Chapter 3 dives into the BCT components relevant to the agri-food sector, including traceability and claim verification, trust and identity, and supply chain finance and payments. Chapter 4 discusses the added value, limitations and challenges of BCT for LMICs. The report ends with conclusions about the added value of BCT, also in comparison to existing systems, as well as the benefits and limitations of a BCT system for the agri-food sector and LMICs. The appendices include examples of ten prominent BCT projects in the agri-food sector and the interview outline and participants list.

2. WHAT IS BLOCKCHAIN TECHNOLOGY?

Blockchain technology is a technical and complex concept. To create an understanding of the workings, this chapter provides a technical crash course.

2.1 SOLVING TRUST ISSUES

In basic terms, BCT is an advanced database with extra functionality. In a regular database, there is always one central party who owns and controls the data. This owner can determine what happens with the data, and what data people using the database can see. However, issues can arise when there is a lack of trust in this owner to manage and safeguard data discretely and/or to provide all users of the platform with honest and correct information.

BCT solves this trust issue by distributing the database among all participants of a network, eliminating the need for one central authority to oversee and control the database by creating a so-called distributed 'list' or 'ledger' (see Figure 1). In principle, because a blockchain is replicated and synchronized on every computer (the synchronized computers in a blockchain are referred to as nodes), it is also open and accessible for all participants. Additionally, blockchains are immutable: once data is stored it cannot be altered or removed.

Deloitte defines BCT as "a distributed ledger that provides a way for information to be recorded and shared by a community. In this community, each member maintains his own copy of the information, and all members must validate any updates collectively" (Deloitte, 2017). BCT can be used to store any type of online transaction or interaction. Bitcoin for example uses BCT to store and synchronize money transactions.

All transactions are bundled into blocks to ensure that everybody keeps the same list of transactions. When someone makes a new transaction in the blockchain, this transaction is uploaded from a node to the global pool of transactions. Next, a consensus algorithm elects a temporal leader to bundle these transactions into blocks and upload them to the network (Federico & Zarko, 2018). All nodes in a blockchain verify these latest added transactions against a set of criteria and then copy the latest state of the ledger to their blockchain (Nakamoto, 2008).

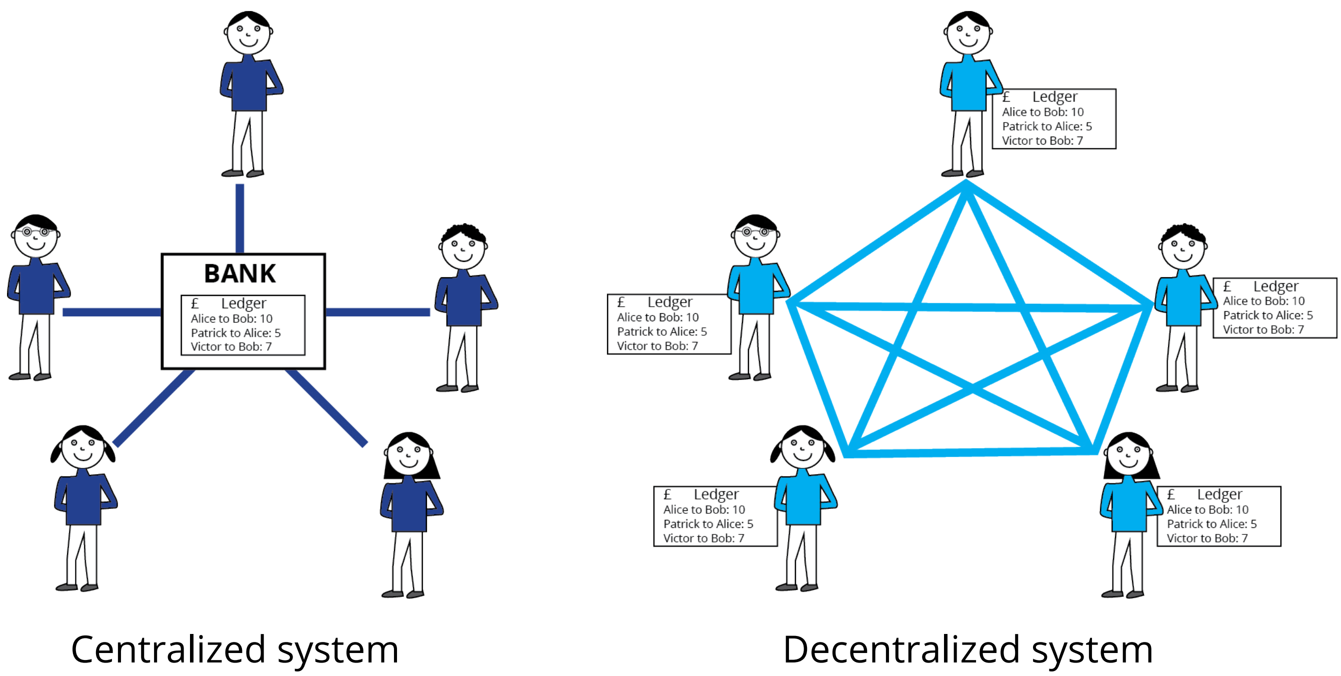

Figure 1: Centralized versus decentralized systems (Woodhead, 2017)

2.2 DIFFERENT CHARACTERISTICS AND DESIGNS OF BLOCKCHAIN

There are many different types of blockchains, each with their own specifications and consensus algorithms. When developing a blockchain application, it is important to know the different functionalities and principles behind each type, so that users can choose one that best fits their specific implementation desires. This section discusses key dimensions one has to consider when choosing the 'right' blockchain for the needs and demands.

2.2.1 PROOF OF WORK VERSUS PROOF OF STAKE

The most decentralized method of deciding the temporary leader to upload the latest transactions to the network would be by choosing people at random. However, blockchain is a network of nodes, not a network of people. Therefore, some sort of proof is necessary from a node in order to demonstrate to the network that it is a legitimate network participant. This is to avoid a scenario whereby one person can actually create many different nodes in an attempt to increase his/her influence on the network (Nakamoto, 2008).

One of the main differences between the various consensus algorithms is how nodes provide this proof. In the first implementation of BCT, which was bitcoin, Satoshi Nakamoto introduced the Proof of Work (PoW) algorithm to overcome this problem (Nakamoto, 2008). In a PoW algorithm, nodes prove themselves by providing processing power to the network. Where it is easy to create an endless number of different nodes, it is much harder to add an endless amount of processing power.

As the value of bitcoin quickly increased over the past few years, so did the total amount of processing power required to secure the network and thus the total electricity usage (Digiconomist, 2018). With increased environmental concerns, other consensus algorithms have been developed that do not rely on processing power to secure the network. Firstly, introduced by Peercoin, is the Proof of Stake (PoS) algorithm (Sunny King, 2012). The first implementations of PoS worked in a similar way as the PoW in bitcoin described above. However, PoS uses the amount of coins that are "staked" as a security measure instead of processing power.

In order to take over the network in PoS, attackers would need to have more than 50% of the coins in circulation rather than more than 50% of the processing power. Although this system circumvents the needs for electricity consuming processing power, some critics argue that PoS is less secure as it is easier to buy more than 50% of the coins in circulation than it is to install processing power that surpasses 50% of the network capacity (Greenfield, 2017).

2.2.2 CENTRALIZATION VERSUS EFFICIENCY

The choice of which consensus algorithms to use is mostly a decision between 1) security concerns and levels of decentralization, and 2) side transaction costs, transaction speed[2] and throughput - or the total number of transactions a blockchain can handle in a set timeframe (Vucolic, 2015).

When choosing to allow only a small group to create and validate transactions, less connections within the system are needed. This makes it less resource intensive to upload a large number of transactions at the same time. The total transaction throughput and speed will then be higher, which makes the cost per transaction generally lower, especially when this smaller group of nodes is chosen based on their internet speed and processing power. However, when a small group controls the creation and validation of transactions, the system is easier to manipulate and therefore arguably less secure. Centralized or decentralized systems can be compared to the differences between a democracy and an autocracy. In an autocracy there is only one decision maker, which means decisions can

2 There are more recent implementations of PoS systems in which only a few people are allowed to produce blocks. These people are often voted by all participants and need to have very powerful hardware and strong internet connection in order to be eligible. These systems can handle up to a thousand-fold faster, cheaper and more transactions per second. However, due to their more centralized nature they are often considered to be less secure.

be made very fast but are centralized and thus less fair and secure. In a democracy, many people are involved in the decision making, which increases the trustworthiness and fairness of the system. However, the more people involved in the decision making, the longer it takes to make that decision.

2.2.3 PRIVATE VERSUS PUBLIC BLOCKCHAINS

There are public and private blockchains. M. Greiner and H. Wang (2015) state that the open nature of blockchains increases transparency and trust in the system. In a public blockchain, everyone can see every transaction made on the network and participate in the consensus algorithm. In some cases, however, you don't want everyone to access all the information on your blockchain, e.g. because it contains private or sensitive information. It can require a great deal of resources to secure a public blockchain, which in turn slows down the system, making it less efficient and more expensive to operate. For this reason, some companies choose to run private blockchains. In private blockchains the owner or operator of the blockchain can control who is allowed to view transactions and participate in the consensus algorithms, and who is not (IBM, 2017). Some people therefore consider private blockchains not to be real blockchains.

2.2.4 PERMISSIONED VERSUS PERMISSIONLESS

In some cases, companies or organizations want third parties to be able to participate in their blockchain, but only under certain conditions. There is a wide variety of customization options available for giving permission for certain actions on blockchains, based on set criteria (Investopedia, 2018). These are called permissioned blockchains as the accessibility relies on gaining permission from the operator under certain conditions.

2.2.5 BEYOND BLOCKCHAIN - DIRECTED ACYCLIC GRAPH

In recent years, the distributed ledger technology surpassed the limitations of BCT. Newer systems have been developed, which work in a fundamentally different way than BCT. A commonly used technology is the directed acyclic graph (DAG) network. While for blockchains the global truth is determined by a consensus algorithm that elects a temporal leader to bundle transactions into blocks and upload them to the network, DAG systems do not elect a leader but delegate transaction ordering to users (Federico & Zarko, 2018). The global truth in this case is determined by collecting all of the communication in the network. Some examples of DAG networks are IOTA, Hashgraph, Nano, and Holochain, which all have their own implementation of a DAG network.

2.3 BUILDING TRUSTWORTHY BLOCKCHAIN APPLICATIONS

A common misconception is that blockchain is decentralized and secure, thus applications using BCT are by definition also decentralized and secure. As discussed in chapter 2.2, the level of decentralization and security depends a lot on the specific blockchain chosen to build on. However, it is the architecture of an application, the specific way in which the application makes use of and interacts with the blockchain, which has the most influence on the level of decentralization and security. This paragraph discusses how this works, and how it influences the level of trust and security in the system.

2.3.1 SMART CONTRACTS

Vitalik Buterin introduced the concept of smart contracts (2015). With the introduction of smart contracts not only transactional information but also logical rules can be added to the blockchain. Smart contracts are made up of computer code that automatically executes certain actions based on a set of criteria (Peters & Panayi, 2016). Once a smart contract is created, just like any transaction in the blockchain, it can never be removed or altered. This means it will only be executed when the criteria are met. Smart contracts are public, meaning everybody can verify that they do as advertised.

With smart contracts, every user can know for sure that when X happens, Y will be the result. When applications don't interact with the outside world, as is the case in the poker example mentioned on page 13, the input, X, originates from other blockchain transactions and smart contracts inside the application. The input is therefore immutable and transparent for all participants, resulting in a completely trust-free environment.

SMART CONTRACTS IN ONLINE POKER GAMES

A great example of smart contracts can be found in online gambling sites such as those for poker. Currently, participants have to trust the poker site to apply fair logic and give every player the same chance of winning. When there is a great deal of money involved this becomes increasingly difficult as the poker site could make more money simply by changing their algorithm slightly, and it would be very hard to discover. A decentralized poker site could have all of the poker rules engraved in smart contracts—viewable for all participants and unalterable for the poker site. Their fee will be engraved into the smart contract. This ensures that the poker site still has incentive to host the site and provide this service.

2.3.2 SECURITY CHALLENGES

In 2015, M. Greiner and H. Want introduced the concept of trust-free-systems. Within trust-free-systems, BCT's capability to create an immutable, consensually agreed upon, and publicly available record of transactions is utilized to mitigate trust issues in online platforms. Smart contracts allow contractual agreements to occur automatically without possible interference from third parties. Therefore, BCT could automatically enforce rules within its chains even if parties do not trust each other (Casino, 2018). In this way, the design of the platform eliminates the need for trusting third parties. However, when blockchains interact with elements from the outside world, as is the case for almost all agri-food implementations, data still needs to be entered into the blockchain correctly. For automated applications that run on smart contracts, this means that only when X is entered correctly, everyone can know that Y will be the result. In other words, there is still need for trusting a reliable data entry. People refer to this principle as "garbage-in-garbage-out" as the data found in blockchains is only as reliable as the data that is being entered. In order to design a trustworthy and decentralized application one needs to be sure X is also entered correctly and decentralized. To do this there are three main challenges that must be overcome.

Trusting the data entry

The first challenge is to make sure the source of the entered data can be trusted. Whereas in trust-free systems there is no need to know the identities behind transactions, within trusted systems it is crucial. There are two ways to have a reliable data source. The first way is whereby a real person is identified (e.g. fingerprint or verification by third party) and connected to a blockchain wallet. This way, a transaction originating from this account on the blockchain can be trusted to have originated from the connected real identity, increasing the reliability of the data.

The second way to have a reliable data source is by having the data entered directly by sensors, laser scanners, or other "Internet of things" devices. In this case, users of the system will still need to trust that the sensors are functioning correctly and the communication between the sensor and the blockchain is secure. To address this problem, special RFID—Radio Frequency Identification—chips and sensors are currently being developed in order to add additional security to the data entry (Waltonchain, 2018).

Connecting directly with the blockchain

The second challenge in designing a trusted blockchain application, is to connect directly with the blockchain when there is no chance of interference. Once data is ready to be entered into the blockchain, it still needs to be sent from a device to the blockchain, which leaves room for error. In order to upload a transaction (or smart contract) to a blockchain, a full blockchain node needs to be downloaded and connected to the internet. Most blockchains require a significant amount of storage, and a decent amount of bandwidth and computing power to stay up and running. An option is to connect to the blockchain through a node stored on someone else's database through an API—Application Programming Interface—connection. This sounds less secure, but when done correctly, this doesn't require anyone to trust the third-party node host as private keys can remain private to the host.

When you have a blockchain node on your device the private key will be stored securely in a special type of file on this device. However, when connecting through an external node, the sender needs to submit their private key in order to sign off and validate the transaction on the blockchain. This can be done by simply copying and pasting the key, but this imposes security risks. Another option is by signing the transaction through a hardware wallet—a special device designed to securely store private keys and sign transactions. Hardware wallets are considered the safest way to sign and upload transactions on a blockchain.
Securing private keys

The last challenge that needs to be overcome is the secure storage of the private key. There are a variety of ways to store private keys and sign transactions. However, storing and managing private keys is always risky and is still considered to be too complicated for the average user. Due to the decentralized aspect of blockchain, mistakes cannot be corrected, and lost funds will be lost forever. Most new users don't fully understand the implications of these risks, which is why many blockchain application providers choose to store the private keys for their users. In this case the private key is stored and encrypted on the provider's servers. Users can access their private keys by providing a normal password. This is called a “hot wallet”, and, although secured with encryption, is still considered to be a less secure way of storing your private key as this still requires one to trust and rely on a third party. This imposes a single point of failure, making it easier for hackers to access many private keys at once. For instance, in 2014, hackers managed to steal 7% of all available bitcoins from “hot wallets” [3].

2.4 DISCUSSION

BCT solutions differ in terms of both, their architectural design and in their characteristics. These distinctions include decentralized versus centralized, private versus public, and permissioned versus permissionless. Decisions on these aspects of the BCT solution have implications regarding the technical performance of the application (e.g. speed and required computational power). Besides technical considerations, the choices concerning these aspects ultimately determine the extent to which the often-heard claims about BCT (e.g., decentralized, distributed ledger of records and democratized system) hold up. Consequently, these choices also determine the amount of trust users put into the technical solution itself, and into organizations or third parties. User organizations need to make trade-offs in this regard, and critically evaluate the applicability and added value of BCT to solving their particular problem.

Another critical point to consider is that the common notion that BCT eliminates the need for trusting third parties is not always correct. As discussed above, blockchain applications that interact with the outside world, e.g. when being used in agri-food supply chains, are only as trustworthy as the data being entered into them. To prevent unreliable data to enter the system, a third party might still be needed to verify the data.

Taking away the middlemen therefore mostly refers to banks, online platforms and other central middlemen facilitating interactions between people. If anything, third party validators will only become more important in blockchain systems in the coming years. Especially when used in more complex agri-food value chains where data is scarce or incomplete (often the case in remote areas and working with data from smallholder farmers).

3 https://cointelegraph.com/news/the-mess-that-was-mt-gox-four-years-on

3. BLOCKCHAIN FOR AGRI-FOOD

BCT rapidly caught the attention of the financial sector and is now starting to become of great interest to the agri-food sector as well. It is undoubtedly attractive, combining cryptography that guarantees the integrity and permanence of data, with a peer-to-peer architecture that avoids centralizing intermediaries, and with principles of collective governance where each player can access transactions and guarantee their legitimacy.

This chapter will address examples of how BCT is used to ensure fair trade practices and to strengthen the position of smallholder farmers and producers in LMICs. It will cover five main areas where blockchain has the potential to add value in the LMICs agri-food supply chains. These areas are: 1. Traceability of products, 2. Verification of claims, 3. Verification of identities and ownership, 4. Supply chain finance, and 5. Financial inclusion for farmers.

3.1 TRACEABILITY

Due to globalization, agri-food supply chains are more and more internationally connected, but as a consequence are also more fragmented. Food moves through a vast network of producers, processors, distributors and retailers before reaching the consumer. With the actors in agri-food supply chains, commodities are difficult to trace back to the origin. Also, actors have limited trust amongst each other. Especially in food supply chains there are multiple risks. The mass production of food increases the risk of contamination. With lack of traceability, this has resulted in numerous global food safety issues in the last years[4]. It also makes it very difficult for food brands to meet consumer's ethical standards with regards to food (Korthals, 2006). Traceability requires that there is an effective information connectivity between the information systems in the supply chain (Bosana & Gebresenbet, 2013). BCT has the promise to bring back the trust in supply chains by making them more transparent and making products traceable to their source.

In order to follow a product's movement through a supply chain, every actor in the supply chain should confirm that they both received and sold the product to the next actor in the chain. To do this in the most trustworthy way, every player in the chain should also send a confirmation of the volumes of products transacted. This is also how Fairtrade products are traced, ensuring that for every sale of a product, an equivalent volume has been bought from Fairtrade producers. In this example, Fairtrade is used as a trusted third party to gather this information and ensure integrity about the 'fairness' of the products.

Therefore, traceability of food is not a new concept, centralized traceability systems such as Fairtrade, have been functional for quite some time. The reason that most of our food isn't traceable yet is not due to technical limitations. It is the competing interests and resulting lack of trust that often hamper traceability. Also, in agri-food supply chains, sharing information often directly leads to a competitive disadvantage. Many agri-food companies rely on keeping information about their suppliers and customers confidential and would not trust a third party with their data.

For traceability to work, supply chain actors need to be willing to share correct information and have consensus about transactions. BCT provides opportunities to overcome these challenges and achieve consensus on every transaction between supply chain actors, without the need of a trusted middleman. There are several ways to trace correct information and transactions through the supply chain using BCT.

3.1.1 TRACEABILITY VIA HASHES ON THE BLOCKCHAIN

Confirmation of transactions can be achieved by storing the transaction data on a centralized database and then uploading a hash—a type of encryption function—of that data to the blockchain. Hashes generate a digital fingerprint from input data (an invoice, for example). Just like a human fingerprint

4 See for example the 2017 Fipronil egg contamination incident, or the 2008 scandal where milk powder contained over 500 times the allowed quantity of melamine.

TRACING AVOCADOS FROM HAITI

The Haitian Ministry of Commerce & Industry conducts a WB funded project that aims to allow mango and avocado producers to directly access the USA market. In the present system they sell their fruits to middle man for prices that hardly allow them to break even. Quality is low, and the sector is not well organized. The project has designed a blockchain structure with detailed technical requirements for harvesting, handling, storing, packaging and tracing the fruit produce. This has been tested in 2018 with a few farmers and will be scaled in 2019. Fruit boxes all get a QR code allowing farmers, consumers and any other person to scan the QR code with their mobile and know from which producer and tree the fruits originate, changes in temperature registered with a logger, the timeline of transport, and overview pricing. In the new system a farmer receives 41 USD cents, compared to an average 4-5 USD cents in the present system. Farmers as well as consumers now have information on data as mentioned above, which makes the chain much more transparent and commercially interesting for Haitian fruit producers (Oostewechel R., et al 2018).

matches a single individual, a digital fingerprint identifies a single, unique unit of data. The slightest change to the input data will yield a completely different fingerprint (Toulon, 2017). Any supply chain actor can always prove that a hash matches to a certain dataset. Therefore, actors can prove to anyone that the information about their supply chain matches a previous uploaded hash. This gives extra security and transparency to their data as it would stop one from altering any data in their database at a later time. A limitation of this method is that there is still a centralized database that uploads the hashes to the blockchain, hence a single point of failure.

3.1.2 TRACEABILITY VIA TOKENIZATION

Traceability can also be done by tokenizing assets. A common way of tokenizing assets is by creating tokens with the use of smart contracts to represent physical goods. One token can correspond with one batch of goods that could be measured in an item´s weight, volume or size. These tokens are non-fungible, meaning that each token is unique. This allows distinguishing between batches of the same type of good (Westerkamp, Victor and Küpper 2018). To apply this concept, after manufacturing or sourcing a batch of products in the physical world, the contract

TRACING COCONUTS FROM INDONESIA

In 2017, Fairfood was one of the first companies to implement an agri-food blockchain solution in the Netherlands. In this pilot, Fairfood used BCT to trace a batch of coconuts along the supply chain from Indonesian farmers until reaching Dutch consumers. For this pilot, Fairfood partnered up with Provenance, a supply chain traceability tool that uses BCT. Every transaction between the supply chain actors was logged on the Provenance platform, which again uploaded a “snapshot”, or “hash” of their database on the Ethereum blockchain about every 10 minutes. Every time a hash of the data was uploaded to the Ethereum blockchain, anyone could prove from that moment, the data hadn’t been tampered with.
Due to the lack of infrastructure, farmers used SMS to confirm on a blockchain that they sold a certain amount of coconuts on a certain day and that they had received a fair price. This verification was again visible to the end consumer through a QR code on the coconut.

owner creates digital tokens. Tokens are passed on through the supply chain together with the transaction of physical goods.

3.1.3 TRACEABILITY VIA VOLUME VERIFICATION

Another action to increase trust and secure correct information is to verify volumes. Volumes received by an actor should match the processed volumes moving out. Hereby the system verifies if volumes that come in and out of every supply chain actor match with the other volumes throughout the chain. In order to correctly do so, the conversion rate of every supply chain actor should be taken into account. The main goal of volume verification is to prevent supply chain actors from mixing or selling any goods that aren't traceable, so that the end product is 100% traceable to its source or is mixed with untraceable products.

3.2 VERIFICATION OF CLAIMS

Due to the increased demand for transparency among consumers, companies have started to make many claims about their products (Label Insight 2016). Some claims, like organic and fair-trade certifications, carry a label, which means the claim is safeguarded and controlled by a third party. This is necessary in order to give trust to the legitimacy of the claim. However, consumers often have little knowledge of the actual meaning of many of these certifications. Additionally, a fair-trade logo is often not a direct guarantee that the farmers producing the product have actually received a "fair" price for their products, let alone a living income.

BCT offers the ability to go beyond certification. Instead of having one central certification body to safeguard and control a general claim such as fair-trade, BCT provides the ability to verify a specific claim related to a specific product batch directly from the source. From our extensive analyses of a multitude of blockchain for agri-food implementations, we identified four basic elements that are used in verifying claims.

• **The claim** – The claim that a company makes about their product
Example: Fairtrade or organic
• **The criteria** – The criteria that needs to be met in order to prove the claim
Example: A minimum price of €3,00 per kilo of coffee
• **The authority** – The person or organization who has the authority to verify the claim
Example: The farmers who produced this specific batch of coffee
• **The proof** – The proof that needs to be delivered by the authority to verify the claim
Example: A confirmation through SMS that the farmers received at least €3,00 per kilo of coffee for a specific batch

This method of claim verification brings more trust and transparency providing a clear and direct indication of the specific meaning of a claim. Rather than making the judgment for the consumer— "this product is fair" —one can provide the consumer with all relevant information to make that judgement themselves.

By identifying supply chain actors and matching their uploaded supply chain transactions in a public immutable ledger, a food brand can prove their claims in a completely distributed fashion. Rather than having to trust a central authority to provide the right information, BCT in combination with transparent identification can assure that all the information comes directly from the supply chain stakeholders themselves, without the possibility for a central party to tamper with this data.

3.3 VERIFICATION OF IDENTITIES AND OWNERSHIP

Once the identity of a person is connected to a blockchain wallet, any transaction originating from this address can be associated with this identity. If this person has a certain authority, for example an organic certification body, transactions originating from this account can be used to verify claims. A transaction originating from this account can for example verify that a certain batch of produce is organically certified.

This can also be used to quickly verify identities. Currently, banks and other financial institutions use complex KYC (Know Your Customer) procedures, which often require customers to go through a long process and upload sensitive documents, like passports and utility bills to prove their identity. Using BCT, an identity only has to be verified once.

CLAIM VERIFICATION OF 'FAIR' NUTMEG PRICES

In cooperation with Dutch company Verstegen Spices & Sauces, Fairfood is making use of BCT to verify whether Indonesian nutmeg farmers have received a fair price for their high quality harvest (see example in Appendix 3 – BCT cases). To verify this claim, a 'fair price" first had to be quantified into measurable criteria. In order to do so, Fairfood is conducting a living income study amongst the farmers in North-Sulawesi, Indonesia. In this case, the authority of the claim are the farmers producing the product.
By connecting their phone numbers to a blockchain address, farmers can upload transactions by sending an SMS. To verify whether they have received the agreed price, farmers receive an SMS a few hours after every raw nutmeg purchase that took place. The purchaser uploads a transaction to the blockchain containing the volume, price, transaction ID and farmer related to the transaction. Some hours later the farmer will receive an SMS containing the transaction information to which they can answer a simple yes or no. Upon verification from the farmer, the product batch, represented by a token in the purchaser's wallet, will receive the "fair price" attribute. As the token gets passed on through the supply chain, it can receive more attributes or claims until it reaches the end consumer.

After this, one can simply send a cryptographic proof to prove he or she is the rightful owner of an address and thus the identity which is connected to that address (CIVIC, 2017).

In some cases, people don't even have any government identification documents. This is often the case for smallholder farmers from LMICs. In these cases, a biometric identity, like a fingerprint or iris scan, can be connected to a blockchain address. Now, every interaction with a third party can become a validation of this identity. During every interaction, for example a check-in for a flight or a car purchase, the biometric identity can be provided in order to prove one's identity. This connects another real live event to this newly created digital identity and can, over time build up a track record of trust (CIVIC, 2017).

3.4 SUPPLY CHAIN FINANCE

According to the World Trade Organization (WTO), micro, small and medium-sized enterprises (MSMEs) often struggle to obtain trade financing due to a lack of sufficient collateral or poor credit histories (WTO, 2018). This is even more common for smallholder farmers from LMICs as their limited knowledge of the sector, remote locations and high collateral requirements result in high interest rates (FAO, 2015). Giving financiers greater transparency into the supply chain's cash and product flow and credit history of companies and smallholder farmers, blockchain can ease access to affordable finance (WTO, 2018).
When identities are verified and products within a supply chain are traceable from farmer to consumer, it opens the doors to a variety of useful cases. In an extensive report by WTO titled "Can Blockchain Revolutionize International Trade?", WTO identifies a wide array of platforms that "leverage blockchain technology and smart contracts to streamline financial flows between buyers, sellers and financiers, and enhance the security, speed, transparency and reliability of supply chain financing" (WTO, 2018). These findings are confirmed by recent studies which demonstrate that BCT can indeed deliver substantial benefits to all parties involved in supply chain financing, by expediting the process and lowering the overall cost of financing programs (Niforos, 2017; Hoffman, Strewe, & Bosia, 2018). Hereunder we elaborate on some key advantages BCT powered traceability has to offer for supply chain finance.

3.4.1 DIRECT PAYMENTS

According to the World Bank's Remittance Prices Worldwide Database (2018), the cost of sending money to LMICs currently takes an average fee of 6.94% for a transfer of 200 USD, making it very costly to transfer smaller amounts.

IDENTIFYING REFUGEES ON THE BLOCKCHAIN

In 2017, the World Food Programme (WFP) started Building Blocks, a blockchain pilot used to distribute food among Syrian refugees. As many refugees lost access to their identification, the WFP made use of iris scans and BCT to create a digital identity for every refugee. Upon purchase of food in the refugee camp in Jordan, refugees could simply scan their iris, automatically triggering the purchase. Building Blocks helped the WFP to distributed cash-for-food aid to over 100.000 Syrian refugees in Jordan, covering over 500.000 refugees in the country by the end of the year.
The project started as a simple means to save costs; however it has potential to do much more than that. When adding functionalities for entries of land ownership, educational credentials, and travel histories, refugees could bring their digital identity and history with them on their phone, anywhere they go. This could ease access to financial services and support integration to other countries. Although the solution would work without blockchain, the WFP opted for using blockchain so they could work towards providing a real digital ID and have beneficiaries stay in control over their data.

One of the biggest advantages of blockchain powered traceability is the ability to make direct payments to any actor in a supply chain which reduces transaction costs. Supply chain actors can use their blockchain address to send cryptocurrency payments[5] across borders directly to the farmers in LMICs who are at the start of a supply chain. As an example, a transaction in cryptocurrency Ethereum currently costs about $0.005 (bitinfocharts, 2018), which makes it a far more attractive means of remittance than traditional bank transfers. Many companies refer to this concept as "tip the farmer" (Accenture, 2018), as the traceability and low transaction costs allow customers to send actual tips to the producers of their food (Figure 2). The main challenge associated with the "tip the farmer" concept is to find a way for farmers to spend this crypto money in their own local currency. Various solutions are currently in development to solve this problem. One such solution is PundiX, a cryptocurrency payment start-up that is planning to deploy at least 100,000 cryptocurrency point of sales devices[6] by February 2021, with a focus on LMIC (PundiX, 2018).

3.4.2 INVENTORY FINANCE

Another potential use of blockchain for supply chain finance, especially for farmers from LMICs, is in inventory financing. Supply chain actors must have enough liquidity to cover their investments cost and production costs until they sell their products to the next person in the chain. Frequently, companies pay for these costs through inventory finance in which financiers provide a loan against the inventory as collateral (ABE EBA, 2014).

In their study regarding supply chain finance and BCT, Hoffman, Strewe and Bosia (2018) explain how this process typically involves multiple third parties under different agreements in order to mitigate risk. Essentially, multiple parties are involved in the agreement in order to give trust to the agreement. This results in a series of issues such as incorrect, unclear or forged storage documents, double financing and ownership disputes.

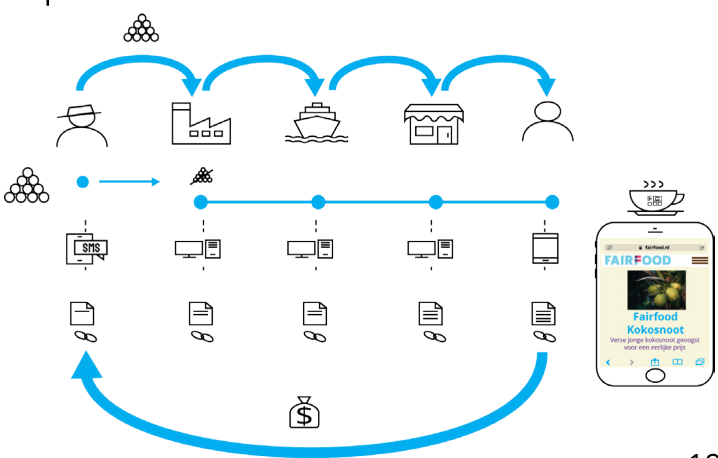

Figure 2: Tip the farmer

5 This cryptocurrency could represent any currency, e.g. dollars

6 This device allows to anyone to change between crypto currencies and local currencies

USING BLOCKCHAIN TO CIRCUMVENT HIGH REMITTANCE PRICES

Bitpesa is a blockchain company that uses bitcoin to make cross border transactions. The solution focuses on Africa where remittance prices are very high at the moment. Bitpesa provides ways for companies to accept bitcoin and get paid in local currency or vice versa. With Bitpesa, anyone can send money in their local currency and have someone in Africa cash out that payment in their local currency, at a fraction of the cost.

When tracing a supply chain on the blockchain, the inventory of a supply chain actor is digitally registered and confirmed by the previous actors in the chain. Every player in a chain also builds up an immutable track record of credit and supply chain transaction activity. Due to this increased layer of trust and transparency for financiers, blockchain can facilitate MSME's, and smallholder farmers, access to affordable finance (WTO 2018). With the use of smart contracts this process of supply chain finance could even become automated with less middle-men, which further cuts costs (Hoffman, Strewe and Bosia 2018).

3.4.3 SUPPLY CHAIN AUTOMATION

When engaging in international trade, supply chain actors must also protect themselves against international trade's unique inherent risks, such as currency fluctuations, political instability, issues of non-payment or the creditworthiness of one of the unknown parties involved. Reducing the risks as described above requires the establishment of multiple agreements with various third parties. This process is very costly and time consuming.

With the use of smart contracts (discussed in chapter 2.3.1) this process could become completely automated. The terms of the loan agreement between the supplier and financing party can be embedded in a smart contract, with the tokenized inventory as collateral. The smart contract then acts as an escrow for the payment versus delivery, increasing speed and reducing cost and the probability of human error (Hoffman, Strewe and Bosia, 2018). With the use of Internet of Things (IoT) sensors the physical location, transit temperature and time of arrival can all be uploaded directly into the blockchain to give additional security about the correct execution of the conditional agreements set in the smart contracts. Newer sensors go even further than location and temperature, having the ability to also sense pressure, motion, acceleration, and sound (Nucleus Vision 2018). Latest developments are even working with "chemical barcodes" in which certain chemicals are used to trace food and pharmaceutical products (Stockhead, 2018). All of these developments contribute to solve the "garbage-in-garbage-out" problem that is often associated with BCT and help give more trust in supply chain automation.

3.5 FINANCIAL INCLUSION OF SMALLHOLDER FARMERS

One of the main promises of BCT is its ability to bring inclusion to the world's poorest who do not have access to financial services. By the latest measurements, there are still 1.7 billion people without an account at a formal financial institution (The World Bank, 2017). Nearly half of the world's farmers are unbanked, with 70% of the world's poor living in rural areas where agriculture is the predominant occupation (The World Bank, 2016).

Moreover, smallholder farmers often do not have access to insurance, asset registry or even credible means of identification, leaving them more vulnerable to social, economic or environmental disasters (The World Bank, 2017). The lack of land tenure and formal property titles makes it very difficult for smallholders to use their land as collateral when attempting to access loan capital (FAO, 2015). Although there are some commercial banks providing loans to smallholders, their limited knowledge of the sector, their remoteness from urban areas, and the resulting high interest rates given their high-risk profile, have all made it very challenging for smallholder farmers to get access to finance (FAO, 2015).

On top of that the payment to smallholder farmers for their goods is often delayed by a few weeks (Ton, Haddad, Bijman, Sraïri and Mshenga, 2016) because buyers cannot pre-finance the goods themselves and have to wait to get paid as well. As a result, 55% of farmers in Sub-Saharan Africa are unable to invest in farm inputs, forcing them to postpone harvest (DHL, 2013). The lack of credit makes it difficult for them to invest in equipment, storage facilities, animal stock and necessary services for intensification of crop production.

All of these factors result in them being the least protected when economic instability, political conflicts, environmental disasters and other challenges occur. Sadly, this is the case since most of the unbanked live in the regions where these challenges occur the most. The sections below provide examples of how BCT can improve accessibility of financial services for smallholder farmers and how the technology has the potential to transform them to active players in supply chains.

3.5.1 MOBILE PAYMENTS

Mobile phone coverage has expanded considerably during the past years. Two thirds of the currently unbanked worldwide already own a mobile phone, however, most of them still lack access to internet (The World Bank, 2017). These effects are strongest for remote markets in the developing world, particularly within Sub-Saharan Africa.

The Findex 2017 report shows how mobile payments significantly increase account ownership in Sub-Sarahan Africa (The World Bank, 2017). In 2012, 17.7% of the population had access to a formal financial institution with 2.4% of the population using a mobile phone to receive money (The World Bank, 2012). In 2018, 42.6% of the population had access to a formal financial institution with a staggering 20.9% of the population owning a mobile bank account (The World Bank, 2018). Solutions as M-Pesa, a mobile payment provider with over 19 million mobile users in Kenya and seven (7) million in Tanzania are contributing to this exponential growth (IFC, 2017).

The sending and receiving money (remittances) in the form of cryptocurrency via blockchain has great potential, but one of the key challenges associated with sending remittances in the form of cryptocurrencies to unbanked smallholder farmers is their ability to spend that money. Once mobile payment systems become more widely adopted in the LMICs, cryptocurrencies can be converted through local exchanges and used for mobile payments. The high remittance prices and low access to financial services could drive cryptocurrency adoption in LMICs like it did with mobile phone payments. This could provide another great opportunity for LMICs to catch up with the rest of the world financially.

3.5.2 ACCESS TO FINANCE

When having real identities connected to a blockchain wallet, any assets can be registered as ownership the same way inventory is confirmed in decentralized supply chain (see 4.3.2. Inventory finance). This provides opportunities for farmers to access capital. Ownership of an asset is also a claim which can be confirmed through claim verification on the blockchain. The criteria are always the same: this asset belongs to this identity. The authority can be anyone who brings enough trust to the claim, such as previous house owners, neighbors, purchasers in a supply chain etc. The more verified identities that confirm a claim, the more trustworthy the claim becomes.

A farmer that can prove he or she has been consistently producing a certain number of crops per year in a digitized supply chain confirmed by the next players in a chain significantly increases the chance of receiving credit. With this ‘digitized proof’ the farmer builds a track record of consistent delivery of supply, which increases their credibility and reduces their risk profile. In addition, having an address of the farmer provides the financier with a security measure in case the farmer needs to be traced. Moreover, blockchain and smart contracts functionalities can facilitate the process which can significantly decrease the costs of financing, making it a far more attractive and viable solution for providing loans to smallholders.

INSTANT DIGITAL PAYMENTS FOR EVERYONE

Electroneum (ETN) is a cryptocurrency which currently has about 2.8 million registered users of which many are in Africa and other LMICs. They are the only cryptocurrency that requires of their users to validate their identity so they can provide them with a legitimate means of payments. They offer easy solutions for merchants and mobile phone providers across Africa to easily accept their currency as a payment, with the goal of driving financial inclusion.

To attract new users, their mobile app allows anyone to mine up to 3 USD worth of cryptocurrency per month, using any smartphone. Their fast blockchain allows for instant transactions, allowing anyone to send and receive money, without the need for a bank account. On top of that, they have an online freelancer marketplace which anyone can use to learn and sell their digital skills to earn ETN.

3.6 DISCUSSION

Traceability systems based on BCT can offer radical transparency on transactions from the origin of a product up to the end consumer. This makes it easier for supply chain stakeholders to provide information on costs and payments at all steps of the chain. On the one hand consumers may be interested in the conditions under which a product was produced and whether agricultural workers and producers get a fair share of the product price. On the other hand, to be able to understand and decide whether payments are fair the context needs to be well-understood. This context can include risks taken by each party in the chain or value addition at different steps, for example. In this regard, how this information is communicated to the end consumer is very important. Third-party organizations, such as consumer organizations and certification bodies, will have a role to play in ensuring that data and information is responsibly shared.

BCT cannot solve the issue of trust alone, however it can help create trust in agri-food supply chains. The reviewed literature and interviews show that BCT is particularly interesting when there is an issue with trust between supply chain actors. One of the interviewed experts, however, expressed his concerns regarding giving full trust to a system just because BCT is used. The expert explained that at its current state, BCT solutions are often embedded in bigger software systems of companies. This could mean that some shared claims are safe and immutable, but some are not.

USING LIVESTOCK AS COLLATERAL

One solution that helps small holder farmers collateralize their assets is Sentinel Chain. Sentinel Chain is a blockchain startup which provides physical tags that farmers can use to register and tokenize their livestock. Sentinel Chain brings various actors together in order to provide smallholder farmers with insurance, loans, payment functionality and crowdfunding (Sentinel, 2017).


HAMMER

4. IMPLICATIONS FOR LMICS

In Chapter 3, the BCT applied use cases relevant to the agri-food sector were discussed. It was explained that BCT can ease access to supply chain finance for smallholder farmers and other chain actors, can enable direct payments to any of actor in the supply chain, can reduce transaction costs of money transfer in LMICs and can provide solutions to inventory financing, among others. Similar application fields were mentioned in the interviews conducted with key informants. This chapter aims to further highlight the implications and critical considerations regarding BCT in LMICs, based on the outcomes of the key informant interviews, literature review, and the cases presented in Appendix 3.

4.1 POTENTIAL FOR BCT IN AGRI-FOOD IN THE CONTEXT OF LMICS

The literature suggests, and the interviews confirm this, that in countries where the market is less organized and regulated, BCT can offer solutions to strengthen the trust between supply chain actors. Toulon (2017) perceives the potential of BCT in delivering peer-to-peer solutions to small-scale producers. In this regard, BCT has potential in the context of LMICs, in the areas described hereunder.

4.1.1 REDUCING THE NEED FOR MIDDLEMEN

BCT solutions may offer benefits to smallholder farmers because BCT may eliminate or reduce the need for middlemen, such as banks, lawyers, brokers and traders. Farmers may then be less reliant on those actors. Through BCT, farmers can be directly connected to buyers and to global supply chains. That direct connection may result in farmers being better informed about the market and provided with more transparent information on pricing. Also, transaction costs may be reduced (WTO, 2018). Besides, eliminating middlemen, BCT has the potential to reduce the fraud and corruption that middlemen are often known for (Kalan, J., 2013). However, it should also be noted that middlemen, such as traders, can have different roles, including aggregation of farmers' produce, which may in fact add value to the transaction (Rene Oostewechel, personal communication, 2018). Hence, it is context-specific to what extent eliminating middlemen is beneficial. Toulon (2018) explains that elimination of certain intermediaries may lead to new power structures and redistribution of roles. Consequently, a new balance needs to be struck.

4.1.2 INCREASING POWER ON THE FARMERS' SIDE

BCT solutions may increase the transparency in supply chains, which can ultimately raise awareness to the conditions under which producers and agricultural workers live and work and lead to increased power on the farmers' side. In this regard, a number of cases in Appendix 3, are presented. In case of the BCT solution by Verstegen, farmers are able to report if they do not receive the agreed price, which increases their power over their returns. Moyee also aims to provide a fair price to coffee farmers in Ethiopia and give them more control over their parts of the coffee chain by increasing transparency through their BCT solution.

4.1.3 PROVIDING ACCESS TO FINANCE FOR FARMERS

BCT may contribute to the financial inclusion of farmers in remote areas that do not have access to banks and loans due to lack of collateral as discussed in chapter 3.5.2. The information recorded on the Blockchain can serve as an identity or track record to access financial services. To develop such solutions, cooperation with local authorities and organizations is necessary. Cases, such as Humaniq, Sentinel Chain, and Agri-Wallet presented in Appendix 3 provide examples for this area of application. For example, in case of Agri-Wallet, farmers get an extra digital wallet for their business so they can keep their finance separate. This way they can invest money themselves in tokens knowing they can only spend it on farm inputs. This earmark allows them to profit from an increased credit rating in order to get access to loans. Another example regarding financial inclusion relates to the warehouse receipt system. Warehouse receipts enable farmers to access post-harvest financing by using their stored crops as collateral. Such systems usually require verifiable data on the quality and quantity of the crops being stored in the warehouse. BCT or other distributed ledger technologies would allow farmers, by providing the necessary data to prove their creditworthiness to financial institutions, access to loans (Tripoli & Schmidhuber 2018).

4.1.4 STORING AND SHARING PRODUCT CERTIFICATION

BCT offers benefits in storing and sharing product certification, which can be particularly relevant for cooperatives delivering to export markets. As certification requirements are getting tighter, improvements in digital infrastructure are necessary, such as better digital balances, farmer digital ID methods, or labelling the sack with QR code and displaying data by scanning the QR code. Although such digital solutions can work without BCT as well, the immutability of data provided by BCT is an added value (Chris Addison, personal communication, 2018).

4.1.5 ADDRESSING MISTRUST BETWEEN FARMERS AND CO-OPERATIVES

BCT is relevant in addressing mistrust between farmers and cooperatives in a way that the records of cooperatives about the volume of produce farmers delivered to them are immutable provided that it is recorded through BCT (Jaclyn Bolt, personal communication, 2018). For example, AgUnity, an Australian agri-tech start-up, developed a mobile application which records all transactions in the value chain in the immutable ledger of BCT. That application replaces the paper-based records by cooperatives and eliminates the disputes originating from false records between farmers and cooperatives. For further information on this example, please see the case on AgUnity in Appendix 3.

4.1.6 CREATING CERTAINTY UPFRONT ABOUT PAYMENTS

Smart contracts based on BCT can create certainty upfront about payments, hence increasing trust. For example, in case of weather insurance, payments can be linked to algorithms with satellite data. In that case, the payment part can be automated as you can trust the registration of the event due to the linking of satellite data (eg. heavy rainfall, or drought) happening (Mateo, 2018). Toulon (2018) explains that BCT can offer an alternative to traditional agricultural insurance due to lower management and transaction costs. Etherisc, a Swiss blockchain start-up, is building a platform that uses distributed ledger technology to provide crop insurance to developing countries, in particular in Africa (Tripoli & Schmidhuber, 2018). Aigang, an autonomous insurance network in partnership with drone imaging business, i.e., Skyglyph, are developing an autonomous crop insurance product using drone hardware, Geographic Information Systems (GIS) software, BCT, and smart contracts (Tripoli and Schmidhuber, 2018). Automation of payments by smart contracts is not only useful in case of insurance but also when farmers are selling their goods. Smart contracts can provide real-time payment and increase the working capital of farmers, and all supply chain actors (Tripoli and Schmidhuber, 2018).

4.1.7 RELEVANCE OF BCT FOR ENTIRE ECONOMY

Looking beyond the applications of BCT in the agricultural sector, it was emphasized that it is important for developing countries to understand the value of BCT for the entire economy and not only for agriculture, e.g. land ownership registration, remittances, microfinance, and storing biometric data (Ken Lohento, personal communication, 2018). In terms of land registration, Toulon (2017) underlies that 90% of rural areas in Africa are not recorded in the land register, which hampers economic development. In Ghana, Bitland, a blockchain start-up, addresses this problem by recording real estate transaction using Blockchain. Also, some governments show interest in land registry using blockchain. In 2015, to address issues with fraud, the Honduran government registered its entire land registry on a blockchain with help from Epigraph and Factom (Toulon, 2017). To assess whether the distributed ledger technology, including BCT, is relevant and appropriate for a case in an international development context, a recent study by USAID presents guidelines (Nelson, 2018).

4.2 CRITICAL ISSUES FOR IMPLEMENTING BLOCKCHAIN SOLUTIONS IN LMICS

Besides its potential, there are also challenges and limitations that need to be considered when designing and implementing a BCT solution in LMICs. The interviews also gave insights in these aspects, which are briefly elaborated in the following paragraphs. This list of challenges and limitations are not intended to be exhaustive but more an exploration of experiences of the interviewees.

4.2.1 CONTRASTING INTERESTS IN THE CHAIN

Often, when a BCT is implemented in a supply chain, you compete with someone who is already involved in the chain, like traders. Regarding the case of mango and avocado transport from Haiti to the United States, (for more information in the case, see Appendix 3) mangos are already exported and the current trader is not really interested in a fully transparent chain. Sometimes traders pre-finance the crop, so farmers need to sell the product to traders because of their debt. Also, the trader might be a relative or has another relationship with the farmer. These examples illustrate that relationships between farmers and middlemen can be complex and eliminating middlemen may not always be easy or wanted (Rene Oostewechel, personal communication, 2018).

4.2.2 FARMER'S MOTIVATION, ATTITUDE, AND BEHAVIOR TOWARDS BCT APPLICATIONS

Selling produce on BCT systems may result in higher prices for farmers, but in the particular case of Haitian mango's payment took longer and farmers bore more risks. The Haitian mango farmers remain owners of the mango until the product gets sold in the US. This implies that farmers bear the risk until the produce is sold in the US and only get paid when the produce is sold. Farmers, however, may have a preference for immediate cash payment for their produce rather than waiting for weeks until the produce is sold to the end consumer (Rene Oostewechel, personal communication, 2018). In general, BCT solutions can offer farmers ways to get paid instantly, or ease access to trade finance while their produce in transit.

Farmers may also be wary to trust BCT or have competing interests. For example, it might be difficult to convince farmers to use BCT mobile payment option as a substitute of physical cash. Especially when they do not have a digital bank account due to lack of trust in banks, they might not understand the difference between banks and this technology (Tim Timmermans, personal communication, 2018). Hence, it is always necessary to partner with local organizations to reach out to them (Ad Rietberg, personal communication, 2019). Furthermore, if farmers see the direct benefits of the application, it is more likely that they will adopt such solution if they get paid faster (Rene Oostewechel, personal communication, 2018; Ad Rietberg, personal communication, 2019). Additionally, farmers might be reluctant to registration, even more so traders. Most small farmers do not pay tax in LMICs. But traders do. If you register everything on a transparent system, the authorities will also have the possibility to know more about your operations. Traders might not want to expose all their profits (Rene Oostewechel, personal communication, 2018).

Another important aspect influencing farmer attitudes and behaviour is the ease of use. The BCT system should be very easy to use and understand, and the technology should be compatible with old(er) mobile phones, preferably via SMS. In Africa, for example, 80% of the farmer population still uses an older phone. In order to convince farmers to use the service, the direct benefits should be made very clear, and preferably proven (e.g. by using frontrunners and trusted community members) (Ad Rietberg, personal communication, 2019).

With regard to reaching smallholders, it might be required to work through aggregations, e.g. cooperatives, farmer led business, or lead farmers sourcing form smallholders. Those groups are very much interested in BCT but for different applications (Bakker et al, 2019). Another point in this regard is that defining the target group may be of importance, because not all farmers are interested in full transparency or earning more than they do now. For farmers who depend on agricultural production to a large extent, BCT may be interesting because it gives them the possibility to professionalize

(Rene Oostewechel, personal communication, 2018).

4.2.3 Enabling environment and sustainability

In LMICs, there are a number of factors that can hinder wider implementation of BCT in agri-food, lack of digitalization in the agricultural sector, limited digital infrastructure (e.g. limited bandwidth speed), weak knowledge of BCT opportunities (CTA, 2017). For example, when implementing BCT in such countries, the limitation of digital infrastructure can make them dependent on the cloud system of foreign providers (CIPE, 2018). Regarding digital infrastructure, Tripoli and Schmidhuber (2018) underlie that internet services in general need to be more accessible to people in developing countries, parts of Asia and Pacific and Arab States. For many BCT applications involving smallholders, mobile phones also needed to be provided to farmers (see cases in Appendix 3). Furthermore, the use of public and private keys for data encryption in BCT may pose challenges in developing countries as public key infrastructure is lacking in some of these countries (Zambrano, 2017). Hence, such infrastructure or alternative solutions need to be developed in the countries concerned. Another factor to consider is the lack of organization of the value chain, which makes difficult to reach farmers with BCT. That is, contract farming schemes involving smallholder farmers are limited. Especially in case of produce for local consumption, farmers would rather sell individually in local markets than organize themselves in order to pool their produce (NEPAD, 2013). At last, inadequate or lack of government regulation regarding BCT (e.g. national banks, legal framework) may also limit implementation of BCT (Ken Lohento, personal communication, 2018). Creating an enabling environment including digital infrastructure and institutional frameworks that allows for a wider adoption of BCT is, therefore, needed (WTO, 2018; IFC, 2018). Tripoli (2018) underlies the role of government, intergovernmental organizations and development partners in providing BCT outreach. This serves to improve infrastructure and digital skills in rural areas and supports and facilitates pilot projects in agricultural supply chains.

Governments may also have a role to ensure long-term sustainability of BCT. Currently, BCT solutions implemented in LMICs are mostly pilots. In the pilot phase, the management of the BCT framework is facilitated by an implementing organization. Already in this phase, a strategy to ensure the long-term sustainability of the management of BCT should be developed, e.g. the management of BCT has to be handed over to government or private actors.

4.2.4 Need for additional technologies to establish trustworthiness

To make sure that BCT applications provide the promised trust (earlier referred to as garbage-in-garbage out in chapter 2.3.2), additional technologies, such as sensors and other applications, may be needed. Potma (2018) explains that information registered on blockchain (BC) originates from sources and procedures of which the trustworthiness should be established separately. In other words, a credible link needs to be established between offline events and their online records (WTO, 2018). To address this issue, Moyee is implementing an application to take over data collection and checking before it is put on the blockchain. This is done by creating digital wallets and IDs for the farmers, which are then connected to the blockchain. Such solutions help to eradicate the possibility of all human errors before information is added to the blockchain (Potma, 2018).

4.3 Discussion

Since use cases are scattered in terms of areas of application and the problems they are addressing, it is difficult to draw overarching conclusions on what really works for LMIC. Some critical points, however, were highlighted in this chapter. Similarly, to other chapters, chapter 4 also shows that BCT may strengthen the trust between supply chain actors. However, implementing such solutions still requires collaboration between various organizations, e.g. companies, local organizations and non-governmental organizations (NGOs). Hence, other ways of establishing trust between people and organizations are still inevitable.

Farmers' motivation and behaviour towards BCT is of key importance. Easy-to-use solutions, which are also compatible with older technologies should be the focus of developments. Also, it should be noted that some farmers may be more interested than others. To reach farmers with an interest in BCT, working through aggregations in LMICs appears to be an effective way to go.

Long-term sustainability of BCT solutions should be explored already in the pilot phase of a blockchain project and strategy for the future should be developed. In the context of LMICs, it also holds that BCT should be considered as an element of a bigger system, which is a combination of hardware, software, data and people who use them. The further development of digital infrastructure including increasing internet access and bandwidth speed in LMICs is inevitable to be able to fully exploit the opportunities offered by BCT.

5. CONCLUSION

BCT offers the potential to develop decentralized and democratized ICT systems that enable transparent information sharing in a community. However, choices made during the development of BCT solutions influence to what extent this potential is realized.

Nowadays, private companies rather go for more private and centralized BCT solutions, because the added value of decentralized applications is not yet fully understood and involved data is sensitive and confidential. Also, in some cases, technical challenges hinder the implementation of decentralized applications (such as energy consumption, speed and scalability). As a consequence, the potential of BCT is not yet fully utilized.

For agri-food, it is not yet easy to offer a standardized BCT solution because BCT is still in a maturing phase and examples of BCT use in this field are not yet 100% validated. Within agri-food, a number of specific cases are being developed, but in general companies have their own separate solutions.

In the context of LMICs, a number of use cases have proven that BCT can contribute to creating a fair distribution of rewards and risks throughout the value chain and to making farmers active players within the value chain. More specifically, the potential of BCT in LMICs lies primarily in creating direct contact between farmers and buyers, in enabling farmers to participate in global supply chains, in increasing farmers' power within supply chains, in allowing farmers to build their track records to prove their creditworthiness in order to access loans, in broadening the accessibility of financial services, and in creating upfront certainty about payments in supply chains. However, the further development of digital infrastructure—such as internet access, bandwidth speed and access to mobile phones—in LMICs is essential in order to be able to fully utilize the potential of BCT in those countries.

In summary, blockchain is not a ready-made system, it is a technology in development which can be used for different purposes in different forms. Besides addressing the technical design of BCT, the societal and contextual realities should not be underestimated. This is because multiple stakeholders, who are rarely accustomed to the method of sharing that BCT enables, need to get on board to implement, roll-out and scale BCT. Getting used to and accepting this new way of information sharing in supply chains takes time and effort.

Due to BCT's unique feature of being truly democratic, it offers supply chain actors the remarkable ability to self-report on the intricacies of their work in the supply chain. While other ICT systems can track an item's path throughout the supply chain, only BCT allows for 100% transparent self-reporting at all levels of this chain, eliminating the need for trusting a central ICT system with safeguarding sensitive information and providing correct information to the stakeholders involved. This becomes particularly useful in scattered supply chains where stakeholders often don't trust or even know one another, as is common in agri-food supply chains.

Furthermore, BCT allows supply chain stakeholders to make international transactions at considerably lower cost compared to the transaction costs in the current system, automatically execute certain agreements and prove certain claims directly to one another. This new way of interacting between supply chain stakeholders takes away power from central authorities and has the potential to eliminate the need for many of the bureaucratic procedures currently in place to tackle counterparty risks, especially common in supply chain finance. This has the most potential to give power back to smallholder farmers who otherwise don't have access to the legal framework, or even basic identity documents, needed to insure themselves and gain access to credit.

5.1 TOWARDS A COMMUNITY OF PRACTICE

As discussed, besides the technical limitations of BCT and challenges with regard to the digital infrastructure in LMICs, the social scalability and willingness also needs to be considered to be able to come up with standardized, mainstream solutions for agri-food.

During the interviews we found that there is interest in BCT and a need to share experiences among BCT practitioners. Hence our initial idea for establishing a learning platform was validated. This study demonstrated that there are initiatives in LMICs that benefit smallholder farmers, however a learning community could help to expand the range of BCT solutions with the ultimate aim to improve livelihoods of smallholders. Such a community could also contribute to solving challenges related to technological issues and social scalability of BCT.

Our ambition is to attract a core group of Community of Practice (CoP) members that are convinced of the benefits of BCT in agri-food and actively involved in experimenting with the technology. In order to start the CoP, it would be ideal to engage with (international) networks, organizations and companies based in the Netherlands, but it is also highly important to involve a number of frontrunners from LMICs from the outset of the project to ensure that we are shaping ideas with them and not for them. In this core group, a few physical meet-ups per year would be organized to share knowledge regarding specific technological issues, such as privacy and coding.

Besides the core group, our intention is also to attract “co-learners”, such as embassies, Southern BCT learning/interested organizations or developers, funding actors and interested private sector parties. That is particularly important from the social scalability perspective, e.g. by showcasing successful use cases the added value of BCT will become more obvious. This could be involved through, for example, webinars, newsletters, access to reports, white papers and articles.

Over time, as the CoP establishes a solid foundation, the activities could be expanded beyond a virtual platform for a broader community.

6. REFERENCES

ABE EBA. (2014). Supply Chain Finance. EBA european market guide, 64. Retrieved from https://www.abe-eba.eu/media/azure/production/1544/eba-market-guide-on-supply-chain-finance-version-20.pdf

Accenture. (2018). Supply chain rewind: Tip the farmer with blockchain. Retrieved from https://www.accenture.com/be-en/insights/blockchain/supply-chain-rewind

Bakker, Y., Bronckaers, J., Rejeb, F.B., Addison C. 2019. Can access to data really transform agriculture for smallholders?, ICTupdate 89, 2019, CTA, Wageningen. http://ictupdate.cta.int/2019/01/24/2430/

Bitinfocharts. (2018). Ethereum Avg. Transaction Fee historical chart. Retrieved from https://bitinfocharts.com/comparison/ethereum-transactionfees.html

Bosana, T., & Gebresenbet, G. (2013). Food traceability as an integral part of logistics management in food and agricultural supply chain.

Buterin, V. (2015). A next generation smart contract & decentralized application platform. Ethereum white paper. http://blockchainlab.com/pdf/Ethereum_white_papera_next_generation_smart_contract_and_decentralized_application_platform-vitalik-buterin.pdf

Casino, F. (2018). A systematic literature review of blockchain-based applications: current status, classification and open issues. doi:10.1016

CIPE, 2018. Digital Economy Enabling Environment Guide: Key areas for Business and Policymakers. Center for International Private Enterprise and New Markets Lab. https://www.cipe.org/wp-content/uploads/2018/10/Digital-Economy-Guidebook-FINAL-PDF.pdf

CIVIC. (2017). Whitepaper. Retrieved from https://tokensale.civic.com/CivicTokenSaleWhitePaper.pdf

Cossack Labs. (2017). Explain Like I'm 5: Zero Knowledge Proof (Halloween Edition). Retrieved from https://hackernoon.com/eli5-zero-knowledge-proof-78a276db9eff

CTA, 2017. Perspectives for ICT and agribusiness in ACP countries: Start-up financing, 3D printing and blockchain, Workshop 2017 ICTAgOutlook, https://s3-eu-west-1.amazonaws.com/cta-scr-media/79cafc00-178b-4a14-a421-b13f54e8846a.pdf

CTA, 2018. Unlocking the potential of blockchain for agriculture, ICT Update, Issue 88, September, 2018, CTA, http://ictupdate.cta.int, Accessed: 19 December 2019

Deloitte. (2017). Blockchain trust economy. Retrieved from Deloitte: https://www2.deloitte.com/insights/us/en/focus/tech-trends/2017/blockchain-trust-economy.html

DHL. (2013). Five reasons why companies and small-scale farmers are not in business together. Retrieved from https://www.howwemadeitinafrica.com/five-reasons-why-companies-and-small-scale-farmers-are-not-in-business-together/23079/

Digiconomist. (2018). Bitcoin Energy Consumption Index. Retrieved from https://digiconomist.net/bitcoin-energy-consumption

FAO. (2015). Challenges and opportunities to improve the livelihoods of. Retrieved from http://www.fao.org/fileadmin/user_upload/sap/docs/Challenges%20and%20opportunities%20to%20improve%20the%20livelihoods%20of%20Smallholder%20farmers%20in%20Pacific%20Island%20Countries.pdf

FAO. (2018, August). Emerging Opportunities for the application of blockchain in the agrifood industry. Retrieved from http://www.fao.org/3/CA1335EN/ca1335en.pdf

Federico, M. B., & Zarko, I. P. (2018). Distributed Ledger Technology: Blockchain. Retrieved from University of Zagreb: https://arxiv.org/pdf/1804.10013.pdf

Frederic, J. (n.d.). de Blockchain, een oplossing voor bijna niets. Retrieved from De correspondent: https://decorrespondent.nl/8628/de-blockchain-een-oplossing-voor-bijna-niets/519071687772-2a5ee060

Greenfield, R. (2017). Vulnerability: Proof of Work vs. Proof of Stake. Retrieved from https://medium.com/@robertgreenfieldiv/vulnerability-proof-of-work-vs-proof-of-stake-f0c44807d18c

Greiner, M., & Wang, H. (2015). Trust-free Systems - a New Research and Design Direction to Handle Trust-Issues in P2P Systems: The Case of Bitcoin. Adoption and Diffusion of Information Technology. AISEL.

Hoffman, E., Strewe, U., & Bosia, N. (2018). Supply chain Finance and Blockchain Technology The Case of Reverse Securitisation. Springer.

IBM. (2017). The difference between public and private blockchains. Retrieved from IBM: https://www.ibm.com/blogs/blockchain/2017/05/the-difference-between-public-and-private-blockchain/

IFC. (2017). How Fintech is Reaching the Poor in Africa. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/30360/114396-BRI-EmCompass-Note-34-DFS-and-FinTech-Mar-28-PUBLIC.pdf?sequence=1&isAllowed=y

IFC, 2018. Blockchain Governance and Regulation as an Enabler for Market Creation in Emerging Markets. EMCompass Note 57, September 2018, Washington DC: International Finance Corporation (World Bank Group) https://www.ifc.org/wps/wcm/connect/aea347b3-d57d-457c-a34d-04cab3da3417/20180921_EMCompass-Note-57-Blockchain-Governance_v1.pdf?MOD=AJPERES, Accessed 19/12/2018

Investopedia. (2018). public private permissioned blockchains compared. Retrieved from Investopedia: https://www.investopedia.com/news/public-private-permissioned-blockchains-compared/

Kalan, J. 2013. Tech fix for Africa's big farming challenge http://www.bbc.com/future/story/20130408-tech-taps-africas-farm-potential

Korthals, Prof. Dr. M. (2006). Ethics of Food Production and Consumption. Retrieved from https://www.researchgate.net/publication/40110417_Ethics_of_Food_Production_and_Consumption

Label Insight (2018). How Consumer Demand for Transparency is Shaping the Food Industry. The 2016 Label Insight Food Revolution Study. https://www.labelinsight.com/hubfs/Label_Insight-Food-Revolution-Study.pdf?hsCtaTracking=fc71fa82-7e0b-4b05-b2b4-de1ade992d33|95a8befc-d0cc-4b8b-8102-529d937eb427

Mateo, M. 2018. IBISA: Inclusive Blockchain Risk Sharing Using Space Assets. https://business.esa.int/projects/ibisa

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved from https://bitcoin.org/bitcoin.pdf

Nelson, P. (2018) Primer on Blockchain. How to assess the relevance of distributed ledger technology to international development. USAID, Washington, US. https://www.usaid.gov/digital-development/digital-finance/blockchain-primer

NEPAD, 2013. African agriculture, transformation and outlook. NEPAD, November 2013, 72 p http://www.un.org/en/africa/osaa/pdf/pubs/2013africanagricultures.pdf

Niforos, M. 2017. Blockchain in Financial Services In Emerging Markets: Part II. EMCompass Note 44, August 2017 Washington DC: International Finance Corporation (World Bank Group). https://www.ifc.org/wps/wcm/connect/b08ac5cd-11f8-4eb5-8b85-a082765727f7/EMCompass+Note+44.pdf?MOD=AJPERES, Accessed: 19/12/2018

Oostewechel R., et al (2018) Haiti technical cold chain dry run. Applying distributed ledger technology to connect Haitian mango and avocado producers to foreign markets. Report 1838 ISBN 978-94-6343-470-6 https://library.wur.nl/WebQuery/wurpubs/539324

Peters, G. W., and E. Panayi. 2016. Understanding Modern Banking Ledgers Through Blockchain Technologies: Future of Transaction Processing and Smart Contracts on the Internet of Money. Pages 239-278 in Banking Beyond Banks and Money: A Guide to Banking Services in the Twenty-First CenturySpringer International Publishing, Cham.

Potma, M. 2018. Blockchain to restore trust in food supply chains? A case study in the cacao sector of Costa Rica, https://waag.org/sites/waag/files/2019-01/Blockchain-trust-food-supply-sector-margo-potma-article.pdf

PundiX. (2018). PundiX. Retrieved from https://pundix.com
Stockhead. (2018). IPO watch: Blockchain play Security Matters launches $6.5m offer ahead of ASX listing. Retrieved from https://stockhead.com.au/special-report/ipo-watch-blockchain-play-security-matters-launches-6-5m-offer-ahead-of-asx-listing/

Sunny King, S. N. (2012). PPCoin: Peer-to-Peer Crypto-Currency with Proof-of-Stake. Retrieved from https://peercoin.net/assets/paper/peercoin-paper.pdf

Tapscott, A. and Tapscott, D. 2017. How blockchain is changing finance, Harvard Business Review, Harvard Business School Publishing Corporation, March, 2017. https://www.bedicon.org/wp-content/uploads/2018/01/finance_topic2_source2.pdf, Accessed: 19/12/2018

The World Bank. (2017). measuring financial inclusion-and the fintech revolution. Retrieved from https://www.worldbank.org/en/news/video/2018/04/19/the-global-findex-database-2017-measuring-financial-inclusion-and-the-fintech-revolution

The World Bank. (2018). Remittance Prices Worldwide. Retrieved from https://remittanceprices.worldbank.org//sites/default/files/rpw_report_sept_2018.pdf

Toulon, N. (2017) Blockchain and agriculture. Understanding, exploring and evaluating. An AgroTIC Business Chair Study. Chaire AgroTIC, France, https://www.agrotic.org/wp-content/uploads/2018/06/ChaireAgroTIC_Blockchain_English.pdf, Accessed 19/12/2018

Toulon, N. 2018. The blockchain: opportunities and challenges for agriculture. ICT-update, Issue, 2018, pp.8-9, CTA. http://ictupdate.cta.int/ Accessed: 28 January 2019

Vucolic, M. (2015). The Quest for Scalable Blockchain Fabric:. Retrieved from IBM Research - Zurich: https://allquantor.at/blockchainbib/pdf/vukolic2015quest.pdf

Tripoli, M. and Schmidhuber, J. 2018. Emerging Opportunities for the application of blockchain in the agrifood industry. FAO and ICTSD: Rome and Geneva. Licence: CC BY-NC-SA 3.0 IG. http://www.fao.org/3/CA1335EN/ca1335en.pdf >> previously cited as (FAO, 2018)

Waltonchain. (2018). Waltonchain whitepaper V 1.0.4. Retrieved from https://www.waltonchain.org/doc/Waltonchain-whitepaper_en_20180208.pdf

Westerkamp, M., Victor, F., & Küpper, A. (n.d.). Blockchain-based Supply Chain Traceability: Token Recipes model Manufacturing Processes. Technische Universität Berlin. doi:10.14279

Wognum, P. M., H. Bremmers, J. H. Trienekens, J. G. A. J. van der Vorst, and J. M. Bloemhof. 2011. Systems for sustainability and transparency of food supply chains – Current status and challenges. Advanced Engineering Informatics 25:65-76. doi https://doi.org/10.1016/j.aei.2010.06.001

Woodhead, P. (2017). Explaining Blockchain with Where's Wally and a camera. Retrieved from Medium: https://medium.com/swlh/explaining-blockchain-with-wheres-wally-and-a-camera-79e860a05815

World Trade Organization. (2018). Can Blockchain revolutionize international trade? Retrieved from https://www.wto.org/english/res_e/booksp_e/blockchainrev18_e.pdf

The World Bank. (2012). The little data book on financial inclusion. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/12253/68169.pdf?sequence=1&isAllowed=y

The World Bank. (2016). Of Maize and Money: How to Bring Farmers into the Financial System. Retrieved from http://www.worldbank.org/en/news/feature/2016/01/07/of-maize-and-money-how-to-bring-all-farmers-into-the-financial-system

The World Bank. (2017). The Global Findex Database.
The World Bank.. (2018). The little data book on financial inclusion. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/29654/LDB-FinInclusion2018.pdf?sequence=1&isAllowed=y

Zambrano, R. 2017. Blockchain: Unpacking the Disruptive Potential of Blockchain Technology for Human Development. Ottawa, Canada: International Development Research Centre. https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/56662/IDL-56662.pdf

7. APPENDICES

7.1 APPENDIX I - USER DATABASE OF BCT APPLICATIONS IN AGRI-FOOD

A database, which currently contains around 50 use cases in the agri-food sector, was created (for a screenshot of the database, please see Appendix). This database is to inform interested parties about existing BC solutions. It contains information on the user organization (name, profile, base) and partnering organizations, application of BCT, scope of the application/agri-food commodity, country of origin and destination (for traceability applications). The database allows to filter BC solutions according to these aspects. Although this database in its current form is not sufficient to draw wide-ranging conclusions, it shows that that use cases were mostly found in the area of traceability and claim verification. Also, use cases regarding supply chain finance, supply chain payments, smart insurance and financial inclusion were found. The range of commodities targeted by these applications is broad and includes, banana, coffee, poultry, pork, beef, tuna, different vegetables, wine and grain. Some of the applications connect LMICs to global supply chains.

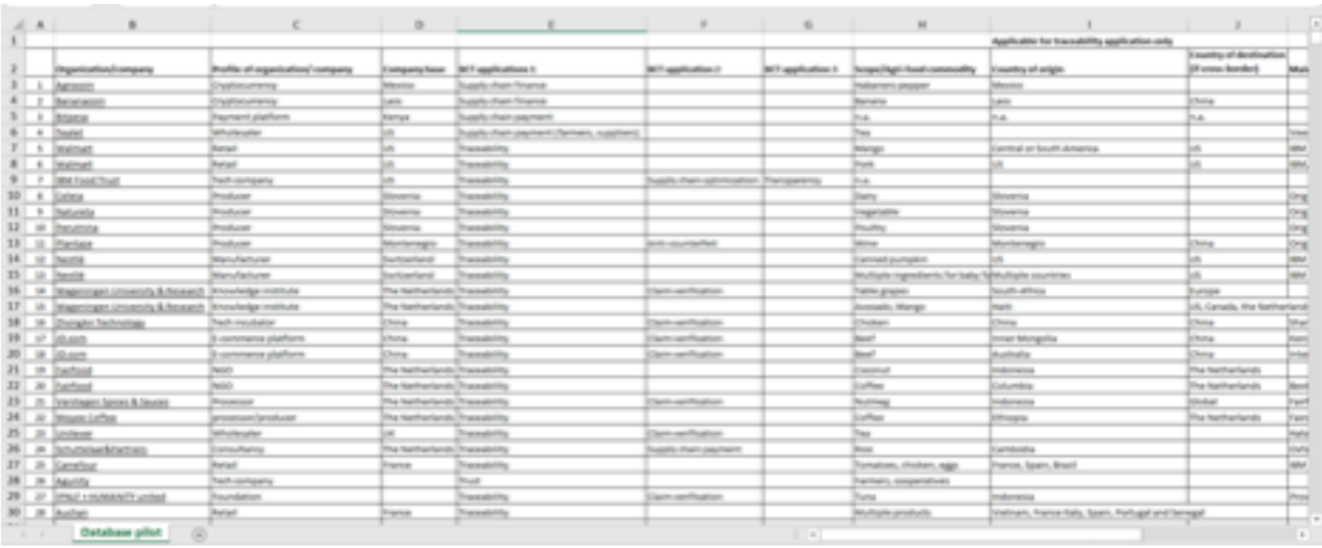

Figure 3: Screenshot of the user database

7.2 APPENDIX 2 - LIST OF INTERVIEWEES AND INTERVIEW QUESTIONS

Interviewees:
Ken Lohento, e-Agriculture, Entrepreneurship & ICT4Ag Expert, CTA
Chris Addison, Data4Ag Expert, CTA
Tim Timmermans, Blockchain researcher, WUR/WEcR
Anton Smeenk, Fresh Food & Chains expert, WUR/FBR
Jaclyn Bolt, Business Innovator, WUR/WEnR
Rene Oostewechel, Expert Postharvest Technology, WUR/FBR
Ad Rietberg, Director, Agri-wallet
Lan Ge, Researcher in Innovation- and Risk Management and Information Governance, WUR/WEcR
Marianne van Keep, Director of Sustainability, Verstegen Spices & Sauces B.V.

Interview questions

1. **Added value of Blockchain**
   - What is the added value of blockchain technology in traceability applications? Why not use a normal database?
   - Is blockchain alone enough to create a decentralized trustworthy application? If not, how do you create trustworthy and decentralized applications? (e.g. combination of different technologies)
2. **Applications**
   - What other use cases than traceability and transparency do you see for blockchain in agri-food?
   - Who are the main actors in agri-food piloting/using BC?
   - Can you mention some examples of BC pilots/use cases?
3. **Relevance for emerging markets and LMICs?**
   - What are the potential benefits of blockchain technology for smallholder farmers?
   - What is needed to facilitate that smallholders indeed benefit from this new technology?
   - How can we give access to people in emerging markets to blockchain technology?
4. **Challenges and limitations**

   Social aspects, critical issues
   - Why does blockchain creates more trust when it is only as secure as the person entering the data? (aka, how to deal with the "garbage in garbage out" problem?)
   - How can blockchain increase security and trust when working with competing players on one platform?
   - Do you see other relevant social issues?

   Technical aspects, critical issues
   - Blockchain in traceability is nice, but what happens with a digital batch of products when the real products are lost?
   - Data in blockchain is permanent, how do you revert mistakes?
   - Do you see other relevant technical issues?
5. **Risks**
   - Are there any risks attached to making the supply chain fully transparent?
   - What components of your supply chain would, and wouldn't you make transparent and why?
   - Personal information is stored permanently in the blockchain, do you see this causing any risks in the future?
   - Any other risk you consider when BC would be mainstreamed?
6. **Next steps: evolution of BC**
   - What is needed to take BC to the next level? What are the needs of the different actors of agri-food sector? How would this next level look like?
   - What are the gaps that we need to address to further develop/scale-up existing BC pilots?
   - Is there a need for learning and sharing knowledge among different players? If yes, what would be a relevant learning question?
7. **Closing down**
   - Do you have question for us?
   - Would you be interested in getting involved in a Community of Practice around Blockchain as a co-learner, case provider, facilitator, researcher.. or in any other role?

AGRI WALLET

WHAT IT IS

Launched in Kenya in 2018, Dodore Kenya ltd.'s Agri-wallet provides short-term loans to farmers and farm produce buyers through the use of a blockchain-based virtual wallet. The currency they provide to farmers is earmarked and can only be spent at affiliated input suppliers. This allows farmers to build up a credit history and gives confidence to their ability to repay the loans, allowing them to get access to much needed credit at a fraction of the costs.

SUCCESSES

Farmers using Agri-wallet are able to produce up to 400% more food because they are helped to divert funds from non-income generating private consumption and because they get quick access to the capital needed to fund their next round of harvest

Farmers can then invest more money into income-generating expenses such as seeds and fertilizers. Furthermore, Agri-wallet increases transparency in the supply chain which allows farmers and buyers to have more active roles in their businesses.

Agri-wallet works together with Rabobank to provide the loans and M-pesa to disburse the loans. M-pesa is a well-established payment network in Africa, allowing smallholders to quickly participate and spend the loans at local input suppliers. By building on existing infrastructure, Agri-wallet could quickly expand, allowing them to reach over 10.000 smallholder farmers within their first year of launching.

CHALLENGES

As with other blockchain-initiatives in LMICs, for Agri-wallet to be successful farmers and buyers must have access to basic technology—mobile phones and internet service/data. This can present a challenge in underdeveloped regions which often lack such technology. Therefore, projects like Agri- wallet would need people on the ground to visit these farmers and buyers to ensure they have access to these technologies or to provide these technologies.

POTENTIALS FOR LMICS

Small-scale farmers produce a substantial portion of the food that feeds the rapidly growing populations in LMICs. So, by providing these farmers with short-term loans and greater financial security, Agri-wallet provides these farmers with financial stability and allows them to produce more food. In this way Agri-wallet is fighting poverty and increasing food security in LMICs.

AGUNITY

WHAT IT IS

Founded in 2017, AgUnity developed a mobile app which records small farming cooperatives transactions on blockchain. The organization conducts pilot projects in Kenya, Indonesia, Solomon Islands, and Papua New Guinea. Farmers and farmer cooperatives in LMICs loose up to 50% of crop value between harvest and the point of sale due to underpayment. AgUnity is working to reduce that loss and make these transactions more transparent so that the farmers can see where their money is going and report underpayment.

AgUnity is also working to improve food security by using blockchain to trace food produce from farm to market and in that way identify where food is going to waste or being lost. Furthermore, AgUnity's App (AgriLedger) allows farmers to manage their incomes through the built-in digital wallet and securely record their transactions.

CHALLENGES

AgUnity is still in the early pilot stages of development and project implementation. So, it is still too early to definitively say whether their initiatives have been successful and to identify challenges that these projects have faced.

Based on their broad mission of improving the lives of "billions of people" through supply-chain traceability, increasing small-holder farmers' incomes and reducing food waste - it can be argued that AgUnity's mission is broad. Time will determine how successful they will be and if their mission will narrow and focus on more specific regions or projects.

SUCCESSES

AgUnity is a prime example of how blockchain technology can be used to increase transparency in food supply-chains, aid in financial planning for farmers and farming co-operatives and reduce food waste.

By providing farmers with smartphones, AgUnity solves a common problem that many agri-blockchain initiatives face—lack of access to technology. This ensures that all participating farmers will have equal access to the blockchain traceability system and can participate with ease.

POTENTIALS FOR LMICS

AgUnity's vision of providing small-holder farmers and cooperatives with access to a blockchain system to trace their products has huge potentials for LMICs, especially considering the large scale of AgUnity's planned projects. Small-holder farmers make up a significant portion of LMICs populations. Therefore, by facilitating the increase in income of this population sub-section and decreasing food insecurity, AgUnity may have a significant impact on LMICs.

ALBERT HEIJN ORGANGE JUICE

WHAT IT IS

Dutch supermarket Albert Heijn announced in September 2018 that in partnership with their supplier, Refresco, they apply BCT to make the production chain of its orange juice transparent. Consumers are able to scan a QR code on the orange juice packaging and trace the route their orange juice took—from grove to store. The main focus of this project is to "increase transparency for consumers."Albert Heijn states that its goal is to produce '100% sustainable juice' by 2030. However, it is unclear what percentage of their juice is currently sustainable, or what they are defining 'sustainable' as.

SUCCESSES

Albert Heijn's store-brand orange juice is Rainforest Alliance certified, meaning the farmers must follow sustainable farming methods to protect the environment and nature and improve the lives of farming families. This new blockchain project received praise from Rainforest Alliances CEO, Han de Groot.

CHALLENGES

While BCT offers the opportunity to connect all levels of a supply chain and make these chains transparent, a clear challenge that Albert Heijn's blockchain project faces is the lack of transparency at the farmer level. Albert Heijn's partner, LDC Juice, who grows the oranges for this project has long been linked to labor rights violations. BCT provides the opportunity to disprove this. So, AH faces the challenge of increasing transparency in a level of the supply chain that they may not have much control over—the labor in the orange orchards.

Albert Heijn states that they promote "responsible and ethical working conditions." The challenge here will be for Albert Heijn to more clearly define what these conditions look like on blockchain and to incorporate the grove workers into the blockchain process.

POTENTIAL FOR LMICs

While Albert Heijn's orange juice BCT initiative allows consumers to send a "Like2Farmer," it does not actually inform customers who picked their oranges, and under what condition. The only assurance that is available is that this orange juice is Rainforest Alliance certified. In this way there is a lack of connection to the plantation workers and these workers do not gain any additional benefit from this blockchain project.

However, this project holds the potential to benefit LMICs, like Brazil, if the first stage of the supply chain (agricultural workers) is included in this blockchain.

MOYEE COFFEE & BEXT360

WHAT IT IS

Launched in 2017, Moyee Coffee & Bext 360 started the world's first blockchain coffee project. The goal of this project is to use blockchain to revolutionize the coffee industry. Currently coffee producers receive an estimated 2% of the added value of each cup of coffee. By using blockchain technology to make this system more transparent, Moyee Coffee—in collaboration with tech company Bext360—hopes to change this by placing Ethiopian coffee on blockchain. The architecture of this blockchain interface was created by Fairfood in cooperation with Moyee Coffee & Bext 360.

SUCCESSES

The first 'block' of this project recorded real-time payments Ethiopian farmers received for their coffee cherries. By starting at the origin, this project makes the whole chain fully transparent and benefits farmers in Ethiopia as well as customers in Europe. All chain members are given access to data across the supply-chain. This helps to identify and reduce inefficiencies in the chain. In mid 2018, Moyee reported that they were in contact with 350 Ethiopian Coffee farmers.

Bext360 is also working on a new virtual token technology which will reduce transaction costs within global supply-chains and streamline certification processes by reducing the amount of paperwork and inspections needed.

CHALLENGES

As with many blockchain projects which engage the farmers this project likely requires farmer training and ensuring these farmers have access to technology.

After almost two years of piloting, Moyee's blockchain project is still in the very early stages. Only some payments for farmers are made transparent for those making specific web searches, however their blockchain traceability system is still not available for the public. This is a strong indication of many challenges that need to be overcome when implementing blockchain in LMICs.

POTENTIALS FOR LMICS

Projects like this have the potential to improve the livelihoods of vulnerable populations in LMICs, like Ethiopia, by giving them more control over their portion of the coffee supply-chain and by making consumers more aware of where their coffee comes from, they are more likely to pay attention to if the farmers are receiving a fair price for their beans.

FAIRFOOD COFFEE

WHAT IT IS

Together with ID Coffees and Bext 360, Fairfood placed 100 kilos of Colombian coffee on Blockchain in 2018. The coffee was part of Fairfood's WAKEcUPCALL Campaign that advocates for more transparency and better payments for farmers in the coffee supply-chain. By simply scanning a QR code on the package customers can see the path that their coffee took—from farm to consumer. The interface shows that farmers received a premium for their high-quality coffee, which was confirmed by roaster Bocca in The Netherlands.

SUCCESSES

By increasing transparency in the supply chain, customers can not only see the path that their coffee took but also which actors along the supply chain earned what from their purchase. In this way customers gain a deeper understanding of how their purchase supports small-scale farmers.

On the other end of this, coffee farmers and the countries of origin also benefit from this increased transparency. By reporting whether they've been paid the agreed upon price for their beans, these farmers gain a level of influence over the supply chain that they are an integral part of. It also disclosed useful information for farmers in other cooperatives that didn't partake in this project. Overall, projects such as the WAKEcUP coffee shed light on segments of the supply chain that were previously operating in the dark without any meaningful regulation and gives farmers unprecedented access to information.

CHALLENGES

As with other Blockchain projects, the WAKEcUP Coffee consumer interface requires a basic level of technology in order to function.
Therefore, in order to start these types of projects one must ensure that the farmers or agriculture workers have access to this technology.

POTENTIALS FOR LMICS

Many small-scale farmers are forced to borrow money under unfavorable conditions which prevents them from having any savings. This results in a number of issues such as lack of access to medical care, excessive pesticide use and child labor.

Currently only 15% of the total revenue earned from the coffee trade remains in the countries of origin. Through examining the more transparent chain, actors can make more informed decisions regarding who to or not to trade with—therefore increasing their revenue and making these valuable trades more profitable for their local economies.

HUMANIQ

WHAT IT IS

Launched in 2017, Humaniq is a technology company that developed an app which provides banking services to those who do not have access to traditional banks by developing next-generation financial services in emerging economies. These financial services use blockchain technology to track financial transactions and use cryptocurrencies.

SUCCESSES

The Humaniq App has over 500,000 registered users, in 46 countries, with 3 languages available for users, 60 million messages between users, 28 ambassadors and 13 partners. These are impressive achievements for an app that was launched in the beginning of 2017. Humaniq has also won a variety of innovation and blockchain related awards since their App launched.

Having access to banking and financial services is essential in achieving financial security and planning. Many small-holder farmers around the world lack access to such services. Therefore, they would benefit from Humaniq's App.

CHALLENGES

While the Humaniq App has been able to reach over half a million users in a short time frame, it would seem difficult for those without access to reliable technology or internet—like many small-holder farmers—to participate in these services.

POTENTIALS FOR LMICS

Many communities within LMICs lack access to traditional banking institutions and are therefore unable to borrow money or open savings accounts. This makes them particularly vulnerable to short term economic downturns. So, by providing these communities with reliable banking services, Humaniq is allowing its more than 500,000 users to begin to plan for their financial futures.

SENTINEL CHAIN

WHAT IT IS

Sentinel Chain is a business-to-business (B2B) marketplace started in 2017 which is designed to provide affordable and secure financial services to those lacking access to traditional banking services. Its initial trial was in Singapore in 2017 and it is currently in stage 6 of 9, with 9 being the launch of version 2 of Sentinel Chain.
Sentinel Chain uses blockchain to create international marketplaces for international financial services. Sentinel Chain Tokens or SENC is the cryptocurrency developed by Sentinel Chain and used in their digital banking services.

Sentinel Chain offers a blockchain solution to the problem of 'dead capital' by accepting such assets as hard collateral.

POTENTIALS FOR LMICS

As the first platform that accepts livestock as collateral for financial services, Sentinel Chain presents a huge opportunity to communities in LMICs that lack access to traditional banking services. Farmers in the same communities experience economic up and down turns simultaneously. Therefore, it is difficult for them to borrow from their neighbors during periods of financial hardship. By connecting these farming communities to a global network, Sentinel Chain is providing these individuals with a level of financial planning and security that was previously unavailable to them. This has the potential to provide greater financial security to livestock farmers in LMICs.

SUCCESSES

Sentinel chain recognizes that the 'poor' are much richer than we think. What they lack in cash assets they compensate for with other, more concrete, assets. By accepting resources other than hard cash currency—such as livestock—as collateral for loans, Sentinel Chain ensures that those who lack access to cash can still participate in banking services.

CHALLENGES

By accepting collateral in the form of livestock, Sentinel Chain faces the problem of standardizing values. This is because not all livestock are the same and therefore will naturally differ in value. For example, ensuring that a healthy goat compared to an unhealthy goat are valued appropriately presents a logistical challenge.

VERSTEGEN X FAIRFOOD NUTMEG

WHAT IT IS
In 2018 Fairfood and Verstegen Spices & Sauces BV partnered for their Nutmeg 'Back to the Origin' Project. Together, they are working to trace nutmeg grown by Indonesian farmers on the Sangihe Islands. Currently, on the Beta Version of the interface, the nutmeg's journey is being logged step-by-step.

This project aims to determine whether the nutmeg farmers receive the agreed upon price, strengthen their market position and will allow Verstegen to verify quality claims. It will also engage customers as it allows them to see where their nutmeg came from and who grew it, and how their purchase contributes to sustainable livelihoods.

SUCCESSES
This BCT project creates individual profiles for the farmers which provides a number of benefits. Firstly, simply by sending an SMS each individual farmer is able to log via blockchain whether they have been paid the agreed upon price. In this way the farmers are given a never-before-had power over their yields, as if they do not receive the correct price then they are able to report this. Secondly, by incorporating every actor—from farmer to retailer—on blockchain, this project allows customers to better understand where their food comes from and therefore increase awareness around the importance of providing a living income to agriculture producers.

CHALLENGES
This project is still in the early stages so it is not immediately clear what/if any challenges will emerge. However, from a practical standpoint it is evident that these nutmeg farmers generally lack access to internet and smartphones. Therefore, a team from Fairfood traveled to Indonesia to show the farmers and collectors how the blockchain system works and how to log their transactions on Blockchain via SMS.

So, if a company is looking to start a project similar to this it is important to understand that they will need to take a hands-on approach and have the resources to implement the technology in the country of origin.

POTENTIALS FOR LMICS
Projects such as these hold tremendous potential for LMICs. Often those who produce our food go forgotten. So, projects like this are essential in raising awareness to the conditions under which these actors live and provide these actors with a connection to this global supply-chain.
Furthermore, companies can verify quality and payment claims. A next step could be that also financial transactions are conducted via the BCT- system.

WAGENINGEN CDI

WHAT IT IS
In mid 2018 Wageningen Centre for Development Innovation (WCDI) together with Wageningen Food and Biobased Research (WFBR) launched a project to change the mango and avocado transport systems in Haiti in order improve the incomes of small-holder farmers. This project was conducted at the request of the Haitian Ministry of Trade and Industry and the World Bank.

Experts from the WCDI and WFBR implemented blockchain technology—to increase transparency in the supply-chain—through providing technical advice and connecting chain parties.

SUCCESSES
Haiti exports mangos to the United States. These mangos typically sell for $2, with the farmers receiving only ¢2-¢5 and intermediaries receiving approximately
¢80. While Haiti does not officially export avocados, a significant amount is smuggled to the Dominican Republic and sold on to the United States.

By analyzing the mango chain, WCDI and WFBR experts were able to determine that significant improvements could be made to the logistical handling of the produce which reduces costs and food waste. Furthermore, the Wageningen team successfully placed QR codes on several boxes of mangos and avocados immediately after harvesting. This helped chain partners better understand where food waste occurred, the itinerary with correspondent temperatures that the fruits took and where costs can be cut.

CHALLENGES
The Wageningen team hopes that systems like this can become a new form of “fair trade”, meaning consumers can see where their food is coming from and if it complies with quality and farmer payment claims. As a continuation of this project, in 2019 100 avocado and 100 mango growers will have their produce placed on blockchain. It will be closely monitored whether and, if so, how this endeavor does reduce food waste and increase farmer income.

In order to conduct this program with 200 farmers, the Wageningen team will have to ensure that all of these farmers have access to technology required for blockchain and train these farmers on how this system works. This will require a significant amount of time which will present a significant challenge to this project.

POTENTIALS FOR LMICS
If this project is successful it has the potential for improving the incomes and supply-chain understanding of hundreds of small-holder farmers in Haiti, a LMIC. Furthermore, once QR codes are placed on the produce customers will be able to see where their food comes from which will raise awareness about the discrepancies within our global food supply- chains.

WALMART

WHAT IT IS

After a two-year pilot project and in response to a rising number of leafy green linked case of E. coli in the United States, food giant Walmart announced in 2018 that it will be requiring its leafy green suppliers to put their produce on blockchain.

This blockchain will aim to trace the produce back to the farm. The goal is to allow customers to scan their produce at a self-checkout machine and see where their food was harvested and distributed, right up to the doors of Walmart.

CHALLENGES

This system has yet to be implemented, Walmart expects it to be operational by November of 2019. So, in many ways it is too early to assess potential challenges with this new initiative. However, from Walmart's publication regarding the new project it is evident that the focus is solely on ensuring food safety for customers. While this is important, it does little to promote or protect the rights of the agricultural workers who are working to produce these products. In the future it will be interesting to see if Walmart branches out and includes the agriculture workers in its blockchains.

SUCCESSES

Understanding where our food comes from is essential to understanding the global and more local agri-food systems. Through this blockchain initiative, Walmart customers will hopefully gain a deeper understanding of their food system, even if it is just within the United States.

POTENTIALS FOR LMICS

It is unclear if any of the leafy greens Walmart hopes to put on blockchain are grown in LMICs because the E. coli infected produce was grown within the United States. If Walmart chooses to broaden the scope of its blockchain project to include agricultural workers then there could be real benefits— with regards to transparency, workers' rights and workers' incomes.

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